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27th November to 1st December
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Preface

In the next millennium, it is anticipated that human factors issues will take centre stage in initiatives targeted at enhancing economic competitiveness and productivity. This development is already discernible in nascent knowledge and digital based industries and economies, which are expected to emerge in force in the near future and continue to dominate thereafter. These developments will establish irreversibly the emerging global economy and village.

In the security and military arena, the vulnerability of nations is expected to extend beyond physical projections of threat to encompass electronically led insidious cyber or digital infiltration. Further, advanced semi- and fully automated systems become key performance shaping determinants of superior operational effectiveness and organisational prowess. And, human factors issues are anticipated to take centre stage. Computer-based systems would no longer act in a slave-to-master relationship with humans. Instead, computer systems will become integrated seamlessly with human individuals and teams, working in collaborative and adaptive partnership. Thus, the theme of the APCHI 2000 conference is: "Towards a seamless integration of collaborative human computer systems" to reflect the already discernible shift in focus of human computer interaction (HCI).

In the imminent brave new world, not only would changes in commercial and security practices and activities be inevitable - the quality and very way of life will change dramatically across nations worldwide. Hierarchic organisations and leadership will be supplanted by agile and fluid organisations that provide environments to support thinking individuals empowered to act independently; and yet their decisions and actions remain in harmonious concert with teamwork orchestrated and enabled by technology and digital infrastructures. In this fast paced world characterised by continuous change, life-long employment in a profession will be replaced by life-long learning demanded by economies where knowledge is prized as human capital.

Further, in this digital world of the information superhighway and world-wide web, geographical and national boundaries and identities would no longer exist as we know of them today. As a result, socio-cultural issues will rise up to either avoid or embrace the melting pot; which when viewed positively, may spell the birth of a new world identity and borderless thinking. However, if due care were not taken in the implementation of such a pervasive technology, a negative view would portent the death of cultures and the end of cultural diversity. In addition, age-old concerns pertaining to the socio-economic divide will no longer be confined to material ownership. Disparities between the 'haves' and 'have-nots' will now be shaped by access to information bits and bytes. Depending on the initiatives taken presently, digital technology may widen chasms or level the playing field......... Thus, the theme of the ASEAN Ergonomics 2000 conference is: "From user centeredness to people centeredness" to reflect the imminent shift in focus that is required of human factors.

The above scenarios are but a few that might emerge in the brave new world that are unfolding in the new millennium. To address these concerns and bring to the fore these very important human factors issues, the Asia Pacific Human Computer Interaction Group, the South East Asian Ergonomics Society and the Ergonomics Society of Singapore, have joined forces to host the first ever explicitly combined HCI and Ergonomics conference.

The papers in this proceedings provide a good contrast of human factors contributions to both old and new economies that make up ASEAN and APEC. They highlight the diverse roles human factors can play in advancing the quality of life in developed, developing and third world nations. The papers serve as a guide to human factors practitioners in old economies on what to expect as their economies develop. For their contemporaries in new economies, the papers serve to remind how one could contribute professionally to facilitate knowledge transfer to uplift the working conditions prevailing in less fortunate countries. Only then would we be able to usher in, in this millennium, a golden era of human factors contributions where "ergos nomus" would be practised on a world wide scale. To advance this worthy cause, Ergonomists of the world unite!

Kee Yong LIM
General Chair & Editor
ASEAN Ergonomics/APCHI 2000

Information About the Organisers

Asia Pacific Computer Human Interaction (APCHI) Group
APCHI was founded in 1995 by a team of experts in Human Computer Interaction from industry & academia based in Singapore, Malaysia, Japan, Australia, New Zealand and Hong Kong. APCHI meets every 1-2 years in the Asia Pacific region. The APCHI series of conferences is supported by the TC13 group of the International Federation of Information Processing (IFIP). APCHI '96, the first Asia-Pacific Conference in Human Computer Interaction was hosted in 1996 by the Information Technology Institute, National Computer Board, Singapore. APCHI '97 was combined with Interact '97 and held in Sydney, Australia. APCHI '98 was held in Tokyo, Japan. There was no conference in 1999. APCHI 2000 will be held in Singapore followed by APCHI 2002 in Beijing, China. The aim of the APCHI group is to actively foster regional and international co-operation among its members in the advancement of human factors aspects of human computer systems. Key founding members of the group comprise Professor Masaaki Kurosu, Dr Ying Leung, Dr. Steve Howard, Ms. Linda Herman and A/Professor Kee Yong Lim.

South East Asian Ergonomic Society (SEAES)
The South East Asian Ergonomics Society (SEAES) is affiliated to the IEA (International Ergonomics Association), a global society of ergonomists. SEAES is an international society with members from the Association of Southeast Asian Nations (ASEAN), namely Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. The SEAES membership is expanding fast to include many professionals from outside the region. Members of the Society from further afield hail from Australia, New Zealand, Japan, Europe and America. It is SEAES' aim to actively foster regional and international co-operation among its members in advancement of the human factors discipline. The current President of the society is A/Professor Kee Yong Lim.

Ergonomics Society of Singapore
The Ergonomics Society of Singapore (ESS) is actively helping in the organisation of the joint 4th APCHI and 6th SEAES conferences. ESS aims to promote and create a strong awareness among Singaporeans of the importance ergonomics, in particular professionals and students, who can make great impact in the future. The current Chairman of the society is A/Professor Kee Yong Lim.

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PART ONE

Keynote Addresses

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Human Factors for the New Millennium

K.R. Boff

Chief Scientist, Human Effectiveness Directorate, Air Force Research Laboratory
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The revolutionary advances in information and bio-technology begun during the close of the 20th century have profound human factors implications for society, culture, health care, education, work, commerce and military affairs in the new millennium-- in short - effects on all key aspects of life as we know it today. The integration of humans with technology in ways which result in effective systems, whether simple or complex, remains fundamentally unchanged as the primary research and application objective of the human factors community. However, the challenges involved in achieving this objective have been transformed in interesting ways. This presentation will focus on new challenges for human-centered design with emphasis on task-critical usefulness and usability of information, cross-disciplinary and cross-cultural interfaces, and maximizing human potential in education, training, aiding and collaboration.

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Domain Approach to Decision Support for Planning and Control: a Case-Study of Amphibious Landing Off-Load Planning

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Inspite of the advent of novel technologies, the provision of decision support for planning and control continues to remain a major challenge for Human-Computer Interaction. This paper briefly reviews decision support for planning and control, and proposes a domain approach to its provision. A case-study of planning and control in the domain of amphibious landing off-load planning is used to illustrate the proposed approach. It is concluded that the provision of decision support for planning and control remains a critical problem for Human-Computer Interaction and that the domain approach to that provision constitutes a useful addition to other current approaches.

1. BACKGROUND

Novel technologies continue to develop at an ever increasing rate: broadband communication, integrating data processing and communications; multimedia, synthesising text and graphics; multimodality, combining user inputs from speech, gesture and keyboard; computer-based, distributed networks, supporting collaborative work; mobile computing and telephony; ubiquitous computing; smart buildings; virtual and augmented reality etc. However, to be successful, technology, whatever its novelty, still must be able to support applications effectively. For example, inspite of some wild claims, novel technology per se has notably failed, as yet, to solve endemic problems, associated with internet applications, such as e-commerce services. Central to many of these problems is the need to provide decision support for planning and control, a major challenge for Human-Computer Interaction (HCI). This paper briefly reviews decision support for planning and control, and proposes a domain approach to its provision. The approach is illustrated by a case-study in the domain of amphibious landing off-load planning.

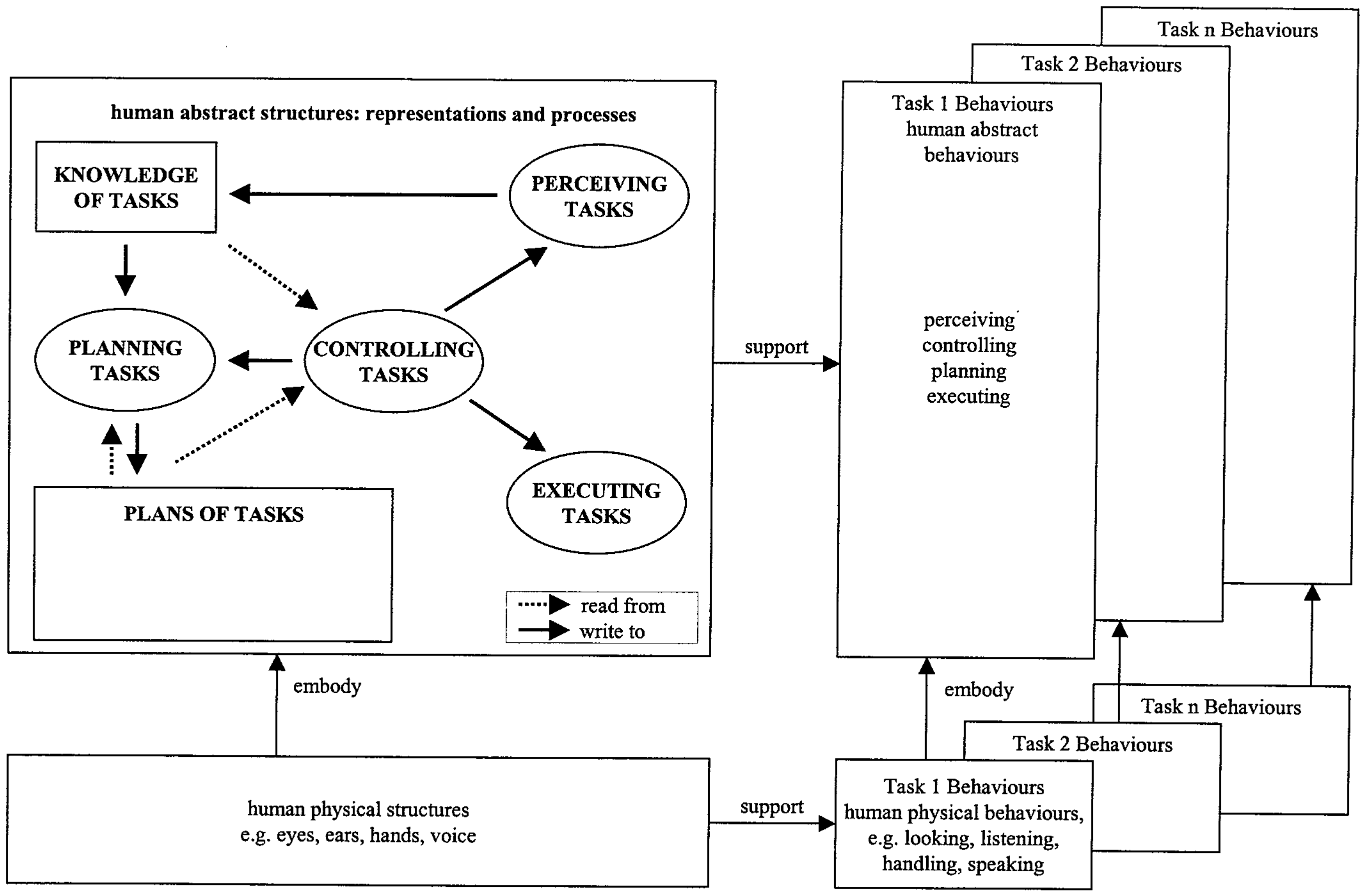

Figure 1: Framework for Task Management as Planning and Control (following Smith et al, 1992)

2. PLANNING AND CONTROL

Planning and control are briefly reviewed, related via a general framework and illustrated in terms of amphibious landing off-load planning.

2.1. Review of Planning and Control

Planning, as future behaviour to achieve a goal, has been conceptualised as the complete specification of a solution search through a determined and known problem space, whose implementation achieves this goal (Newell and Simon, 1972). In problem spaces, which are not determined and so are not known (or even knowable) (for example, which are too complex and/or too dynamic to predict future states), only control, as the next behaviour to be implemented, is possible, that is, a form of 'trial-and-error (Ambros-Ingerson, 1986). Most problem spaces in HCI domains of application, however, are at least partially determined and so partially knowable and known. Hence, the concept of interleaved planning and control (Linney, 1991). In such domains, plans may be partially specified, for example, incomplete in their detail and/or only at a high level of description. Control behaviours make good the incompleteness of the plan. Their implementation may result in successful or unsuccessful moves towards a goal, as well as additional planning or re-planning (Smith, Hill, Long and Whitefield, 1992). Here, planning and control together are conceptualised as task management, as in airtraffic management (Hill and Long, 1996); domestic energy management (Stork, Middlemass and Long, 1995) etc. Management tasks are pervasive in HCI domains of application.

2.2 Framework for Planning and Control

A general framework for interleaved planning and control (PC), as the management of tasks, has been proposed by Smith, Hill, Long and Whitefield (1997), for the domains of: medical reception; secretarial administration; and legal service provision. The framework in turn is based on a conception for HCI engineering (Long and Dowell, 1989; Dowell and Long, 1989 and 1998). Task management is shown in Figure 1, following Smith et al. Tasks are managed by perceiving, controlling, planning and executing abstract and physical behaviours, supported by associated abstract and physical structures respectively. Plans specify task behaviours for achieving goals; controlling selects which behaviour is to occur next, that is, perceiving, planning or executing.

2.3. Off-load Planning and Control

The PC management framework of Smith et al is here applied to the domain of amphibious landing off-load planning (OLP – Colbert and Long, 1996). An amphibious landing may here be considered as an attack against a potentially hostile shore, launched from the sea, and involving air, sea and land forces. It includes the movement ashore of a landing force, embarked on transport ships and naval vessels, by means of amphibious vehicles, landing craft, and helicopters. The landing force arrives ready for combat ashore, and at beaches and landing zones (rather than ports and airfields) (Evans, 1990).

Table

load	desired tactical order	no. men	from	by	timings depart	timings land	to
1	1 2 3 4	7 8 7 4	LSL1	LCA1	H-10	H	beach1
2	5 6 7	7 8 5	LSL1	LCA2	H-10	H	beach1
3	7 8 11	3 8 7	LSL1	LCA3	H-10	H	beach1
4	11 12	1 8	LSL1	LCA4	H-10	H	beach1
5 etc	14 15 etc	2 4 etc	LSL2 etc	LCA7 etc	H-15 etc	H+5 etc	beach2 etc

LCA: landing craft assault
LSL: landing ship logistic

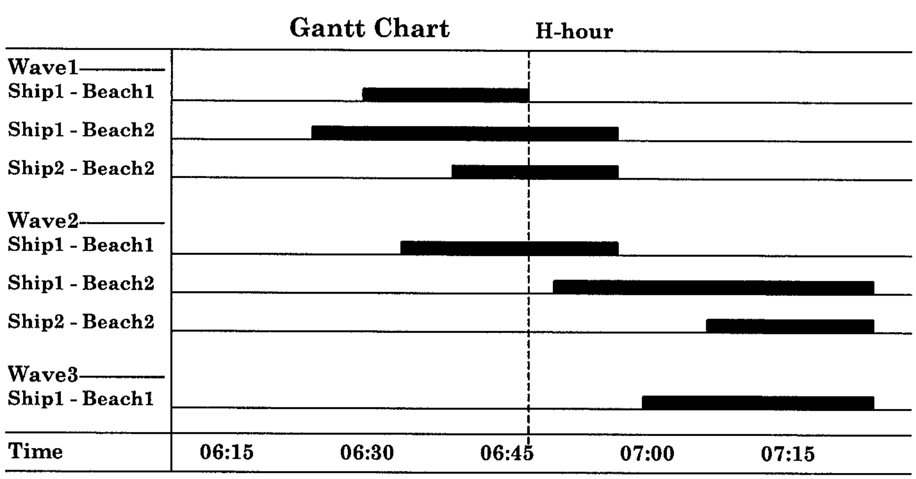

Figure 2. Typical Amphibious Landing Off-load Plan

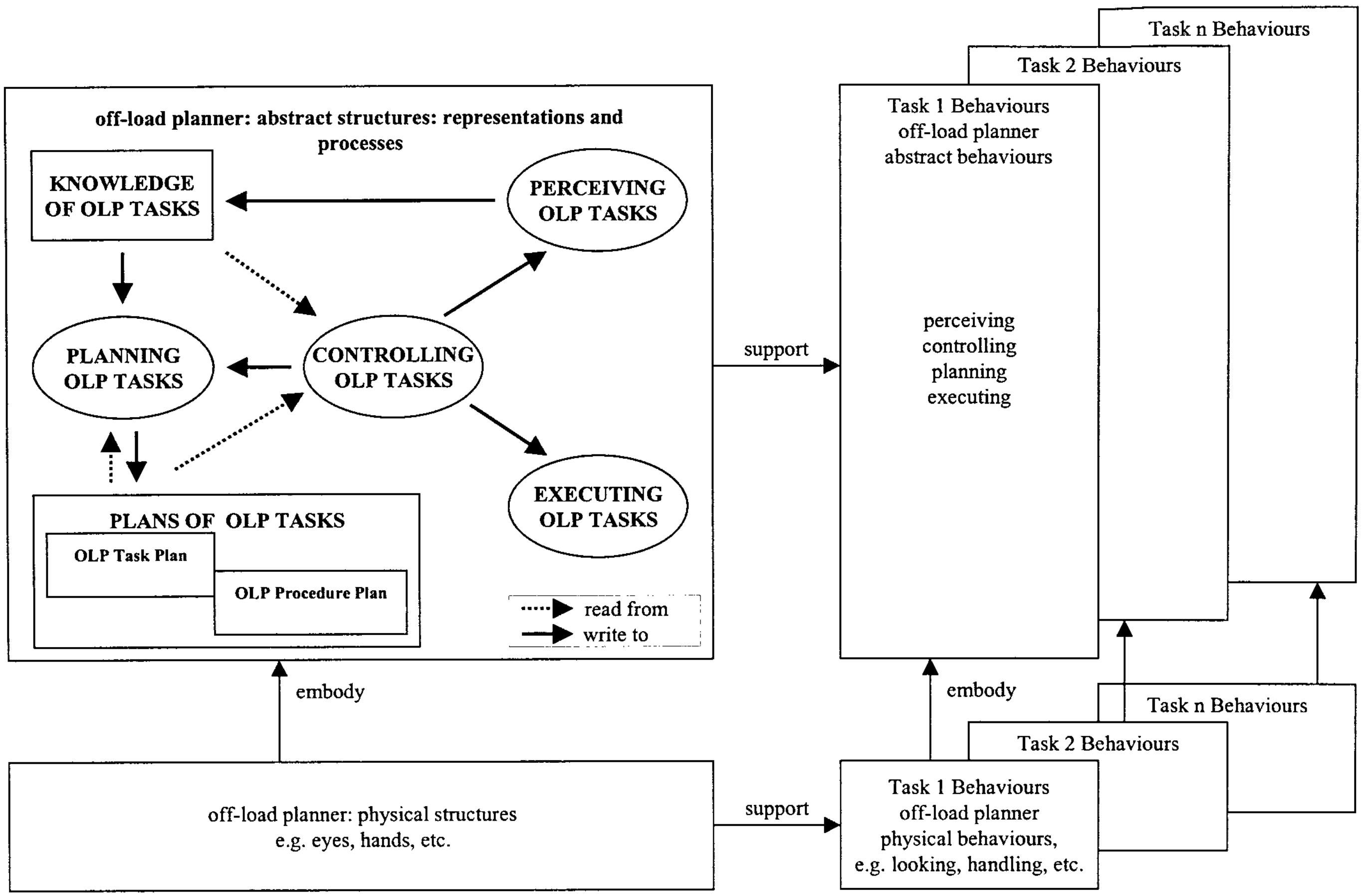

Figure 3: Off-load Planning (OLP) - Model of Off-load Planner (following Hill et al, 1995)

Critical for the landing are the off-load plans (see Figure 2, which represents a typical off-load plan as a table (upper figure) and as a gantt chart (lower figure). These plans specify who is to go ashore (left hand columns of the table) and where, and when (right hand columns of the table). They also specify who is to take the landing force ashore and how the force is to be tactically grouped (middle columns).

Off-load planning involves marine officers (off-load planners) interacting with planning aids to plan amphibious landings effectively. Off-load planning requires the planner to manage a range of tasks, including: selecting next load contents, for example, people and vehicles; checking accuracy of name assignments, for example, '40 Company/008'; relating departure and arrival times, for example, '6:30' and '6:50' etc. A model of the off-load planner, managing the planning and control of off-load planning (PC-OLP) (following the framework of Smith et al, 1997) is shown in Figure 3.

The figure illustrates how the planner performs off-load planning tasks, such as selecting next load contents, by implementing task and procedure plans for content selection and controlling planning, perceiving and executing behaviours. Planning and controlling are thus interleaved (see earlier – Linney, 1991).

Consider next the concept of decision support, as it might be associated with planning and control.

3. Decision Support

Decision support is briefly reviewed, including decision-making and types of decision and decision support. Off-load planning is used for illustration.

3.1. Review of Decision Support

Decision support in HCI has been much influenced by how decision-making has been conceptualised by psychological theories.

3.1.1. Decision-making

According to Zachary and Ryder (1997), decision-making has been conceptualised in three different types of theory. First, rational decision theory holds that decision-making comprises optimising rationality to produce an 'ideal' decision (von Neuman and Morgenstern, 1947) or bounding rationality to produce a 'satisfying' solution (Simon, 1972). Second, behavioural decision theory holds that decision-making comprises a process, by which people acquire and apply knowledge to produce a decision (Keeney, 1982) and such a process includes heuristics and biases (Kahneman, Slovic and Tversky, 1982). Last, naturalistic decision theory holds that decision-making comprises domain knowledge, such as facts, basic concepts, relationships, etc., and a decision-making strategy for its application, such as 'breadth-' or 'depth' first (Klein, 1989).

Each type of decision-making theory is associated with different types of decision and decision support. These types are briefly reviewed next.

3.1.2. Types of Decision and Decision Support

First, rational decision theory was developed on the basis of decision problems having well-defined mathematical expressions and relationships, the latter often characterised in terms of 'odds or probabilities'. There was likely to be a unique and optimal outcome or solution as the correct decision. The decision problem was set in no specific context. Typical decision support involves applying symbolic or numeric techniques to produce mathematical algorithms, which in turn can be computerised. The algorithms optimally solve the odds- or probabilities-type decision problem.

Second, behavioural decision theory was developed on the basis of decision problems having, in addition to the problem, a context for that decision. Typical contexts were those of business or economics. There was no single correct solution, but a range of alternative decisions, all providing satisfying solutions. Typical decision support involves characterising the process by which people apply the contextual knowledge, for example, in the form of judgements. These methods and their computer implementations constitute the decision support for problems having a specified context.

Third, naturalistic decision theory was developed on the basis of decision problems having "no decision event, but rather a larger dynamic task in which decision-makers take actions . . . Importantly, decision-makers in naturalistic settings are expert in the domain" (Zachary and Ryder, 1997). Typical domains include: fire-fighting; emergency management; military command and control; airtraffic management; medical diagnosis etc. Decision support takes the form of computerising the elicited expertise of effective decision-makers.

Decision-making in this paper is generally conceptualised in the manner of naturalistic decision-theory. Management tasks, involving planning and control, have no decision event, but constitute "a larger dynamic task in which decision-makers take actions" and are "expert in the domain". Decision-making is assumed to be based on domain knowledge and a decision-making strategy.

Since the present concern is with decision-making, as it relates to interleaved planning and control (see Section 2), decision problem types are assumed to require the following decision types: (i) solution selection; (ii) solution construction; and (iii) problem elaboration. Solution selection would only require the implementation of an already acquired plan to solve the decision problem. In contrast, solution construction would require the interleaving of planning (and/or re-planning) and control to solve the decision-problem. Last, problem elaboration would be required, if neither solution selection nor solution construction were possible. These decision problem and solution types are consistent with the conception of management tasks as interleaved planning and control. Planning alone would require only solution selection. Controlling alone would always require solution construction, or problem elaboration and solution construction. Decision support could be provided for all decision problem types.

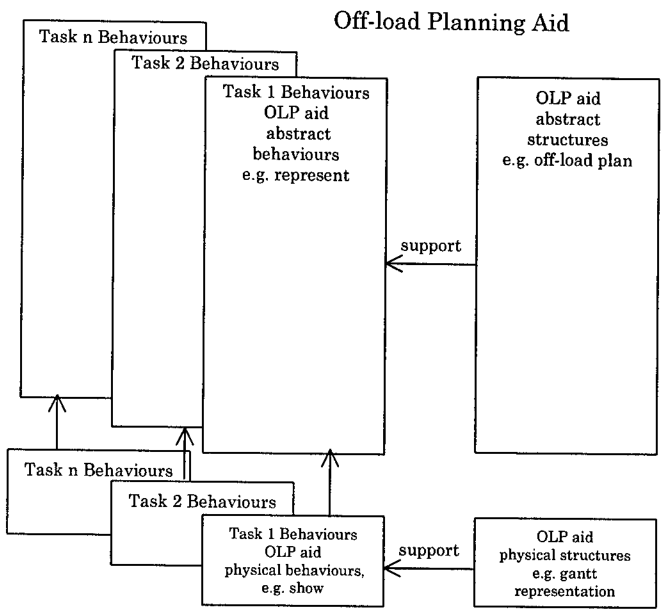

Figure 4: Off-load Planning (OLP) – Model of Off-load Planning Aid

3.2. Off-load Planning Decision Support

An example of the decision support, offered to the planner by a typical planning aid is shown in Figure 2 (see earlier). Both table and gantt chart representations of the off-load plan provide column and row category prompts, such as load, order, wave, beach etc., within a general plan, in the form of a template, so providing support. For example, the gantt chart's graphical representation of time (as thick horizontal bars) generally supports decisions concerning load assessment, required by the off-load procedure plan (see Figure 3). If Ship 2 is to land on Beach 2 at the same time as Ship 1 lands on Beach 1 (that is, H-hour), then the gantt chart representation of the off-load plan would support a 'solution selection' decision of advancing the departure of Ship 2 by 5 minutes. However, if the load for Ship 2 were to be available only 15 minutes before Ship 1 lands (that is, H-15), then the gantt chart would only support a 'solution construction' decision, since it does not show load availability, indicating Ship 2's load could be made available 5 minutes earlier. If the load cannot be so made available, then the gantt chart would only support a 'problem elaboration' decision by the off-load planner. A model of an off-load planning aid, offering different types of decision support, is shown in Figure 4.

The model follows the framework of Smith et al (1997) and so is compatible with the model of the off-load planner (see Figure 3 earlier).

4. DECISION SUPPORT FOR PLANNING AND CONTROL

Decision support for planning and control is briefly reviewed and illustrated by off-load planning. Approaches to decision support for planning and control are identified, including the domain approach, as proposed here.

4.1. Review of Decision Support for Planning and Control

Reviewing the assumptions made so far, planning and control are conceptualised as interleaved and together constitute the management of tasks (see Section 2.1). Decision-making is conceived as naturalistic, requiring domain knowledge and a decision-making strategy (see Section 3.1.1). Last, three decision types are conceived – solution selection, solution construction and problem elaboration, each offering the opportunity for different types of decision support.

4.2. Off-load Planning Decision Support for Planning and Control

Decision support for the management of off-load planning, as interleaved planning and control, involves the planner (see Figure 3) interacting with the planning aid (see Figure 4). Decision-making is naturalistic, requiring knowledge of amphibious landings and a strategy, for example, to ensure the correct allocation of contents to off-loads. As illustrated earlier (see Section 3.2), contents allocation may involve the three decision types – solution selection, solution construction, and problem elaboration. Each contents allocation decision type made by the planner may be supported by the planning aid, for example, by means of the structure of the specified and unspecified loads of the plan (see Figure 2).

4.3. Approaches to Decision Support for Planning and Control

There are three general approaches to the development of decision support for planning and control, within the naturalistic decision-making perspective (Zachary and Ryder, 1997). The first approach attempts a re-allocation of function from the user to the technology in support of decision-making. For example, in off-load planning, checking some types of accuracy of assignments (such as consistency of the naming of load contents - see Section 2.3) could be re-allocated from the planner to a (computerised) planning aid, so supporting the assignment decisions.

The second approach attempts to enhance novice decision-making by transferring expertise from experienced decision-makers to novices via training. For example, in off-load planning, procedure plans for load assessment (see Figure 3) of expert planners could be elicited, documented and then taught to novice planners, so supporting the latters' decision-making.

The third 'domain' approach, and that proposed and illustrated here, is based on a framework comprising: work; the interactive worksystem; and performance (Dowell and Long, 1989 and 1998). The interactive worksystem, consisting of the user and technology, carries out work in the domain of application at some level of performance, expressed as task quality and worksystem costs (workload). The framework is intended to support the general development (as design and evaluation) of interactive worksystems, that is, their interfaces, and associated training. General development includes decision-support for planning and control. For example, in off-load planning, the planner and planning aid interact, as the off-load planning worksystem, jointly to execute work in its domain of application of off-load planning. Plan quality expresses how well the plan has been constructed and planning costs express the workload for the planner and the planning aid in constructing the plan that well. As an illustration, the planner, interacting with the planning aid, jointly carry out load assessment, following a procedure plan (see Figure 3) at some level of speed and accuracy.

The domain approach to decision support for planning and control is further illustrated by means of a case-study. In the latter, the framework is applied to the redesign of a reconstructed off-load planning system.

5. CASE-STUDY: DOMAIN APPROACH TO DECISION SUPPORT FOR PLANNING AND CONTROL

A reconstruction of off-load planning is briefly described. The domain approach framework (see Section 4.3) is used to model off-load planning. The framework is then applied in a case-study to provide decision support for the reconstructed off-load system.

5.1. Reconstructed Off-load Planning

The off-load planning task (see Section 2.3) was selectively reconstructed as a laboratory simulation, and implemented on a PC in Hypercard (called ROPS – Reconstructed Off-load Planning System – Colbert and Long, 1996). ROPS thus constitutes a planning aid, offering different types of decision support, to subject planners, trained in the planning and control of off-load plans. Although selectively reconstructed, ROPS exhibits typical planning-aid functionality, for example, prompts for off-load plans, and requires typical planning and control behaviours, for example, assessing off-load plans (see Section 2.3).

5.2. Domain Approach Framework for Off-load Planning

The domain approach framework for planning and control consists of: domain of application; interactive worksystem; and performance (see Section 4.3). The framework is used next to model off-load planning, as a preliminary to its application in the case-study.

5.2.1. Domain of Off-load Planning

Off-load planning, as the construction of plans for armed conflict, necessarily presumes the domain of armed conflict. The latter seeks to secure national state interests by the display or use of force. A model of the domain of armed conflict, expressed as objects, attributes and values, is shown in Figure 5. The model was constructed on the basis of background reading and elicitation of military expertise.

The model illustrates how 'advantage' is an attribute of the object armed conflict. Advantage has the values of 'prevail' and 'not prevail', as concerns a 'friend' or 'hostile' in a conflict. The aim of an armed conflict worksystem, that is a military system, is to ensure advantage has the value prevail. It is necessary,

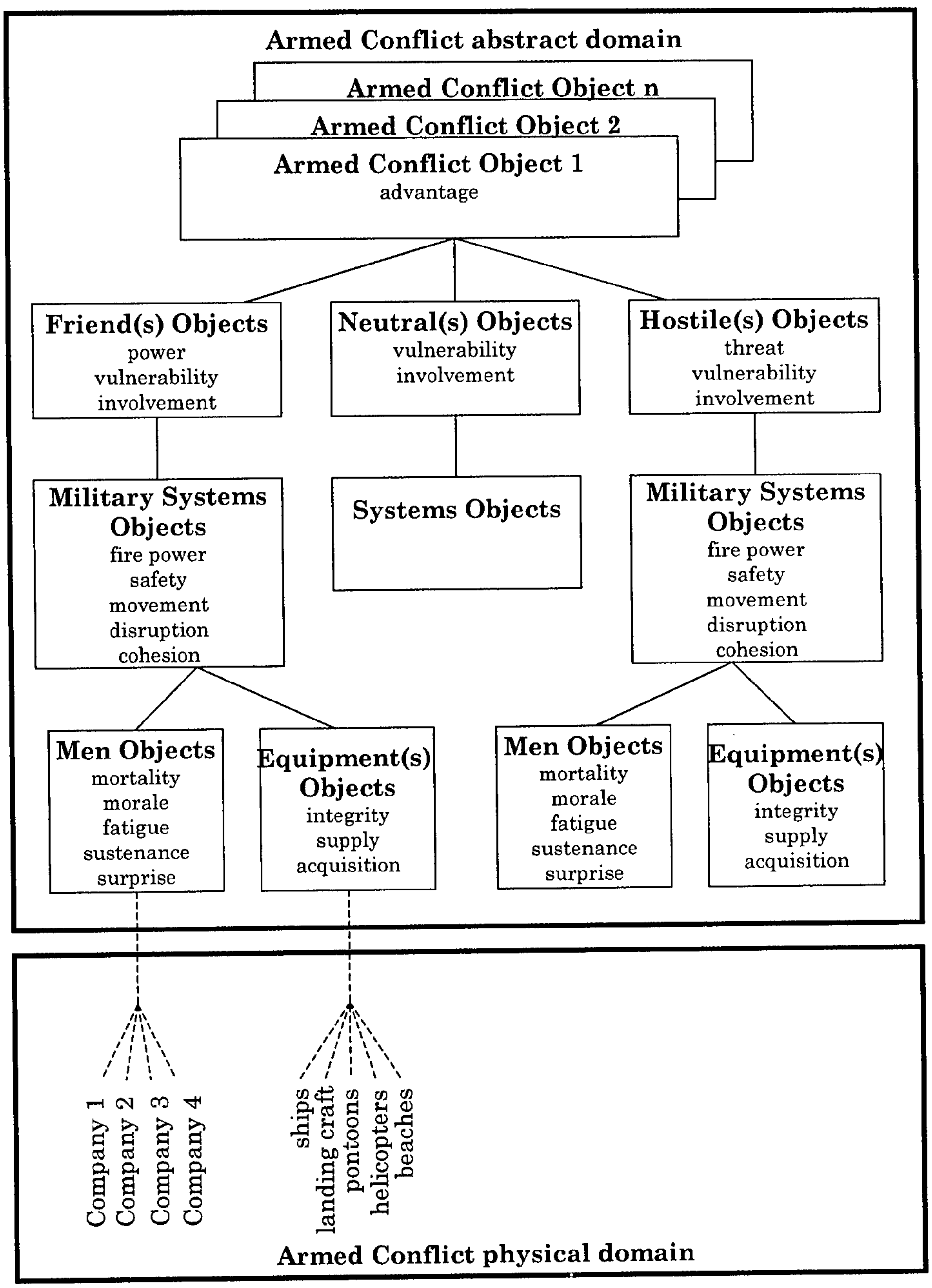

Figure 5. Off-load Planning - Model of Domain of Armed Conflict.

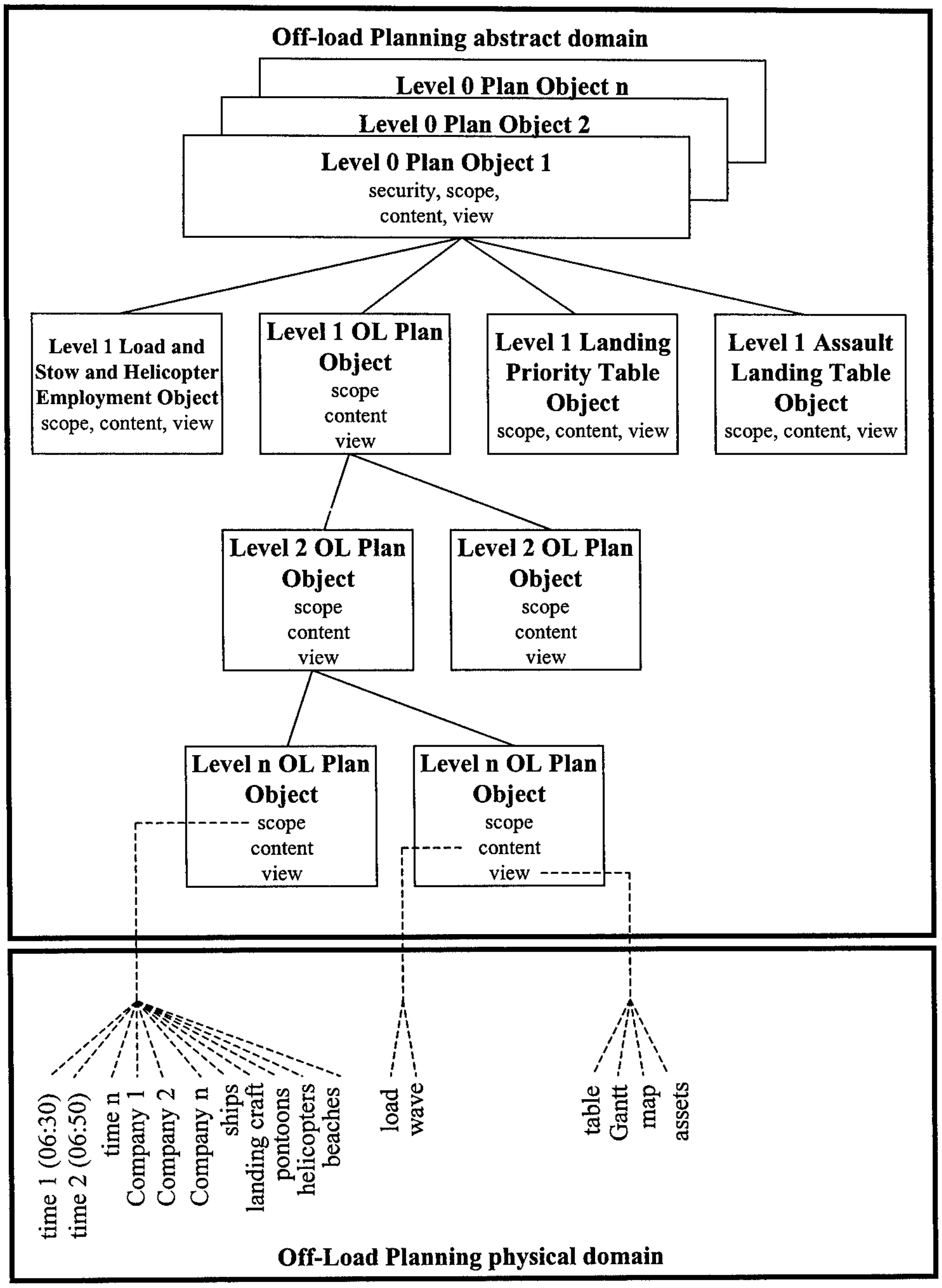

Figure 6. Off-load Planning - Model of Domain of Off-Load Planning.

in the case of off-load planning, to model armed conflict first, because objects such as men, with attributes of fatigue etc, and equipment, with attributes such as integrity etc, constitute part of the scope of off-load plans.

A model of the domain of plans appears in Figure 6. The model was constructed on the basis of background reading and elicitation of military expertise. Domain objects consist of plans and sub-plans, representing goal states of domain objects and/or desired future worksystem behaviours. Plan objects have attributes with associated values. For example, the domain object 'sub-plan' has the attribute 'scope', which delimits plan 'contents' according to values of 'time' (time scope), that is, 06:30, 06:50 etc, and 'objects' (object scope), that is, ships, landing craft etc. The sub-plan also has the attribute 'view' with values of 'table', 'gantt' etc. Last, the sub-plan has the attribute 'content', with values as the specification of 'goal states' of conflict objects, such a companies, ships, landing craft etc., and/or the behaviour of conflict control systems, that is, military systems. The domain approach to decision support exploits the domain models of armed conflict and off-load plans to design worksystem interfaces to achieve desired performance (see Section 5.2.3).

5.2.2. Interactive Off-load Planning Worksystem

Off-loaf planning work is carried out jointly by the planner and the planning aid as in interactive off-load planning worksystem. A model of the planner appears earlier in Figure 3 and a model of the planning aid in Figure 4. As the models are compatible (both following Smith et al, 1997), it suffices to combine them to form the interactive off-load planning worksystem as in Figure 7.

Planners and planning-aid's physical behaviours interact, while embodying respective abstract behaviours, all supported by respective physical and abstract structures. The planning worksystem transforms the object attributes of the planning domain from undesired to desired values (as shown in Figure 8). For example, the worksystem is able to change the time scope value of plan scope, to which plan contents apply, from inappropriate to appropriate.

5.2.3. Off-load Performance

Off-load performance is expressed as off-load plan quality and planning worksystem costs, that is, planner and planning aid workload. Performance relates the planning worksystem to its domain of application, as shown in Figure 9.

Plan quality is derived from the domain model. For example, plan content (see Figure 6), as it relates to military systems, in terms of 'lift' (the potential of a military or non-military system to transport men and equipment – see Figure 5), might be expressed as a 'rate', such as men lifted per hour. Planner costs, as workload, are derived from the worksystem model, and might be expressed as the number of executing behaviours associated with a particular off-load plan (see Figure 3). Planning aid costs, as workload, are similarly derived and might be expressed as response time to a type of instruction (see Figure 4).

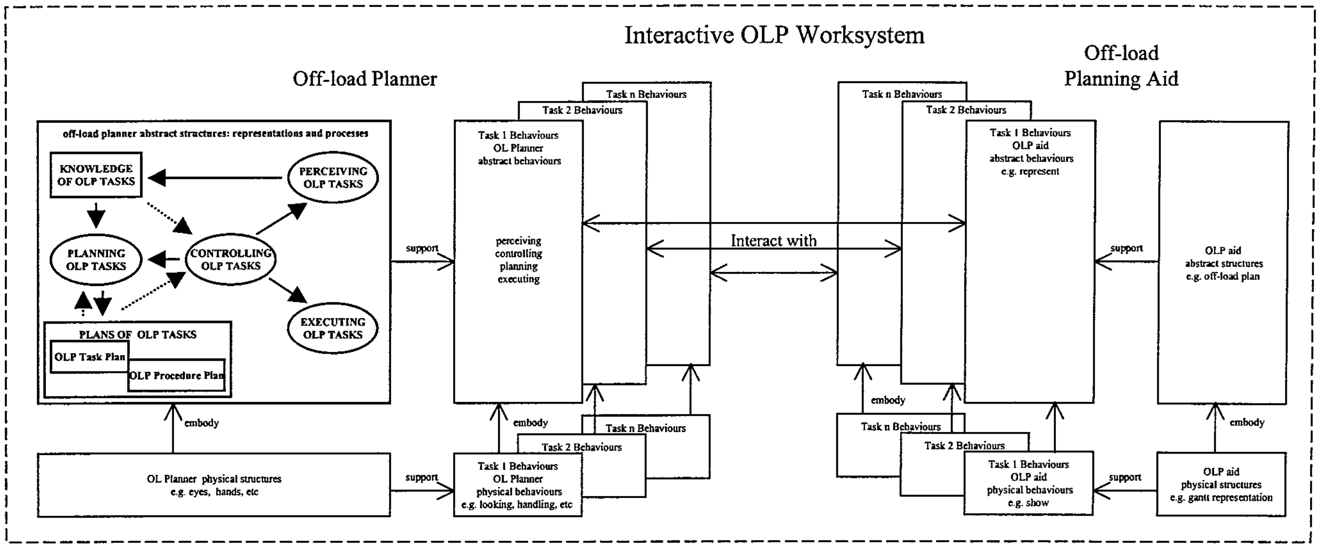

Figure 7: Off-load Planning (OLP) - Model of Off-load Planner and Off-load Planning Aid, as an Interactive Off-load Planning Worksystem

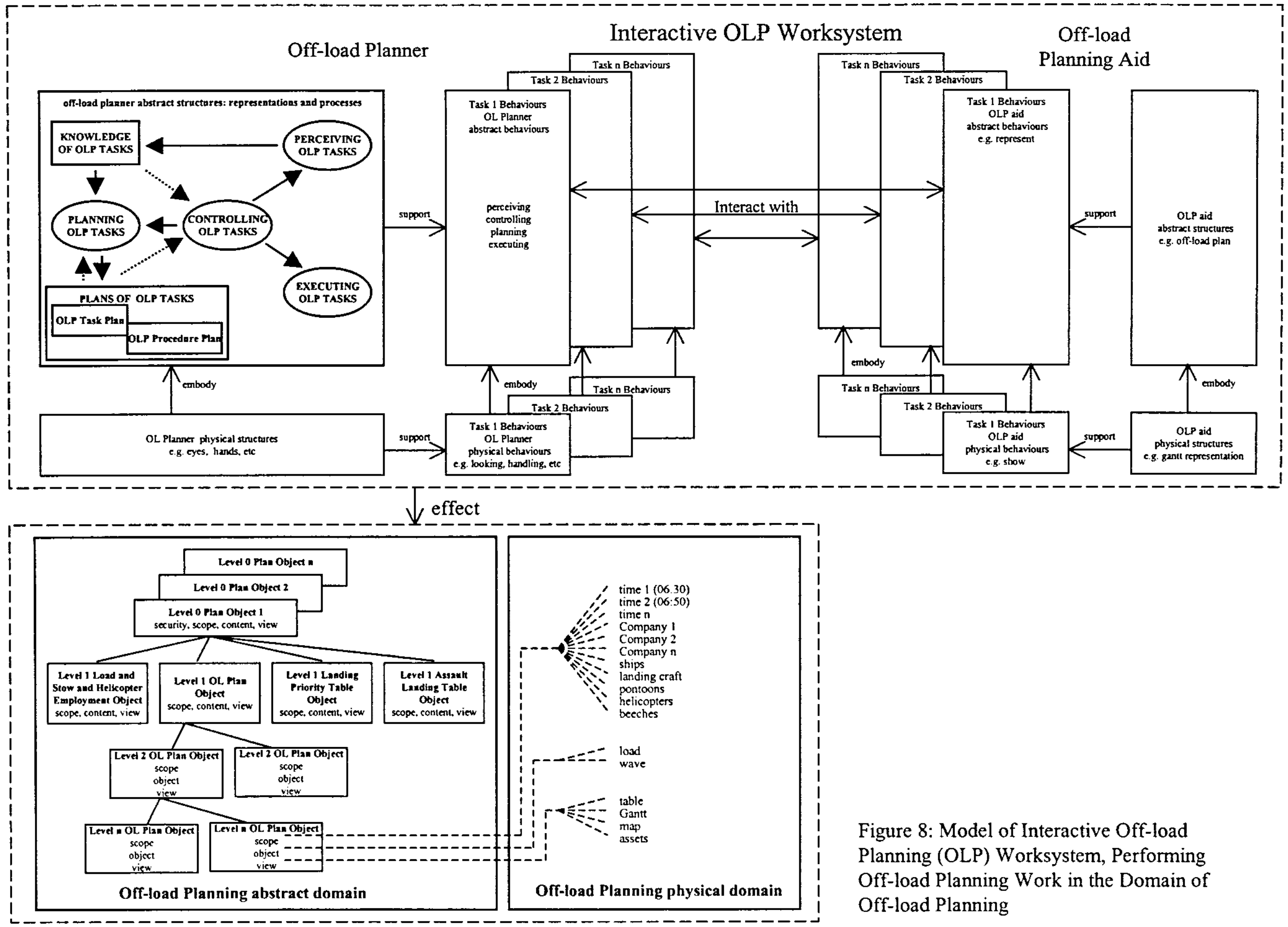

Figure 8: Model of Interactive Off-load Planning (OLP) Worksystem, Performing Off-load Planning Work in the Domain of Off-load Planning

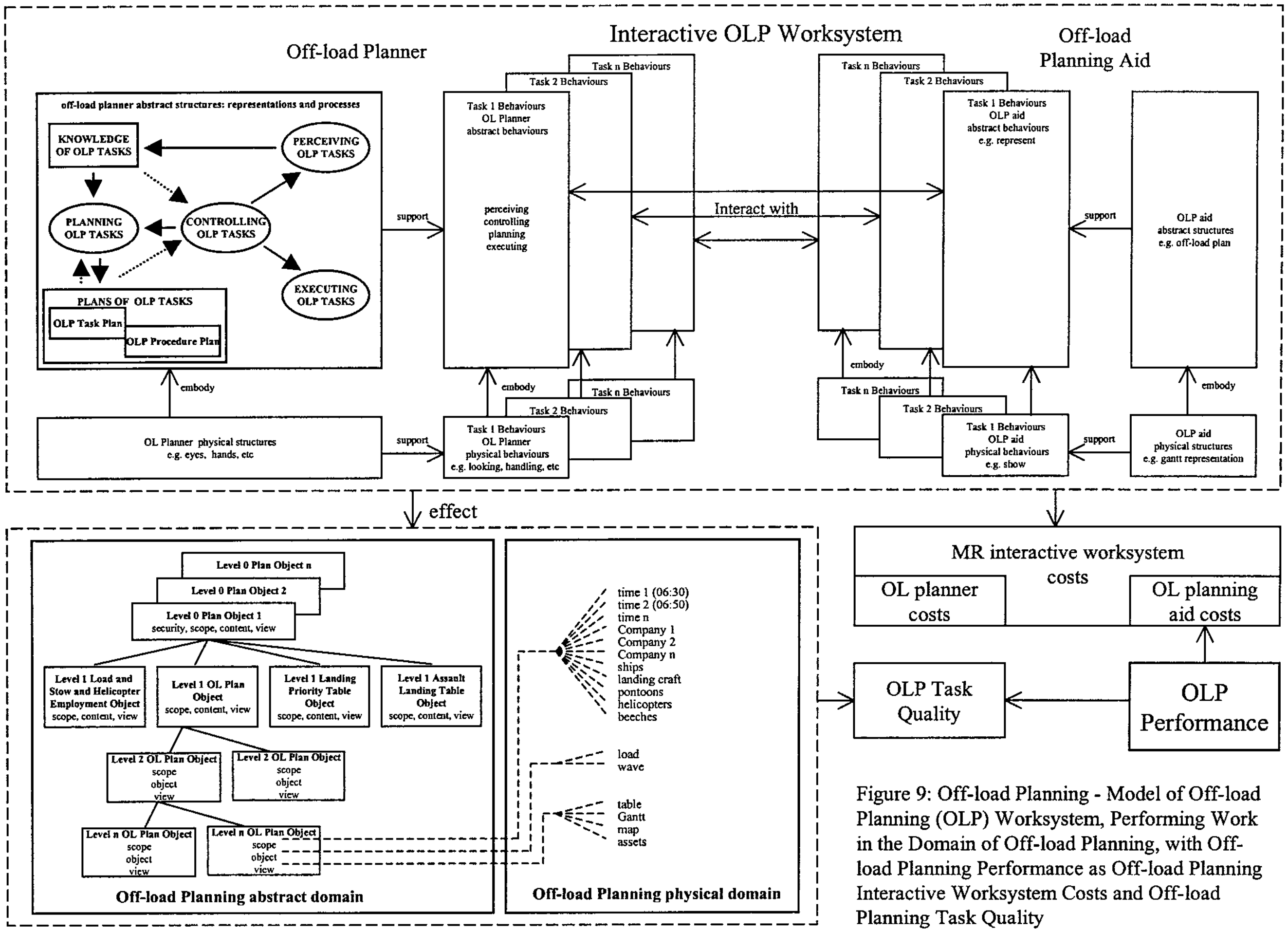

Figure 9: Off-load Planning - Model of Off-load Planning (OLP) Worksystem, Performing Work in the Domain of Off-load Planning, with Off-load Planning Performance as Off-load Planning Interactive Worksystem Costs and Off-load Planning Task Quality

File	Objects	View	Utilities
New	Landing Force...	Table	Import Data
Open...	Landing Craft...	Gantt...	Clerical Check
Close	Helicopters...	Map	Next Load
Save	Pontoons...	Assets	Next Wave
Save As...	Beaches...	Filters...	Until...
Page Setup...		Format...	Assess
Print...			Compare
LPT			All Scores
Load&Stow			
HEALT			
X-Deck			
Quit			

Figure 10. ROPS Menu Incorporating Off-load Planning Domain Scope and Content Attributes

The domain approach framework is now complete and can be applied to the redesign of ROPS.

5.3. Application of Domain Approach to Off-load Planning

Designing interactions for effective work typically involves three stages: analysis; conceptual design; and detailed design (Lim and Long, 1994). The application of the domain approach to off-load planning, in the present case-study, generally follows these three stages.

5.3.1. Analysis of Off-load Planning

Initial analysis of off-load planning produced the domain approach framework of Figure 9, that is: interactive worksystem (planner and planning aid); domain of application; and performance. Additional analysis, based on this framework, selects the domain objects, attributes and values, implicated in off-load decisions, so offering the potential for supporting planning and control decisions. For example, in ROPS, such 'scope objects' include: landing force; landing craft; helicopters; pontoons and beaches. These objects appear as a menu and are shown in Figure 10.

The objects are imported from the domain model of off-load planning (see Figure 6), having their origins in the domain model of armed conflict (see Figure 5). Additional 'content objects', from the domain of off-load plans, include: next load; next wave etc. as shown also in the menu of Figure 10.

5.3.2. Conceptual Design of Off-load Planning

In the case study, the selected domain objects, offering potential for providing decision support, in conjunction with the domain approach framework, are used to specify the conceptual design of off-load planning. Conceptual design constitutes an implementation independent, high-level description of off-load planning interactions. For example, in ROPS, there is an interaction, which modifies the scope attributes of off-load plan objects. The interaction occurs, if the subject decides to generate scope and the planning aid prompts the planner to state the scope, which they have generated. The five associated interactions of this kind relate to: landing force; landing craft etc (see Figure 10), that is, the five military systems participating in off-loads. Likewise in ROPS, there is an interaction, which modifies the content attributes of off-load plan objects. The interaction occurs, if ROPS generates content, according to the subject's specification. The three associated interactions of this kind relate to: next load; next wave etc, since ROPS can generate content load by load, wave by wave etc.

5.3.3. Detailed Design of Off-load Planning

In the case-study, the conceptual design of ROPS is decomposed into the detailed design, which is device specific, here a PC. A typical screen of the ROPS interface appears in Figure 11, which instantiates the menu of file, objects, view and utilities of Figure 10. At the start of planning, ROPS imports data from a tactical database (see Figure 10 under utilities). Then, plan content (see Figure 6) may be generated by adding loads (in Figure 11), to the off-load table one line at a time, starting from the beginning of the landing. For the first load, ROPS generates a number of alternative load options and displays them in order of preference (see Figure 11 for next load-options for Load 3). The subject planner then 'approves' one of these options and ROPS adds the 'approved' load in the next load-pending window to the bottom of the off-load plan (here Load 2). ROPS, as the planning aid, provides decision support by automatically generating another five options for the next load in the plan, and so on, until the off-load plan is complete.

To examine one of the pending load options in detail, the subject planner may select by clicking on the object of interest. ROPS will then display the details of that option in the next load-pending window and assess it against a number of criteria, for example, power, lift, safety etc – attributes of armed conflict domain objects (see Figure 5). The domain approach thus supports planning and control decisions by exploiting the domain model of armed conflict, as it relates to the domain model of plans, with respect to the interactive worksystem. The aim of the design, however, continues to be one of improved performance, that is, increasing plan quality, while reducing planner costs (workload). By providing detailed assessments, ROPS would be expected to increase plan quality, while reducing planner costs. Detailed illustration of ROPS' support for planning and control in terms of the three decision types, identified earlier (see Section 3.1.2) follows. It is claimed that ROPS provides more effective support, on the basis of the domain approach, than, for example, the typical off-load plans, illustrated in Figure 2.

As concerns solution selection, ROPS provides decision support by generating, displaying and assessing alternative load options. If the preferred option meets the planner's criteria, as is the case, for example, for Option 1 for Load 3 (in Figure 11), then the planner simply selects that option. The support derives from the domain models and would be expected to increase task quality (the armed conflict attribute values are as desired) and reduce planner costs (the selection workload is less than the selection, generation and assessment workload). Decision support, and so performance, would be expected to be more effective and so superior to typical off-load planning aids (see Figure 2).

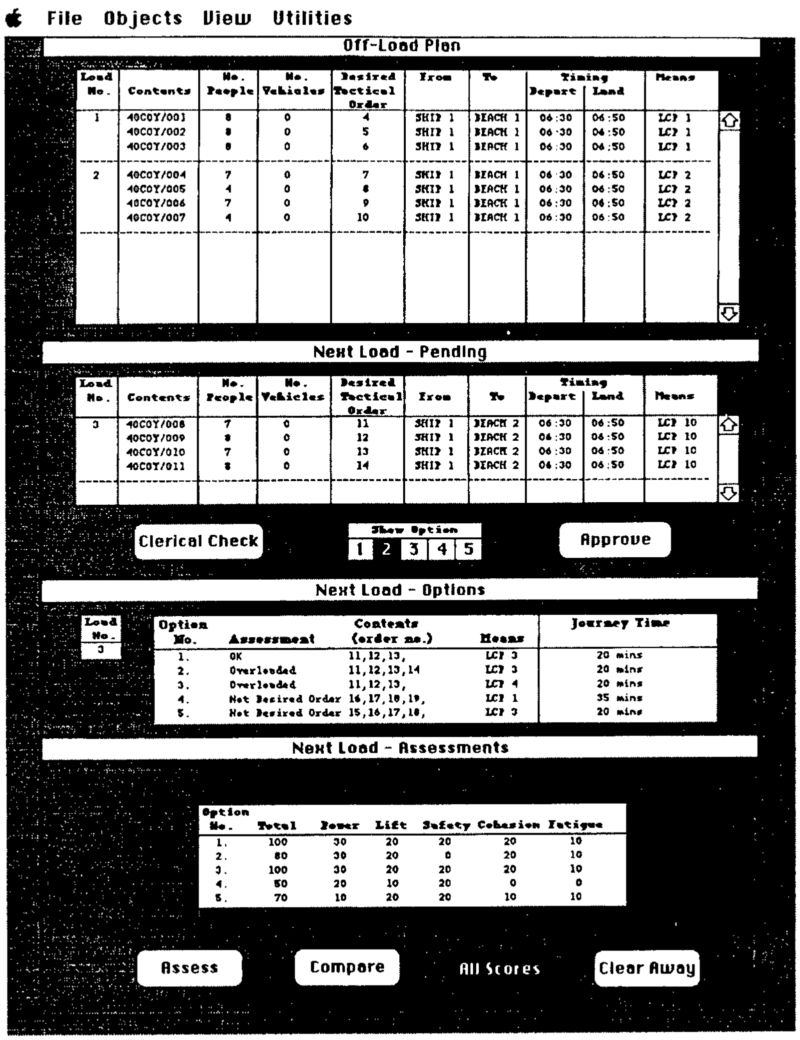

Figure 11. Typical Display of ROPS' Interface

As concerns solution construction, ROPS provides decision support by offering a 'clerical check' (see Figure 10 under utilities and Figure 11 in the next load pending window). ROPS clerical check searches for clerical errors in the identity of units, participating in the landing, for example, 40COY/001 etc. In Figure 11, if there were no 'OK' option (that is, Option 1) and Option 2 were ROPS' preferred option, inspite of being overloaded (see next load-options) and so having zero safety rating (see next load-assessments), then ROPS would provide some decision support for solution construction by enabling the planner to check the identity of the military units involved. Identification and correction of an error might reduce the overload and increase load safety. ROPS provides further support for solution elaboration by generating and displaying next load-options, such that the planner can more easily identify other types of possible error, for example, whether there is a landing craft identification error (LCP3 or LCP10 for Option 2 for Load 3). Again, error identification and correction would support solution construction to solve the overload/safety problem. Increased performance and greater effectiveness over typical off-load plans would be expected to result.

Last, as concerns problem elaboration decisions, ROPS provides decision support by generating, displaying and assessing alternative load options, which explicitly indicate how they fail to meet desired criteria, for example, 'overloaded', 'not desired order'. If in the previous illustration, no errors were identified and so no decision solution could be constructed, the planner would need to elaborate the problem, before solution selection or construction again became possible. For example, 'not desired order', once elaborated, might be a more tractable problem than the 'overloaded/safety problem'. Again, decision support, and so performance, would be expected to be more effective and so superior to typical off-load plans (see Figure 2).

As an addendum, ROPS was evaluated, not with respect to typical off-load plans, for which there was no baseline, but with respect to 'desired' performance, that is, a level intended to support the illustration. (However, desired performance was informally intended to be superior to typical off-load plans actual performance.) Subject planners were trained on ROPS by having them read background material and then take a multiple-choice test on what they had read. They also watched demonstrations of how to use ROPS and explored ROPS for themselves. Subjects then produced two practice lines for an off-load plan. Finally, each planner was instructed to produce five more lines of the off-load plan, within fifty minutes. Planners were unobtrusively observed and informally debriefed. The conformance between desired and actual ROPS performance (following Figure 9) is shown in Figure 12. It can be seen that in the majority of cases, ROPS' performance is acceptable, rather then unacceptable. Further, the performance is intended to be superior to typical off-load plans – see earlier. The evidence, however, can only be interpreted as suggestive as concerns the domain approach to decision support. The evaluation remains of interest, because the resulting performance can be compared to that of other planning aids. The case-study report is now complete.

Concept		Index
Quality of ROPS off-load plans		
	Content	Unacceptable (91.5% available by the deadline is less than 100%)
		Acceptable (a planned rate of lift 267 men/hr is between 255 and 275 men/hr)
	Scope	Acceptable (0.4 errors, in Columns 2, 3, 4 and 10, is less than 1.8)
Costs incurred by ROPS subject planners		
	Overall structural	Acceptable (32 mins 31 secs exploring is less than 35 mins 39 secs)
		Acceptable (15.9 correct answers on test, is not less than 15.9)
	Overall behavioural	Acceptable (a mean workload rating of 3.00, which is less than 3.3)
	Behavioural (associated with considering content)	Acceptable (7.7 notepad entries last 2 lines of plan, is between 4 and 8)
Costs incurred by ROPS planning aid		
	Structural	Unacceptable (299 lines of code is too large an increase on 166; 40 interface objects is too large an increase on 22. But 1 handler calls 1 handler on other stacks, which is less than 2)
	Behavioural	Acceptable (40 mins 6 secs taken to produce a plan, is less than 42 mins 54 secs)
	Behavioural (associated with considering content)	Acceptable (1.5 secs estimated run time, is less than 2.5 secs.)

Figure 12. Conformance between ROPS' Desired and Actual Performance

6. Summary and Conclusions

This paper has briefly reviewed decision support for planning and control and has proposed a domain approach to its provision. The approach has been illustrated by a case-study of planning and control in the domain of amphibious landing off-load planning. Before concluding, there is a need to comment on the status of the domain approach framework and of the case-study.

6.1. Status of the Domain Approach Framework

At its highest level of description, the framework, as a conception of HCI engineering (Long and Dowell, 1989; Dowell and Long, 1989 and 1998), has been applied generally and with some success. However, at the level of planning and control, and amphibious landing off-load planning in particular, the status of the framework continues to be 'under construction'. There are alternative proposals of how plans should be formally related to their implementation (Stork, 1999). The domain models of Figures 5 and 6 are incomplete, inasmuch as object attributes can be related vertically as well as horizontally (forming hierarchies of complexity – Dowell and Long, 1989). The off-load planner and planning-aid components of the interactive worksystem (see Figure 7) need further validation. Last, the expression of off-load planning performance (see Figures 9 and 11) requires more complete and explicit operationalisation. The domain approach framework, then, remains under construction, and further research is required for its validation.

6.2. Status of the Case-Study

The case-study formed part of a programme of research, attempting to develop a class-based theory of HCI, to improve the carry forward between military procurement projects (Colbert and Long, 1996). The case-study would have benefitted from a more explicit use of design and evaluation methods. For example, integration of the domain framework with a structured analysis and design method, such as MUSE (Method for Usability Engineering – Lim and Long, 1994), would have made the framework's support for design more explicit. Such integration has been initiated elsewhere (Stork, Hill and Long, 2000). A direct comparison, as an empirical evaluation, between typical off-load plan decision support (see Figure 2) and the domain-based support provided by ROPS would have provided clearer evidence as to the advantages of the domain approach. Such an evaluation remains to be conducted.

6.3. Conclusion

In spite of the need to develop the domain approach framework further and to evaluate it systematically against the decision support provided by typical off-load plans, the case study, it is claimed, nevertheless successfully illustrates how the framework is able to provide planning support in the instance of amphibious landing off-load planning. It is concluded that the provision of such decision support remains a critical problem for HCI, and that the domain approach to that provision constitutes a promising, useful addition to other current approaches.

REFERENCES

1. J.A. Ambros-Ingerson. Relationships between planning and execution. Quarterly Newsletter of the Society for the Study of Artificial Intelligence and Simulation of Behaviour, 57 (1986), 11-14.
2. M. Colbert and J. Long. Towards the development of classes of interaction: initial illustration with reference to off-load planning. Behaviour & Information Technology, 15 (1996), 149-181.
3. J. Dowell and J. Long. Towards a conception for an engineering discpline of human factors. Ergonomics, 32 (1989), 1513-35.
4. J. Dowell and J. Long. Target paper: Conception of the cognitive engineering design problem. Ergonomics, 41 (1998), 126-139.
5. M.H.H. Evans. Amphibious operations. London: Brassey's (1990).
6. B. Hill and J. Long. A preliminary model of the planning and control of the combined response to disaster. Proceedings of ECCE8 (1996).
7. D. Kahneman, P. Slovic and A. Tversky (eds.) Judgement under uncertainty: heuristics and biases. UK: Cambridge University Press (1982).
8. Keeney. Decision analysis: an overview. Operations Research, 30 (1982), 803-838.
9. G. Klein. Automated aids for the proficient decision-maker. Proceedings of IEEE Conference on Cybernetics and Society (1980).

10. K.Y. Lim and J. Long. The MUSE method for usability engineering. UK: Cambridge University Press (1994).
11. J. Linney. A review of the reactive planning literature. Internal report. Dept. of Computer Science, Queen Mary and Westfield College, London (1991).
12. J. Long and J. Dowell. Conceptions for the discipline of HCI: craft, applied science and engineering. Proceedings of the Fifth Conference of the BCS HCI SIG (1989).
13. A. Newell and H.A. Simon. Human problem solving. US: Prentice Hall (1972).
14. H.A. Simon. Theories of bounded rationality. In C.B. Radner and R. Radner (eds.) Decision and organisation. Netherlands: New Holland (1972).
15. W. Smith, B. Hill, J. Long and A. Whitefield. The planning and control of multiple task work: a study of secretarial office administration. Proceedings of the Second Interdisciplinary Workshop on Mental Models (1992).
16. W. Smith, B. Hill, J. Long and A. Whitefield. A design-oriented framework for modelling the planning and control of multiple task work in secretarial office administration. Behaviour & Information Technology, 16 (1997), 289-309.
17. A. Stork and J. Long. Structured methods for human factors research and development. Proceedings of HCI International (1997).
18. A. Stork, B. Hill and J. Long. A structured method for research and the design of an in-car information service. Proceedings of ECCE10 (in press).
19. A. Stork, J. Middlemass and J. Long. Applying a structured method for usability engineering to domestic energy management user requirements: a successful case study. Proceedings of HCI'95, 367-385. (1995).
20. J. von Neumann and O. Morgenstern. Theory of games and economic behaviour. US: Princeton University Press (1947).
21. W.W. Zachary and J.M. Ryder. Decision support systems: integrating decision aiding and decision training. In H. Helander, T.K. Landauer and P. Prabhic (eds.) Handbook of Human-Computer Interaction. Netherlands: Elsevier Science (1997).

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Human Factors of Virtual Collaboration in Product Design

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This keynote address presents human factors issues of collaborative engineering, taking Malaysia's Multimedia Super Corridor and worldwide manufacturing web as the implementation scenario for the Virtual Collaboration in Product Design (VCODE) project. It identifies trends in the development of collaborative systems. The purpose is to uncover challenges in communication and collaboration in virtual product design settings, and propose a methodology to arrive at design solutions.

1. INTRODUCTION

Knowledge is a crucial factor of production in today's global knowledge economy. With growing specialization and globalization, designers often face situations in which the knowledge they possess is no longer sufficient to produce a good design. Increasingly, the knowledge required to make sound design decisions is distributed among many organisations and needs to be leveraged across organisational boundaries. One reason is the increasing use of supply chain to deliver product parts. The design of these rests with the supply chain company and it must be integrated with the overall product design.

There are several emerging trends of the 21st century: the sharing of knowledge through various applications, the use of appropriate technology and methods to create virtual marketplaces and virtual organisations, the management and organisation of knowledge into systems or processes, and the enhancement of human capital (competencies) to sustain knowledge.

Organisations that are involved in the design and development of new products have to adopt flexible, dispersed methods of working to meet the numerous and varied demands of the global marketplace. Connected through the information and communications technology (ICT), manufacturing companies will design new products in direct collaboration over engineering networks, involving multidisciplinary engineering and design teams. The network may enable: (1) worldwide access to engineering and design information, (2) the establishment of unbounded information logistics, (3) the establishment of virtual design studios, and (4) 24 hour engineering around the world. The main objectives of collaborative engineering are: to speed up product development, to access the best competencies, and to make use of the knowledge and know how of the specific markets. A major challenge, however, is the coordination and management of the worldwide distributed engineering and design teams (Bichler, 2000). Concurrent Engineering (CE), indeed, is a management and engineering philosophy, aimed at improving the total value chain in product development. Since most decisions made during Product Development affect life cycle perspectives, decision making should proceed collaboratively. Therefore Collaborative Engineering is a systematic approach to control life cycle cost, product quality and time to market during Product Development, by concurrently developing products and their related processes with response to customer expectations, where decision making ensures input and evaluation by all life cycle disciplines, including suppliers, and information technology is applied to support information exchange where necessary (Willaert et al., 1998: 92).

ICT impacts product development, engineering and design processes in various ways:

- the ability to use new communication capabilities, such as multimedia communication, computer supported cooperative work (CSCW) methods, and concurrent design/ simultaneous engineering methods as a source for the creation of new collaboration methods,
- availability of new and integrated application software tools for engineering and design, rapid prototyping technologies, planning and scheduling, and production,
- the ability to apply new product development management tools in the product life cycle,
- the creation of new project-oriented and team-based organisational structures, and
- the introduction of new workflow concepts for structuring the tasks and introducing work procedures.

A Collaborative engineering network requires several tools and work procedures: software for virtual product development, the network environment, and the organisation of teamwork structures. Virtual product development is an engineering and design methodology which exploits potential ICT in the product development process. The approach is to develop the product completely digitally. The network environment relies essentially on internet technology, besides intranet and extranet to support fast and efficient communication. The organisation of distributed engineering and design teams can be difficult due to lack of team coordination and understanding. Equipment for telecollaboration and cooperation should make it possible to: (1) adhere to engineering and design standards, (2) manage quality of the product development process, (3) use common engineering and design methodology and terminology, and (4) use teamwork guidelines (defining availability of team members, telemeeting procedures, decision documentation, and backtracking, briefing procedures, release and change management).

The collaboration marketplace has been evolving over the last ten years, delivering technologies that enable coordination and information sharing, virtual meetings, and more recently virtual collocation. The promise of these technologies is to improve organisational ability to collaborate, coordinate, and share information in order to facilitate inter- and intra-organisational teams. While these new collaborative media promise to reduce cost and time of information exchange, they have other economical, sometimes subtle implications on collaborative design processes, such as the costs of knowledge sharing and the incentives for innovation, that have not been formally addressed in research. In addition, various human-computer interaction (HCI) issues arise in providing collaborative systems.

Many of the early pioneers in HCI considered groupware capabilities important. For example, Vannevar Bush in the 1940s predicted both organisational memory and the Web in *Memex*. In the 1960s Douglas Engelbart demonstrated NLS - a prototype of what we now consider standard groupware applications: electronic mail, shared annotations, shared screens, telepointers, and audio/video conferencing. The 1970s saw the widespread deployment of asynchronous groupware, such as email and threaded text conversations through conferencing systems and bulletin boards. Despite these technical breakthroughs, there was no unifying field to bring these ideas together until 1986 when a CSCW workshop was organised in Austin, Texas (Crow et al., 1997).

This paper highlights pertinent human factors considerations of virtual collaboration, taking the VCODE, **V**irtual **Co**llaboration in (Product) **De**sign, project as a point of departure.

2. THE VCODE PROJECT

VCODE is a national-funded Malaysian project, under the Intensified Research in Prioritised Areas (IRPA) Grant, that began in April 2000. It brought together partners from different technological and cultural backgrounds: the VCODE team consists of 10 academic and research partners with a wide range of expertise in networked Virtual Reality (VR), Computer Supported Cooperative Work (CSCW), human factors, HCI, multimedia, product design and industrial engineering. The overall objective of the project is to comprehensively explore the issues in design, implementation and usage of multiparticipant shared virtual environments, at scientific, methodological and technical levels, for product design (see, http://www.unimas.my/idea/vcode). VCODE aims to:

- document several alternative strategies for virtual collaboration on the Web based on literature review;
- suggest a viable methodology for Web-based collaborative engineering;
- document cultural/individual differences among designers that impede collaboration and communication;
- develop a virtual environment (VE) for product design; and
- develop a methodology for usability evaluation of VE in collaborative design.

The implementation scenario for VCODE is Malaysia'a Multimedia Super Corridor, MSC (see, http://www.mdc.com/msc.html). Collaborative engineering is an essential component of the WorldWide Manufacturing Web (WMW), which is set up in the MSC. In fact WMW is designed to facilitate cost-effective interaction between different companies and individuals (Khalid, 2000). The VCODE project is intended to deliver a State–of–the–Art collaborative system that can be used in WMW. VCODE will utilize several media (graphics, animation, video, text, sound and shared whiteboard) to simulate real environments. VCODE will facilitate Web-based concurrent engineering by presenting product information in a Virtual Environment (VE).

2.1 Malaysia's Multimedia Super Corridor

The World Competitiveness Index 2000 (The Economist, April 22, 2000, p. 102) ranked Malaysia as fourth among non-OECD countries in terms of international competitiveness (after Singapore, Hong Kong and Taiwan). To remain competitive, Malaysia has developed two strategies. First, to become a leader in the region by creating value from IT businesses, and second, to acquire global status by creating a "multimedia utopia" for world class technology-led companies that desire to use Malaysia as a regional hub. Hence the concept of

'Multimedia Super Corridor', which will enable companies to collaborate in new ways using multimedia and telecommunication technologies. The MSC Project is expected to help actualise Malaysia's Vision 2020, that is development into a fully developed nation likewise other industrialised countries by the year 2020. It has attracted large investments, and to date the MSC status has been awarded to 329 local and international companies (MSC Partners, 7 July 2000).

There are seven flagship applications: Smart Schools, Electronic Government, Telemedicine, National Multipurpose Card, Worldwide Manufacturing Web, R&D Clusters, and Borderless Marketing Centres. To develop these applications, the technology and infrastructure supporting the technology include:

- Physical infrastructure, comprising 2.5-10 gigabits fibre-optic backbone to support virtual boardrooms, remote CAD/CAM operations, and live multimedia internet broadcasting.
- High capacity links to international centres to ensure that information, products, and services flow freely and quickly between MSC companies, their overseas partners, and export markets.
- Open standards, high-speed switching and multiple protocols including ATM for the development and implementation of multimedia applications.
- Supporting legislation, policies and practices, such as cyberlaws and bills of guarantee, which will encourage global collaboration.
- Availability of about 25,000 skilled knowledge workers with multimedia education over the next five years.

2.2 The worldwide manufacturing web

The term *Worldwide Manufacturing Web*, unique to Malaysia, is supposed to complement the Second Industrial Master Plan of Malaysia. The ultimate goal is to position Malaysia as a prime choice for manufacturing companies, which can locate manufacturing operations in the region more efficiently and cost-effectively. The WMW encourages companies to build links between their national and regional operational centres around a wide range of support services: Research and Development, Design, Engineering, Manufacturing Control, Procurement, and Logistics and Distribution Support. This will eventually create a "web" of manufacturing-related operations that will reach far beyond Malaysia and the Southeast Asian region (MSC Worldwide Manufacturing Web, 2000). Rockwell Automation, a global electronic controls and communications company, is intended to play a key role in the WMW.

Figure 1 presents a framework of the Human Factors Issues in WMW. The factors relate to four components of collaborative systems: human operator, task, communication technology and collaborative environment. However, VCODE shall address human factors issues at the user interface, such as:

- How to format and present information that enable CE team members to utilise it efficiently. Verbal, graphical and written communication will be used at various stages, supported by the collaborative system.
- How to provide a preset procedure to support design decision making. Distinctions between "Functional Requirements", "Design Parameters" and "Process Variables" will structure and clarify the communication and information coordination. In

addition, design problem solving may be organized top-down, using abstraction hierarchies (such as in IDEF0). This procedure will also improve creativity in design.

- How to make the system intuitive to use by team members. Usability of VCODE will therefore be evaluated. Cultural and individual differences that may impede communication and collaboration will be investigated.

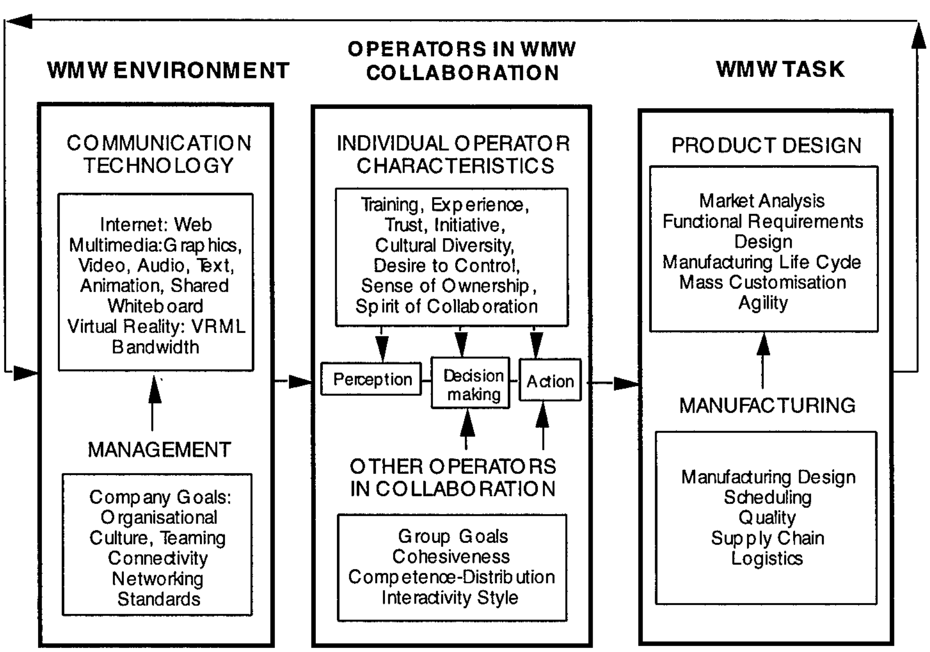

Figure 1. Systems Approach to Human Factors of Collaborative Systems in WMW

A review of the CSCW literature will highlight some human factors concerns of VCODE.

3. COLLABORATIVE DESIGN ISSUES

Collaborative design, also termed as collaborative engineering (e.g. Regli and Hewett, 1999; Willaert et al., 1998) has several benefits: the ability to tap knowledge resources in various geographical locations, the cost savings from reducing the design cycle time, and savings by not having to travel between two or more remote locations.

A typical collaborative system comprises: CAD database, document management system, discussion database, and shared software database. The shared space is where participants coordinate their collaborative design activities. Intelligent engines and agents reside in this shared space to support the activities of the participants by providing automated services, including detecting design changes and scheduling meetings for synchronous problem solving sessions.

Real-time collaboration tools (e.g Microsoft's *NetMeeting*) provide organisations the ability to conduct virtual meetings and share information in real time. Examples include text chat, audio-video conferencing, and data conferencing (e.g. shared whiteboard and real-time application sharing). Commercially available tools, such as CoCreate's *OneSpace*, enable teams to collaborate by working directly on the 3D solid model over low-bandwidth network connections in the Web infrastructure (Mueller, 1999). But these tools tend to emphasise on design modifications in the product life cycle rather than on conceptual design. For instance, Kao and Lin (1996) provided a collaborative CAD/CAM system to interactively coedit CAD geometry at a distance via Internet.

Most collaborative tools do not adequately address the issue of security. Although these tools support some form of authentication, they typically do not support encryption of the chat conference data, and some tools introduce firewall risks. Table 1 presents various forms of collaborative systems (Deus, 2000).

Table 1. Collaborative Systems

Asynchronous Collaboration solutions	Synchronous Collaboration solutions	Integrated Collaboration Environments
- document-centric, share information and ideas - email - bulletin boards/discussion databases - information sharing tools/ intranets - group calendaring	- sessional meetings, interactive and share in creation process - supports formal and ad hoc collaborations - text chatter - shared whiteboards - application sharing/screen sharing - LAN-based video and audio conferencing	- support all models of collaboration - synchronous and asynchronous - people as core component - persistence and place based, provides virtual co-location - very large scale collaboration
Present Baseline 5-10 years →	Present Maturing 2-4 years →	Future, Evolving 6-15 months

The next wave of development in collaboration technologies will address virtual collocation, often referred to as "place-based" collaboration environments. These environments integrate people, communications, and shared data, into a shared virtual space. The environment itself is persistent, which means that the shared space, shared data, and properties of the collaboration environment do not go away (such as in virtual meeting) but remain available to support ongoing collaboration. Some key properties of place-based collaboration environments include: (1) rich communications (e.g. text chat and audio/video conferencing), (2) shared document store to make documents and other data available to others, (3) tailorable virtual spaces to provide the location and context for the collaboration, (4) conference management for managing chat, audio/video, and other conferences within the collaboration context, and (5) presence awareness so that users are aware of others that are available in the collaborative environment.

Place-based collaboration is still an active research area, with two commercial products available in the last two years, TeamWave *Workplace* and General Dynamics *InfoWorkspace* (Deus, 2000). Place-based collaboration environments are not yet interoperable with each other, and there are currently no standards for virtual space environments.

As demand for collaboration grows from workgroup to enterprise and cross-organisational scale, commercial offerings will eventually evolve toward a system framework approach, where the above-mentioned collaboration services become integrated with the information infrastructure (e.g. Davis et al., 1999). The services-based framework will give: (1) flexibility in product choices to satisfy user requirements, (2) competitive advantage to benefit from rapid technology evolution and innovation, and (3) interoperability from leveraging existing enterprise services (e.g. directory, security, document, search, workflow, and network services). Implementing such a framework is challenging and requires time, as the components for the framework and the techniques for integrating the services become better understood.

Despite these offerings, the uptake has been slow. Reasons for the slower adoption can be attributed to technical/infrastructure, security, and cultural issues. In order for an organisation to be able to successfully use collaboration technologies on an enterprise scale, the network and systems infrastructure must be able to support the requirements of the collaboration tools. Real-time conferencing, for example, requires available bandwidth and quality of service from the network.

Evidently, it is still too hard for people to work together through their computers because of the artificial constraints of technology, inadequate interface design, and the poor integration of conventional software with groupware. There is a need to make the computer an affordance for working together (Greenberg, 1998).

Also, there is a lack of comprehensive methodologies in CSCW for analysing system requirements and for evaluating interfaces, as well as doing them cost-effectively (e.g. Olson and Olson, 1997). Understanding a group's work practice is inherently more difficult than understanding a single person's work practice. The same individual will relate to others in a groupware context in quite different ways, depending on their personalities, the dynamics of their group, the organisational structures, and their politics.

Testing groupware is also extremely difficult. It demands more than traditional usability studies. Several evaluators are required to observe each subject, and interactions with other subjects. Field studies on groupware deployment is therefore difficult to research. To futher confound the problem there are no agreed upon measurement metrics for deciding upon the success or failure of groupware. Measuring the end product often shows little difference because people are resilient at working together through even the most limited groupware.

The Web technology gives users the means to contribute and to share information but it is still a long way from true collaborative systems. For example, standard Web browsers are still single user tools that partition one person from another. We need commercial Web browsers with built in groupware capabilities and some kind of XML or Java standard that will make groupware connections easy to create and useful groupware applets easy to build and maintain (Crow et al., 1997).

Among the many impediments to successful virtual collaboration are issues of: cognitive overload, lack of awareness of others' activities, lack of context about the purpose and history of shared objects, lack of appropriate feedback and acknowledgement of contributions to the shared space, disorientation, unbalanced participation, and problems with bringing new team members into a complex and established collaborative space.

Various research has addressed the problem of building systems to support collaborative work. A number of system prototypes have appeared in the literature. Examples include *Answer Garden* (Ackerman and Malone, 1990) for capturing design rationale and maintaining organizational memory, *Collaborative Work Environment* to facilitate real time group work with shared objects and artifacts (Hindmarsh et al., 1998), and *Community Place* to support large-scale shared 3D spaces on the Internet using VRML (Lea et al., 1997).

Regli and Hewett (1999) developed a Networked Engineering Studio consisting of design, manufacturing and collaboration facilities at Drexel University (with collaborators at Carnegie Mellon and University of Southern California). The studio is user-driven, and employs iterative evaluation methodology for distributed design environments. Maher and Saad (1995) created a Virtual Design Studio at the University of Sydney, Australia, for teaching students about computer-mediated collaborative design. The technology available for the studio includes: CAD, image processing, Web, video conferencing, email, shared file and file transfer, and shared whiteboards. The limitations lie in the lack of structure in sharing information and CAD files across the Web.

Multiparticipant, distributed, virtual reality systems are emerging as a new class of tools for supporting groups in collaborative work situations, such as the COVEN project (Normand, 1999), DCEE system (Maxfield et al., 1998), DIVE and MASSIVE systems (Benford et al., 1995). For example, the DCEE system addresses the problems of integrating information that is generated during product development with a distributed virtual environment, and the problems of supporting multidisciplinary teams in the development process. Design issues in developing shared virtual environments are deemed important (e.g. Khalid and Helander, 2000; Amselem, 1995). Some of these research issues will be discussed in greater detail below.

4. DISCUSSION

We see the promise of technology but suffer the limitation of current low levels of effectiveness of interaction with the technology. This shortfall between technical promise and effective interaction arises because the capability to design and build a system does not ensure its usefulness. Too many technologists use a "let's build it and see" approach. Research is needed to study, analyse and reflect on the use of technology. Interdisciplinary research should:

- understand the factors that make technology useful. An important challenge involves identifying factors of demand-pull from those of technology push. What are the characteristics of collaborative systems that can be linked to measurable improvements in user and team performance?
- understand the role of persistent collaborative systems in relation to pervasive information technology. What should be the core functions of the new interactivity?
- produce methodologies and metrics that measure and predict the utility of new forms of work and information access in collaborative engineering.

For collaborative systems to be impactful, there is a need to effect usable and useful interaction. Design of these systems must take into consideration several concerns at the theoretical, methodological-content, organisational and technical levels.

4.1 Theoretical

Lack of theory

The development of collaborative tools has not been driven by a practical theory that covers the cognitive, social and architectural issues concerning any sustainable collaborative environment. One possible approach is to develop an ecological theory that describes patterns of interactions among diverse populations, sometimes competing, sometimes cooperating, in a changing virtual environment. Since collaborative engineering design involves multiobjective decision making, it may be possible to apply the Game theory to model interactions in multidisciplinary design (e.g. Vincent, 1983) although there are limitations such as: incomplete information on the nature of the design due to distributed knowledge and limited communication between the CE team 'players' (Cai, 1999). Moreover decisions in collaborative design are highly coupled and hard to be depicted. The theory of Information Flow (e.g. Csikzentmihalyi, 1990) and Situated Cognition (e.g. Suchman 1987) may provide a basis to uncover the different modes of coordination and information exchange, in addition to workspace awareness.

Modelling the designer/user and design problem

In a collaborative environment, designers interact by sharing common information and reaching agreements. Designers bring their own personal viewpoints to the integrated vision of the product design process. Functional, aesthetic, environmental and life-cycle issues are each characterised by different viewpoints, goals and constraints that have to be balanced with appropriate tradeoffs. To support the CE team to rapidly construct integrated design problem models that account for interactions between different viewpoints, a framework for distributed modelling and evaluation of product design problems in a network-oriented design environment is required. The framework should incorporate specialised engineering analysis applications, CAD models and design problem models under a common design environment.

Peña-Mora and Ali-Ahmad (1998) proposed a framework for: (1) capturing knowledge about users, their preferences and the problems they tackle, and (2) for adapting the presentation of relevant information to those users in order to avoid or resolve conflicts. *ANGELO* models the user by proactively observing user interactions with distinct project information. The system acts as a front-end support for collaborative environments, thereby assisting users to collaborate and negotiate better by presenting information according to their preferences and viewpoints.

Another issue concerns the complexity of current engineering design. Traditionally, design collaboration is carried out through the use of schedules, plans, specifications, drawings and meetings that capture only the end results of the design process. They fail to record reasons for design decisions and design rationale. Lack of documentation often leads to design errors when downstream decisions are made based on conflicting assumptions. Slow information access to information also results in coordination problems, especially when the design process is not explicitly specified. Conflicts in designs by different members of a team often result in inefficiencies in the design process and loss of productivity (Howard et al., 1989).

Developments in OODBMS, distributed processing and networking technology have facilitated the development of a SHARED toolkit for developing environments which need to model, manipulate and communicate product information between distributed cooperating applications, while supporting coordination between them (Wong and Sriram, 1993). Another prototype is CADS tool that employs the Axiomatic design methodology for capturing the design elements and the rationale used to conceive them (Favela et al., 1993).

4.2 Methodology and content

Observation of communication and negotiation processes

Design is a social process (Bucciarelli, 1994), and a complex process that requires a variety of analytical approaches in order to be understood fully. Because of the role of human behaviour in the design process, it is necessary to rely on observations of humans in order to fully understand the design process. There have been some experimental studies of group processes in design (e.g. Tang and Leifer, 1991; Cross and Cross, 1995; Smith and Tjandra, 1998). These experiments have shown that video-based observational techniques can provide a useful and rich record of the design process, which can then be analysed in a variety of ways.

Most design methodologies analyse user requirements or customer needs in order to generate a design that satisfies the functions of the intended use. In order to realise both the functionality and the ergonomic aspects of a design, a consistent mapping from user requirements to final design is indispensable. Design cognition methods – descriptive and prescriptive - may be used to characterise a situated cognition (Helander, 1999).

Design problems are partitioned in an abstraction hierarchy, with discernable input and output. To be effective, a design team must establish a set of common rules or procedures for their design deliberations, and may want to keep track of the "level of abstraction" as the discussion proceeds. Not only would this enhance creativity but it would also minimise mis-communication between team members. Helander (1999) claimed that top-down procedural design offers several advantages since design intentions are easier to communicate to other designers. In addition, a careful elaboration of functional requirements at the top level promotes creative design .

Engineering designers have difficulties in communicating with their partners rather than with technical issues (Frankenberger and Auer, 1997). Crabtree et al. (1997) found that activities which involve coordination occupy 69% of an engineer's time in collaborative design, and include all but problem solving and thinking. Similarly, Gorton and Motwani (1996) claimed that collaborative team members spent on average 22% of the project time communicating and coordinating activities, including project management activities.

Negotiation is another characteristic of collaborative design (e.g. Kersten and Noronha, 1999). For example, Bond and Ricci (1992) described how aircraft are designed in a large organisation involving various stakeholders. The negotiation process is controlled at higher levels in the organisation in a sequence of commitment steps that greatly influence and constrain the design process.

Workspace awareness

Workspace awareness brings another dimension to understanding collaborative interactions. It helps people move between individual and shared activities, provides a context in which to interpret other's utterances, allows anticipation of others' actions, and reduces the effort needed to coordinate tasks and resources (Gutwin et al., 1996). Therefore, electronic virtual workspaces must emulate the affordances of physical workspaces, if they are to support a group's natural ways of working together, such as knowing where others are looking, relating body gestures to items in a workspace, glancing around for awareness, and so forth. For example, gaze awareness is an important aspect of collaborative work over a shared workspace. It informs a person's focus of attention, and indicates what objects the person attends to in the shared space, and whether both people are looking at the same thing (Greenberg, 1998).

4.3 Organisational

Teams

At the organisational level, the most difficult challenge is that of dealing with organisational culture and readiness to support collaborative operations. While the emphasis on collaborative design is frequently placed on the technological aspects, it is important that the assembled teams will be productive while using the technology. Since the various teams and individuals may not have met face-to-face, communication through such means as e-mail, telephone, fax and video conferencing need to be established on a continuous basis to build familiarity and rapport. It is also beneficial to monitor the morale of the team members as teams that do not mesh well together will have a difficult time putting a design plan together. The elements of teaming and trust are thus important considerations. Regardless of how skilled and educated the team members are, if they are incapable of working in teams, there is no place in the virtual corporation.

The size of a team is also an important factor. If teams are too large, they may become unmanageable and require a structure to perform in. If teams are too small, this may stifle creativity. A workable team has between 6-15 members, depending on the size of the project and complexity of the product (Baskerville, 1993). This number is optimal for problem solving, decision making as well as open and spontaneous communications (Hudak, 1992).

A further consideration when using globally dispersed teams is the time differences that exist between teams. For example, cooperating teams located in Malaysia and USA may have a 10-12 hour time difference and no common working hours. This makes direct communication inconvenient, and potentially introduces a major obstacle for effective team interaction. On the other hand, time differences between development teams introduce the possibility of continuous shift work on the same task (Gorton and Motwani, 1996).

Knowledge transfer costs

In collaborative design there are individual and organisational goals. Customers, managers, design engineers and manufacturing engineers have different perspectives. In the design process, individuals influence each other through social interaction and change the perspectives. Huang (1999) described the costs of knowledge transfer. There is a broad spectrum of different types of knowledge that is involved in design. Explicit knowledge (e.g. price, quantity) is transferred at low cost. As knowledge becomes more tacit, the cost of transferring knowledge increases. Scientific (e.g. technical properties of a product), idiosyncratic (e.g. skills and preferences of individuals which are place and time sensitive) and experiential knowledge (e.g. personal experience combining intuition, judgment and common sense) are costly to transfer (Hayek, 1945).

4.4 Technical

Conferencing technologies

Much of the development and use of desktop conferencing systems has been driven by technology advances with little consideration for actual human communication. It is important to examine what communication functions are enabled by various technologies, and what may be hindered. Tang et al. (1994) found that technologies that took too long to set up and were unreliable tended to hinder communication and users avoided them.

Present day *NetMeeting* application offers full data-, audio-, and video-sharing capabilities, with shared whiteboard for collaboration. But the video conferencing is still point-to-point unless coupled with a third party multipoint video conferencing system, such as Intel's Proshare. Video is regarded important for videoconferencing but the main effects are in the nature of the interactions and the perceptions of the users, not in the performance of tasks (Patrick, 1999). In contrast to video, audio is crucial as it carries the bulk of the information. Problems such as low quality, audio loss, echo and delay affect the effectiveness of videoconference session.

A shared workspace electronic tool, such as the whiteboard and text editor, can enhance design performance (Olson et al., 1995) than using a normal face-to-face meeting room tools (e.g. whiteboard, pencil, paper). Despite the availability of various conferencing tools, there has been little research on the value of videoconferencing for collaborative work tasks. Olson et al. (1995) found groups using the videoconferencing system spent more time managing the meeting and clarifying what was meant than the face-to-face groups. However, there was no difference in the quality of the designs produced. This meant conferencing technology may be effective for collaborative work but not necessarily efficient.

Synchronous/asynchronous collaboration

Toolkits for developing collaborative applications tend to support either a fully synchronous form of collaboration, or a fully asynchronous form Today, there are toolkits to support both modes and a smooth transition between modes, such as *WeMet* (Rhyne and Wolf, 1992). The *WeMet* toolkit bridges the two modes by providing fine grained, immediate, displayed actions and by providing a history of the actions. All events in the history are timestamped to permit realtime replay. The history supports a branching, lossless model and multiple users, using multiple views of multiple applications.

5. CONCLUSION

A successful collaborative engineering process requires communication systems that support collaborative working among geographically dispersed teams. The systems provide facilities for synchronous and asynchronous sharing of product information that is generated during a product development life cycle. We are now seeing a cornucopia of supporting technologies, including the internet, intranet, extranet, email, groupware, videoconferencing, workflow, data management, data warehousing, and improved networking capabilities.

The true measure of any technology lies in its usefulness – how often, by whom, how easily, and how conveniently. For these technologies to be implemented successfully in the MSC, we need to understand various human factors, cultural and usability issues at the user interface that can enhance affordance of collaborative systems. These issues inspired the VCODE project.

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REFERENCES

1. D. Bichler, Global engineering networks – product design in global teamwork structures, Proceedings of Professional Congress 'The Future of Work', World Engineers' Convention, 19-21 June (2000) 89-103. VDI Verlag, Dusseldorf.
2. S.S.A. Willaert, R. de Graaf and S. Minderhoud, Collaborative engineering: a case study of concurrent engineering in a wider context, Journal of Engineering and Technology Management, 15 (1998) 87-109.
3. D. Crow, S. Parsowith and G.B. Wise, Students: The evolution of CSCW – past, present and future developments, SIGHI Bulletin, 29, 2 (1997).
4. H.M. Khalid, Human factors of IT-based solutions for worldwide manufacturing web, Human Factors and Ergonomics in Manufacturing, 10, 1 (2000) 99-113.
5. MSC Partners, http://www.mdc.com.my/partner/index.html (2000).
6. MSC Worldwide Manufacturing Web, http://www.mdc.com.my/flagship/manufact/index.html (2000).
7. W.C. Regli and T. Hewett, HCI issues in collaborative and networked engineering design, CHI '99 workshop, http://www-eurisco.onecert.fr/events/CHI99/regli.html (1999).
8. A.Mueller, Shared engineering with OneSpace from CoCreate, Technical White Paper (1999) 1-10.
9. Y.C. Kao and G.C.I. Lin, CAD/CAM collaboration and remote machining, Computer Integrated Manufacturing Systems, 9, 3 (1996) 149-160.
10. L. Deus, Collaboration marketplace evolving to meet emerging needs, http://www.mitre.org/pubs/edge_perspectives/february_00/ep_first.htm (2000).
11. J.G. Davis, E. Subrahmanian, S. Konda, H. Granger, M. Collins and A.Westerberg, Creating shared information spaces to support collaborative design work, http://www.uow.edu.au/commerce/buss/dsl-tr2-99.html (1999).
12. S. Greenberg, Collaborative interfaces for the Web. In C. Forsythe, E. Grose and J. Ratner (eds.) *Human Factors and Web Development*, LEA Press (1998) 241-254.
13. G.M. Olson, and J.S. Olson, Research on computer supported cooperative work. In M.G. Helander, T.K. Landauer and P.Prabhu (eds.) *Handbook of Human-Computer Interaction* Elsevier Science, Amsterdam (1997) 1433-1456.
14. M.S. Ackerman and T.W. Malone, Answer Garden: a tool for growing organizational memory, Proceedings of the Conference on Office Information systems, Cambridge, Mass., April 1990, ACM, New York (1990) 31-39.
15. J. Hindmarsh, M. Fraser, C. Heath, S. Benford and C. Greenhalgh, Fragmented interaction: establishing mutual orientation in virtual environments, Proceedings of CSCW '98, Seattle, Washington (1998) 217-226.
16. R. Lea, Y. Honda and K. Matsuda, Virtual society: collaboration in 3D spaces on the internet, computer supported cooperative work, Journal of Collaborative Computing, 6 (1997) 227-250.
17. M.L. Maher and M. Saad, The experience of virtual design studios at the University of Sydney, http://www.arch.su.edu.au/kcdc/design_studio/papers/anzasca95.html (1995).
18. V. Normand, The COVEN Project: exploring applicative, technical, and usage dimensions of collaborative virtual environments, Presence, 8, 2 (1999) 218-236.
19. J. Maxfield, T. Fernando and P. Dew, A distributed virtual environment for collaborative engineering, Presence, 7, 3 (1998) 241-261.
20. S Benford, J. Bowers, L.E. Fahlen, C. Greenhalgh, J. Mariani and T. Rodden, Networked virtual reality and cooperative work, Presence, 4, 4 (1995) 364-386.
21. H.M. Khalid and M.G. Helander, Design issues in virtual environments. In H.M. Khalid (ed.), *Virtual Reality: Select Issues and Applications*, ASEAN Academic Press, London (2000, in press).

22. D. Amselem, A window on shared virtual environments, Presence, 4, 2 (1995) 130-145.
23. T. L. Vincent, Game Theory as a design tool, Journal of Mechanisms, Transmissions and Automation in Design, 105 (1983).
24. J. Cai, Multiobjective decision making in collaborative engineering design: a comprehensive view, http://impact.usc.edu/cer1/Task1/task1-2-1/DecisionMaking.html (1999).
25. M. Csikzentmihalyi, *Flow: The Psychology of Optimal Experience*, Harper Collins, New York (1990).
26. L.A. Suchman, Plans and Situated Actions: The Problem of Human-Machine Communication, Cambridge University Press, Cambridge (1987).
27. F.Peña-Mora and W. Ali-Ahmad, Adaptive retrieval and presentation of information in preference-influenced collaborative design environments. In J.S.Gero and F.Sudweeks (eds.) Artificial Intelligence in Design '98, Kluwer Academic Publishers, Netherlands, (1998) 619-639.
28. A.Wong and D.Sriram, SHARED: an information model for cooperative product development, Research in Engineering Design, 5 (1993) 21-39.
29. J.Favela, A. Wong and A. Chakravarthy, Supporting collaborative engineering design, Engineering with Computers, 9 (1993) 125-132.
30. M.G. Helander (Personal communication), Design cognition, IDEA Seminar Series, Universiti Malaysia Sarawak, Kota Samarahan, Sarawak, Malaysia (1999).
31. L.L. Buciarrelli, *Designing Engineers*, MIT Press, Cambridge, MA (1994).
32. J.C. Tang and L.J. Leifer, An observational methodology for studying group design activity, Research in Engineering Design, 2 (1991) 209-219.
33. N. Cross and C. Cross, Observations of teamwork and social processes in design, Design Studies, 16 (1995) 143-170.
34. R.P. Smith and P. Tjandra, Experimental observation of iteration in engineering design, Research in Engineering Design, 10 (1998) 107-117.
35. E. Frankenberger and P. Auer, Standardized observation of team-work in design, Research in Engineering Design, 9 (1997) 1-9.
36. R.A. Crabtree, M.S. Fox and N.K. Baid, Case studies of coordination activities and problems in collaborative design, Research in Engineering Design, 9 (1997) 70-84.
37. I. Gorton and S. Motwani, Issues in cooperative software engineering using globally distributed teams, Information and Software Technology, 38 (1996) 647-655.
38. G. Kersten and S. Noronha, Negotiation via the World Wide Web: a cross-cultural study of decision making, Group Decision and Negotiation, 8 (1999) 251-279.
39. A.H.Bond and R.J.Ricci, Cooperation in aircraft design, Research in Engineering Design, 4 (1992) 115-130.
40. C. Gutwin, M. Rosenman and S. Greenberg, A usability study of awareness widgets in a shared workspace groupware system, Proceedings of ACM Conference on Computer Supported Cooperative Work, ACM , Boston (1996).
41. D. M. Baskerville, Why business loves workteams, Black Enterprise 23, 9 (1993) 85-90.
42. G. J. Hudak, Concurrent engineering: what are the risks and benefits? Proceedings of the Technical Program, NEPCON West '92, Anahein, CA (1992) 362-372.
43. J. Huang, How do distributed design organisations act together to create a meaningful design? Towards a process model for design coordination. In Eastman, C. and Augenbroe, G. (eds.), Computers in Building – CAAD Futures' 99, Kluwer Academic.
Dordreacht (1999).
44. F. A. Hayek, The use of knowledge in society, American Economic Review, 35, September (1945) 1-18.
45. J.C. Tang, E.A. Isaacs and M. Rua, Supporting distributed groups with a montage of lightweight interactions, Proceedings of CSCW '94, Chapel Hill, North Carolina, USA (1994) 23-34.
46. A.S.Patrick, The human factors of Mbone videoconferences: recommendations for improving sessions and software, Journal of CMC, 4, 3 (1999) 1-36.
47. J. S. Olson, G.M. Olson and D.K. Meader, What mix of video and audio is useful for small groups doing remote real-time design work? Proceedings of CHI'95, ACM Conference on Human Factors in Software (1995) 362-268.
48. J.R. Rhyne and C.G. Wolf, Tools for supporting the collaborative process. Proceedings of UIST '92, November 15-18, 1992, Monterey, California (1992) 161-170.

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Human-Human Cooperation in Airborne Combat System: Designing CSCW Support

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Major breakthrough in Situation Awareness and Workload reduction have been achieved on the Rafale through the use of advanced technologies either for Displays and Controls (such as collimated displays, Hand On Throttle And Stick-HOTAS, Helmet Mounted Display-HMD, Direct Voice Input-DVI, Touch screens) and in crew assistance functions (such as flight management and sensor fusion) adapted to the numerous flight situations of the Aircraft such as High G, Adverse weather or Terrain Following.

Emerging new requirements such as needs for more co-operative missions or crew increased protection to Directed Energy Weapons (DEW) combined to a continuous quest for affordability and fault tolerance justify that R&D activities be continued. These are performed along two approaches

- ◊ Bottom-up (new HMI technologies) : Technologies such as Advanced Direct Voice Input (DVI), 3D Sound, Helmet Mounted Displays, Reconfigurable Large Area Displays (Big Picture Concept) and Virtual Reality
- ◊ Top down : New requirements leading to new concepts (closed cockpits, fault tolerance, remote operations,...)

Along these quite classical approaches the R&D activity leaves a place for more fundamental and theoretical approaches that are in general performed and developed with research organisation and universities; the domains that are considered cover all aspects of HMI : physical and cognitive aspects. Example is given of research in the field of co-operation resulting of research project jointly established by Dassault Aviation and LAMIH (University of Valenciennes France) aiming at defining Computer Supported Cooperative Work (CSCW) assistances.

1. INTRODUCTION

Major breakthrough in Situation Awareness and Workload reduction have been achieved on the Rafale through the use of advanced technologies either for Displays and Controls (such as collimated displays, Hand On Throttle And Stick-HOTAS, Touch screens, Direct Voice Input-DVI, Helmet Mounted Display-HMD) and in crew assistance functions (such as flight management , sensor fusion and co-operation) adapted to to the numerous flight situations of the Aircraft such as High G, Adverse weather or Terrain Following.

Our approach of Man Machine Interface is represented by a list of functionalities that have to be simultaneously performed within systems in order to cope with the interactions the human has to support with its environment. First thing is then to identify what is the environment and second how are the interactions achieved?

Two kind of interactions can be considered:

§ Direct interaction : the operator is directly in contact with the considered element of the environment

§ Indirect interactions : the operator is in contact with the environment through additional devices such as sensors, actuators, displays,...

The environment covers numerous aspects including natural elements, tactical theater elements, crew installation devices, support systems, etc.

The limits of HMI can be clearly defined by what is strictly necessary and sufficient for the operator to be able to perform efficiently the tasks and roles he has been assigned during design.

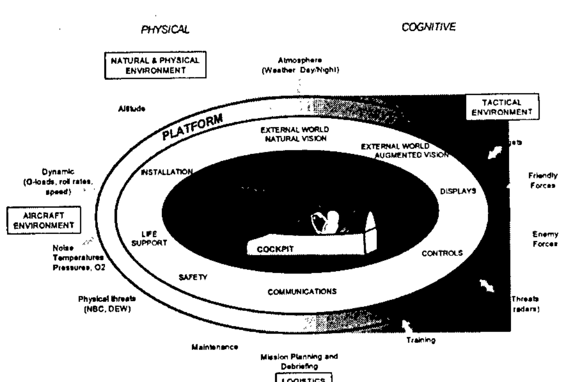

Figure 1 : HMI Functions-Interactions with the environment

Consequently the various functionalities of HMI can be characterised by the transfer function between the operator and the considered interacting environment, one of the aspect of the complexity being the simultaneity of all these requirements. Nevertheless partial approaches are still possible before facing the "Big Thing".

New design will derive firstly from evolution from the mission environment (new missions, new threats, new conditions,...), then changes in the number and simultaneity of functions (assess, assess and control,...location of operator) and finally changes in operator profile (population, skills, variability,...as well as cultural aspects and changes in education) which are the three leading design drivers to be considered.

Emerging new requirements such as needs for more co-operative missions or crew increased protection to Directed Energy Weapons (DEW) combined to a continuous quest for affordability and fault tolerance justify that R&D activities be continued on new HMI technologies and concepts which results could be applied to upgraded versions of existing platforms or to entire new designs. In some areas advanced researches based on scientific analysis are performed in order to establish or consolidate the necessary theoretical background.

2. BASIC APPROACHES

Apart from basic research activities to be illustrated later on in this paper, applied R&D activities are driven two ways, depending on input parameters that are considered, both concurring to an improvement of system global performances (Affordability, Lethality, Flexibility, Availability, Survivability, Safety):

◊ considering available technology that lead to bottom up approaches
◊ considering end requirements that lead mainly to Top down approaches

These two approaches have been described in (Hélie ATS99). and are summarised by the following figures

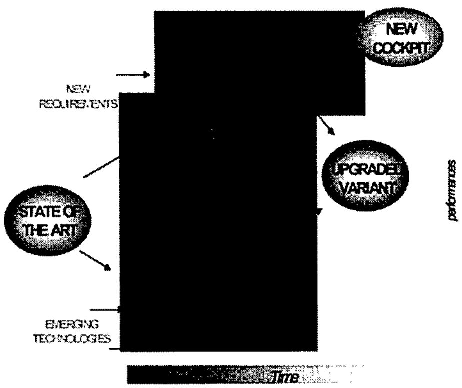

Figure 2 Technical Approaches in R&T: Bottom up and Top down

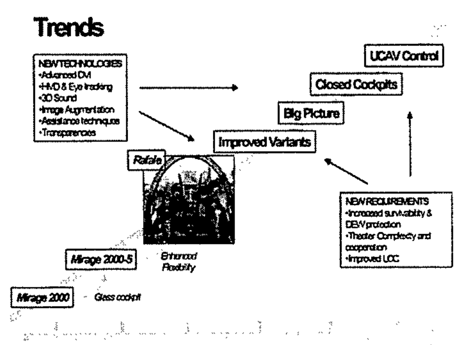

Figure 3 Trends for HMI Requirements versus Technologies

3. ADVANCED R&D

Along with the above pragmatic-approaches, some areas within the HMI domain need that applicative R&T be supported by some basic scientific approaches, for various situations such as :

New areas or environments (e.g. closed cockpits, remote operations)
Lack of theoretical background
Reuse of a theoretical background developed in a different application area
Deployment of theory to the industrial application

These various situations justify that some co-operations with the scientific world be developed to acquire the knowledge for improved efficiency of current systems or satisfaction of future requirements.

The following part of this paper presents one application domain (man-man cooperation) amongst several relevant to HMI where Dassault Aviation is involved with theoretical approaches performed either in house or in cooperation with research organisations for the development and deployment of advanced scientific matter (anthropometry, disorientation might have been developed as well in this paper). The paper develops what has been and is being achieved in the domain of man man cooperation with a very fruitful partnership that has been established between Dassault Aviation and LAMIH (University of Valenciennes-France) The organisation of these advanced activities is in general the following :

- Dassault Aviation defines the research objectives, defines case studies with associated environment, provides support to experiments (facilities, people, scenarios,...), and if successful, ensures deployment of results to aeronautical domain
- Scientific partner develops the necessary approaches, conducts experiments, analysis, and at end establishes recommendations for deployment and follow-on activities (refinement of theory, domain extension), communicates with scientific world

4. MAN MAN COOPERATION

Position of Problem

Modern air operations involve more and more platforms to cooperate in complex dynamic and interacting environments. Cooperative situations may be numerous such as cooperation between crew members, cooperation between leader and wingman, cooperation between pilot and controller, cooperation between man and autonomous intelligent systems.

Each of these situations may generate different problems such as

◊ Sharing of situation representation (linked to various available sensors)

◊ Understanding of activities performed by other humans or intelligent systems in the package

Up to now cooperation has been performed mainly through vocal exchanges between participants using radio-communications. The following figure illustrates current and future cooperation situations for various types of Dassault Aviation military aircraft's.

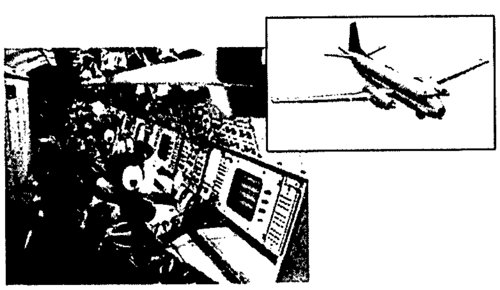

Figure 4. Atlantic 2 Maritime Patrol Aircraft 12 Crew members; Link 11

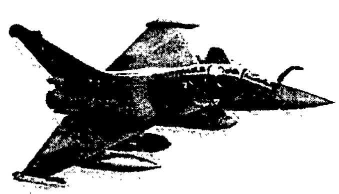

Figure 5. Rafale B Multirole fighter2 seat variant; 1 Pilot + 1 WSO or Instructor; Link 16

The approach of cooperation must not be limited to inside the aircraft cockpit itself. It can be extended to the cooperation between members of one combat package or with a Control and Communication node and, in a future that may prove not to be so far away, between human and autonomous machines (such as UCAV) that may figure behavioural characteristics close to the human in context similar to the one illustrated by the following figure.

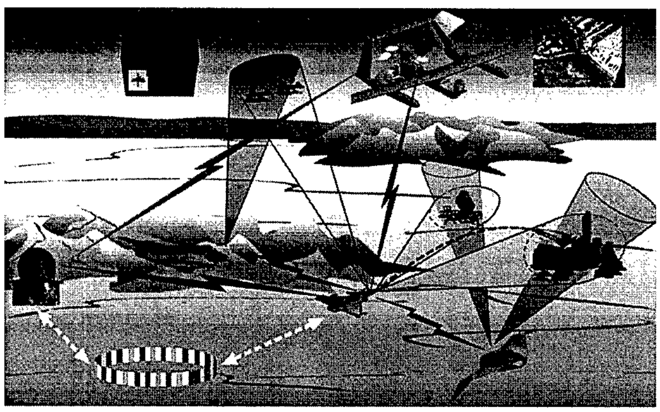

Figure 6. Future Global Tactical Network: Cooperation between Human(Airborne or Ground-based) and autonomous machines

Increasing use of Data-links for tactical communications is accelerating needs for considerations to structure the cooperative activities inside or outside cockpits through the definition of design rules and development of dedicated assistance techniques.

To cope with these new challenges Dassault Aviation has established a research project performed in cooperation with French National Research Centre (CNRS-LAMIH) aiming at the definition of:

- ◊ Cooperation modalities through a theoretical approach, which is being consolidated by an experimental assessment with French Air Force crews
- ◊ Definition of various assistance techniques for the cooperation activities

These experiments are performed through a man in the loop simulation that can figure the various cooperation situations mentioned previously. One originality of this project lies in the method, dubbed "Wizard of Oz ", used to generate the various aids the system may involve. It consists in the involvement of an human expert who generates through a control station the assistance function outputs that are sent to various human actors. The main interest of this method is that it avoids developing complex functions which may be of poor interest. The detailed presentation of this project is developed here after

5. RESEARCH PRESENTATION

Facing the development of collective work, we observed a growing interest for cooperation of cognitive ergonomics studies at the end of the twentieth century. In aeronautics, human-

human (H-H) cooperation has been a research topic for a long time (Foushee, 1984). Spectacular accidents aroused an awareness of the risk related to the psychological features of small group behaviour. Different approaches appeared with time to improve H-H cooperation: training of crews (i.e. Cockpit Resource Management (Wiener, Kanki, Helmreich, 1993)), procedure design, technological assistance design.

Recently with the development of network technology and distributed work, a new research movement appeared, named Computer Supported Cooperative Work (CSCW) (Schmidt, 1994). CSCW researches are mainly oriented towards the design of assistance tools, but application domains mainly concerns static situations, collective design, collective editing, etc. However, it seems interesting to investigate whether tools, techniques and concepts of CSCW are applicable to situations of dynamic processes supervision, and particularly to aeronautics.

In this paper, we focus on cooperation in a small team made up of a pilot and a weapon system officer (WSO) in fighter aircraft. Cooperation takes place in a dynamic and risky situation with a high rate of evolution. Such situations are complex, they require a great adaptability and operators are subject to considerable variations of workload and strong temporal constraints. In real work (particularly in Mirage 2000-D like aircraft), the pilot and the WSO have specific roles and their respective workplaces are also specialised (although largely redundant). The pilot is responsible for the short-term management of the situation (piloting, firing, etc.) whereas the WSO manages middle and long-term processes (management of the flight plan, systems preparation, etc.). An important part of WSO's work consists in setting up pilot's work. The two operators do not see each other but they can communicate continuously by an on-board intercom.

After a brief presentation of our theoretical framework, we summarize the results of a preliminary observation of the cooperation between the pilot and the WSO (for a complete account of the results see Loiselet and Hoc (1999)). From the literature of assistance to cooperation and the results presented, we proposed different tools for assisting cooperation between the two operators in the cockpit. In the last section, the experimental procedure performed to evaluate these assistance tools and the first results stemming from operators subjective evaluation are presented. We conclude with the utility of such a work for the design of cooperative assistance tools.

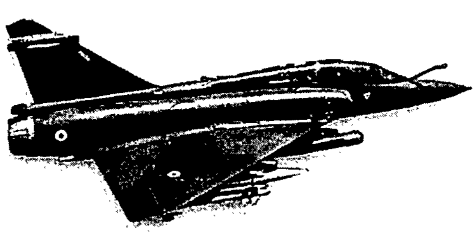

Figure 7 Mirage 2000D-Two Crew Strike Figther

6. THEORETICAL FRAMEWORK

Interference can be considered as the central concept of cooperation. There is an interference between the activity of two agents if some effects of one's activity are relevant for the activity of the other (Castelfranchi, 1998) that is, these effects can favour (positive interference) or threat (negative interference) the achievement or the maintenance of some goal of the partner. Then, cooperation as a cognitive activity can develop at two conditions (Hoc, 1998):

- Each agent's activity can interfere with the activity of others (on goals, resource, procedures, etc.).
- Each agent tries to detect and manage such interference in order to make one's or the partners' activity easier or to facilitate a common task.

The cognitive architecture of cooperation proposed by Hoc (1998), distinguishes three levels of activity allowing the management of interference that are more and more remote from immediate action (in terms of temporal and/or abstraction distance). *Cooperation in action* is mainly reactive, interference can then be created, detected and resolved in the course of process control action execution. The results of these activities are immediate and available in a short temporal extent. Four types of interference have been identified:

- Mutual control interference: Agent A evaluates agent B activity, and A and B reach a consensus;
- Precondition interference: Agent A activity is a precondition to agent B activity;
- Interaction interference: Agent A and B activities can influence, facilitate or jeopardise each other;
- Redundancy interference: Agent A and B perform the same function but each of them can perform the function alone.

At this level, identification of the local goal of the partner provides a fairly anticipated management of interference.

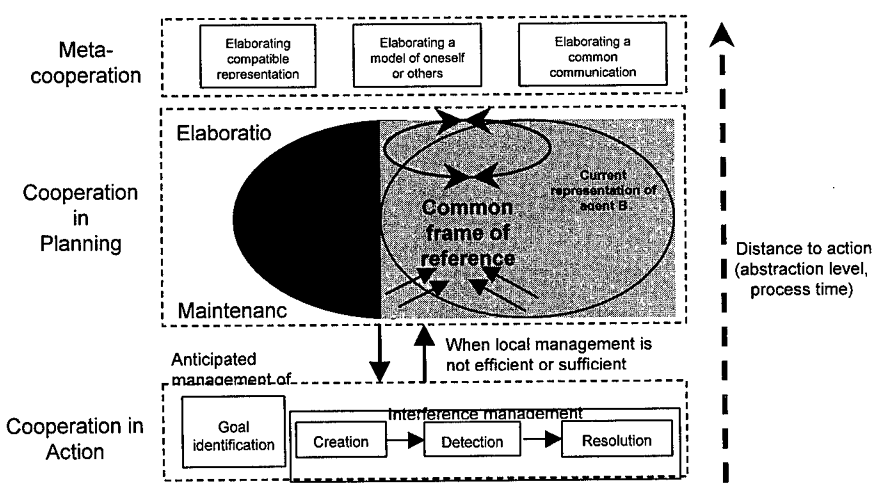

Figure 8 Cognitive architecture of cooperation

When this local management of interference is not efficient or have failed, operators can turn to the level of *cooperation in planning*. The activities at this level also allows anticipated management of interference and then improve activities of the first level. These activities mainly consist in managing the degree to which the agents have a common current representation of the situation. Close to the concepts of situation awareness (Endsley, 1994) or problem space (Newell & Simon, 1972), the current representation plays a central role in the organisation of activity by directing the implementation of the module of the cognitive architecture proposed by Hoc and Amalberti (1995). Using this concept, we want to underline that agents' activities, plans, and expectations are an integral part of the situation (and consequently of its representation). The sharing of current representations will be called the common frame of reference (COFOR) of the crew. This concept is close to those of mutual situation awareness (Salas *et al.*, 1995) and common ground (Clark, 1996). The COFOR is managed by two kinds of activity: maintenance and elaboration. Maintenance concerns the continuous updating, in the course of action, of a pre-existing structure of representation. It consists in merely adding an information, that can be directly integrated, in the COFOR. On the other hand, elaboration creates a specific episode that interrupts or overlaps the course of activity. It consists in jointly elaborating a new representation or largely modifying a pre-existing one. The added information can not be directly integrated to the current representation of at least one crewmember, it requires some explanations (Karsenty, in press).
The third level of the architecture is a kind of metalevel (elaborating compatible representations, elaborating a model of oneself and of the others agents) that will not be addressed in this paper, because it has not been encountered in our study.
In the light of this framework, a preliminary observation has been done and analysed in order to propose some ways to assist cooperation between humans in the cockpit.

7. THE PRELIMINARY OBSERVATION AND ASSISTANCE PROPOSAL

The data comprised results from a single observation of a test pilot team (P and WSO) performing the central part of a military mission (a ground target attack) in a *Mirage 2000*-type generic part-task simulator. The simulator and the test pilot team were provided by Dassault-Aviation and the mission was designed in collaboration with Dassault-Aviation's test engineers. The observation was divided into three steps:

- First, a test engineer briefed the team about the mission it had to complete and we asked the operators to explain the way they planned to perform the task together. In this stage, we recorded the operators' verbal reports.
- Second, the team completed the mission. We used two video cameras to record some operator's interfaces presented in the cockpit and an audio-recording system to record the communication in the crew. Just after the mission, we performed a self confrontation of the team (presenting the recordings of the previous step) and recorded the verbal reports of the operators commenting their own activity.
- Finally, two interviews were done in order to obtain some details about the operators' cooperative activity and about the work domain. The first interview was done two hours

after the self confrontation (once more, verbal reports were recorded) and the second one, two weeks after the observation.

This first study concerns the analysis of the operators' activity during the mission completion. Other data (i.e. self confrontation, interviews) were used in order to perform this analysis.

8. METHOD OF ANALYSIS

We used the individual protocol analysis method (Ericksson & Simon, 1984) to analyse the cooperative activities performed by each operator. This method consists in reconstructing the activity of the operators from the different recorded behavioural (verbal and non-verbal) data, using an easily interpretable and analysable formalism. It requires to infer some operators' cognitive activities. The inferences are based on the operators' behaviour, on a cognitive architecture, on the work domain knowledge, on the activity context, and on the operators' verbal reports during the mission and self-confrontation. We used a predicate-argument formalism where predicates coded the processes and their arguments coded the mental representation processed and some specification of the processes. The coding scheme relative to the cooperative activity analysis stems from the framework presented above. It contains one predicate for each activities presented above (for example, creation of interference, COFOR maintenance, etc.). Arguments specifies different aspects of the activity, for example, the type of interference processed, the type of information that COFOR elaboration or maintenance aims at, the agent who performs the activity, the means by which cooperative activity is performed, etc.

9. RESULTS OF THE STUDY AND ASSISTANCE TOOLS PROPOSED

In this paper, we do not present the whole of the results of the study (Loiselet & Hoc, 1999) but only a summary of the most relevant one's for the design of assistance to cooperation. Proposed assistance tools are not only stemming from our results but also from the literature of CSCW. Results can be polled in three categories that leads to three types of assistance.

The need of information about each member's activity

Members' present, past or future activity is the main topic of communication. The pilot and the WSO often states what they have done, do, or will do. Moreover, efficient management of mutual control and redundancy interference, two types of activity that seem crucial even if not numerous in the observed protocol, require a sufficient awareness of the partner's activity. An important part of the operators' activity consists in managing the temporal ordering of tasks. Half of cooperative activities in action concerns precondition interference. This is not surprising knowing that a major part of the WSO's role consists in preparing the work of the pilot. Another aspect of tasks management is relative to the flight plan prepared by the crew. According to the location on this flight plan, the tasks to do are different (for example, at a particular point, some functions has to be selected, some weapons has to be prepared, the task allocation has to be changed, etc.). Then, the flight plan strongly guides the activity of the crew (Amalberti & Deblon, 1992).

We have proposed a shared diary of tasks (cf. Figure 9) that provides crewmembers with information about tasks to perform in the cockpit. This type of assistance has been previously used in distributed supervisory control *(*Jones & Jasek, 1997*)* or in the management of breakdowns in the domain of civil aviation (Electronic Centralised Alerting and Monitoring (ECAM) systems). There is also a lot of work in CSCW literature about the importance of the awareness of partners' activity and of the support to this awareness (e.g. Gutwin & Greenberg, 1999).

In our case, this diary presents the major tasks that the pilot or the WSO has to perform during the course of the mission: ATC or AB3C radio contacts, activation or deactivation of functions and function's options, altitude and speed control, preparation of weapons, among others. It provides information about which operator is responsible for the task and when s/he is supposed to perform it. The tasks are displayed along a temporal axis (x-axis of the figure) and are vertically organised according to the operator who is responsible for it (pilot, WSO or non allocated). Waypoints also appear on the x-axis showing the connection between the flight plan and the task to do. Operators can only access to task relevant in the short term, they are available in the interface only 2.5 minutes before the time they must be performed and 30 seconds after they must be completed. The progress state of each task is also available to the operators. The different states of task - not realised, in progress, interrupted - are coded by a colour. When finished, a task is removed from the diary. When a task is not completed at the proper time, an alarm is triggered (the task is coloured in red and a written alert message is sent to the main working window of the crewmember responsible for this task).

The tasks diary can be adjusted according to the course of activity. The crew can remove, add or modify tasks (e.g. bringing a task forward or putting it back in time, or re-allocating it) during the mission.

The shared tasks diary makes activity in the cockpit explicit to the operators and then favour the management of precondition, interaction, mutual control and redundancy interference. It also favour the development of an awareness of the activity of each members related to the flight plan. However, it does not present a complete image of each member's activity (it presents only a selection of major tasks). Then, we have proposed two additional assistance tools to improve the knowledge of the partner's activity:

- First, we have provided each crewmember with information about the configuration of the partner's workstation (presented at the bottom of Figure 2). This information allows to infer the type of task the partner is oriented towards.
- Second, we have provided each crewmember with a real time video picture of the partner's face. This type of support is an important topic in the CSCW literature (Olson & Olson, 1997), however results on the effects of a such video on activity remain unclear (Foulon-Molenda, 2000). One of our aim when providing this assistance was an attempt to show a possible effect on the activity in the cockpit.

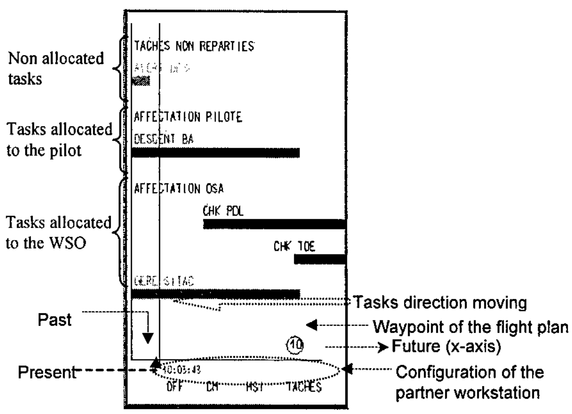

Figure 9 The shared tasks diary assistance

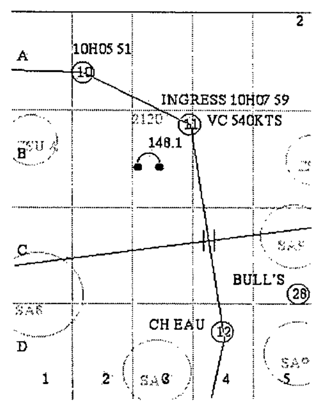

Figure 10 The Common workspace

COFOR (Common Frame Of Reference) management

The assistance presented above mainly concerns the cooperation in action. The results of our study show a fair distribution between cooperation in action and in planning. COFOR maintenance has a prominent role (43% of the coded activities) in the cooperative activity that takes place in the cockpit, whereas we only observed five episodes of COFOR elaboration. However, the presence of these episodes is crucial to recover a divergence between the crewmembers' current representation of the situation (Karsenty, in press), although they must be reduced in the fighter aircraft due to the high rate of the process.

The COFOR concept highlights the operators' needs of a common workspace (Lemoine-Pacaux & Grislin-Le Strugeon, 1998) which provides them with a common reference for the management of their individual current representation. Then, we have proposed a common workspace (cf. Figure 10). The content of this assistance is mainly made up by the crew during mission planning. Operators can insert any information they want, along a "naked" representation (spatial like in Figure 10, or non spatial) of the flight plan divided up into several pages. These commentaries are added using a predefined formalism allowing the use of colours, free texts, simple shapes and graphical symbols. Added information can concern diverse features of the mission (mission orders, targets, flight plan, flight rules, but also tasks, and so on). What is shared is then a common image of the prepared mission. This assistance also allows operators to exchange written information in this shared context during the course of the mission: at any time, the pilot or the WSO can modify the information displayed on this assistance, by changing pages, by modifying, adding or removing information. By the way, these modifications allow to update and maintain the validity of the reference. The shared context is suppose to facilitate the integration of new information in the COFOR and explanation activities (Karsenty, in press). However, providing operators with a shared reference implies neither its actual use, nor the actual sharing of all or part of the information it contains between the crewmembers current representations (Bellorini & Decortis, 1994).

In the simulated situation in which it was planned to evaluate the assistance, we have also proposed to provide each operator with identical workplaces in order to reinforce the common reference for COFOR elaboration and maintenance.

The management of communication

78% of cooperative activities are conducted orally. Any oral communication is likely to create a positive or negative interference, by transmitting some information, by interrupting the partner course of activity, by disturbing partner communication (speaking simultaneously). Operators point out that the management of dialogue is very important in the cockpit: one have to detect the receptiveness of his partner, his information needs, his workload, etc. During high workload period, communication and particularly non-crucial one's must be avoided as much as possible. We also observed that oral message have a poor persistence, resulting in some loss of information (in particular if the receiver is not completely alert to it).

Then we have proposed to provide crews with the possibility to exchange written messages on two working displays of the operator (cf. Figure 11), the Head Up Display (particularly used by the pilot) and the Tactical Display (particularly used by the WSO). It is not possible for crewmembers to type messages, so we have proposed to simulate a voice recognition system. This last assistance aims at:

- Reducing the creation of negative interference on the receiver's activity due to oral communication, allowing silent information exchange.
- Increasing the persistence of transmitted information. Messages are displayed until the operator erases it or when an other message is sent. Moreover, a dedicated window containing the list of exchanged message can be displayed. Then, the receiver can take the information when ready to do so.
- Anticipating the transmission of information and the management of interference. For example, if the sender at the approach of a high workload period of work knows that his/her partner is going to need an information s/he hold, s/he can anticipate the message sending. Then, the information will be available when his/her partner needs it.

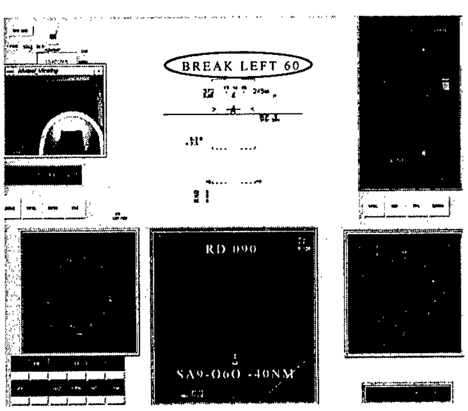

Figure 11: Big picture screen of the simulation and written messages exchanging

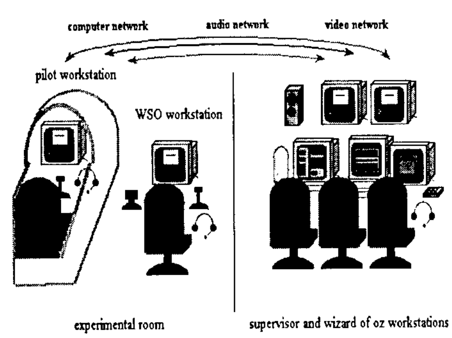

Figure 12: Experimental platform for experience 1 and 2

By the means of this assistance, we try to introduce some useful features of the asynchronous communication.

Communication in the crew is also supported by the common workspace and the identity of workplaces providing the operators with a common ground (Clark, 1996), and by the video picture and the shared task diary providing operators with information favouring the understanding of the state of the partner (workload, current work complexity, etc.).

10. THE EVALUATION OF THE ASSISTANCES

These assistance proposals have been evaluated with operational crews (pilots and WSO of twelve Mirage 2000-N crews). The assistance tools have been implemented using the Wizard of Oz (WoZ) method (Dahlbäck, Jönsson & Ahrenberg, 1993). The WoZ is a simulation technique allowing the observation of the interaction between users and a future system that have not yet been fully implemented. Non implemented functions are simulated by experimenters (called the "wizards"). Users are not aware of the human intervention and believe that they are interacting with a machine. We chose the WoZ simulation method for three reasons:

- It makes assistance modification easier at the different stages of the study (flexibility).
- It allows speed and low cost development.
- It allows to go beyond current technical limits (reliable voice command).

The WoZ, made up of three wizards, was responsible for:

- Performing all the changes in the assistance tools the operators requested (simulation of a voice command system).
- Updating the assistance tools content according to the course of the mission (e.g. the progress state of the tasks displayed).
- Typing and sending the written messages (simulation of a voice recognition system).
- Performing some actions on the simulator the operators requested (simulation of a voice command system).

In collaboration with Dassault-Aviation, a generic two-seater fighter aircraft simulator has been built. It was made up of three workstations (cf. Figure 12). One station was put in a one-place cockpit for the Pilot and a second station was put on a table for the WSO. Both operator's stations were managed from a third station (composed of three interfaces) also dedicated to the management of scenarios and experiment, and of course to the WoZ simulation. The operator interfaces were composed of: First, a big picture screen (cf. Figure 11) putting together the main displays[1] of a military aircraft cockpit, the assistance tools and some device controls (e.g. automatic pilot) that could be activated by the way of a touch screen. Second, the simulator could be mainly controlled by a Hands On Throttle and Stick (HOTAS) device and by the simulated voice-control.

[1] A Head Up Display presenting the outside world and short term flight parameters, two Head Lateral Displays allowing to modify the flight plan, to prepare weapons, to detect threats, to manage the radio, and to control missile guidance equipment, and a Head Down Display setting out the tactical situation.

A near-identity of the operators workstations allowed each crewmember to perform every tasks and then favoured dynamic task allocation between pilot and WSO (in a larger extent than in the preliminary observation).

Two experiments have been done. In the first one, eight crews performed three missions in three conditions:

- Without assistance tools
- With short term assistance tools that is the shared tasks diary, written messages exchanging, the configuration of the partner assistance and the video picture.
- With long term assistance tools that is the common workspace (the configuration of the partner assistance and the video picture remained available).

In the second experiment, four crews performed two missions in two conditions, with or without assistance tools. In the first condition, the assistance tools available to operators were the shared task diary, the common workspace and the configuration of the partner workstation.

In the two experiments, the assistance tools were somewhat different but remained quite similar to the tools we have presented in the previous section.

11. FIRST RESULTS DERIVED FROM THE OPERATORS' SUBJECTIVE EVALUATIONS

We obtained the operators' subjective evaluation of the assistance during debriefing sessions following the realisation of each mission and from questionnaires that the crews filled in after the realisation of all the missions. In the following section, we discuss some results from these evaluations.

First experiment

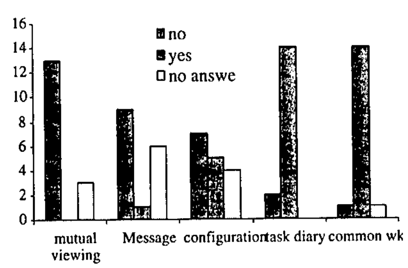

Figure 13: Answers of operators to the question "Is the assistance useful to operators for performing the task?"

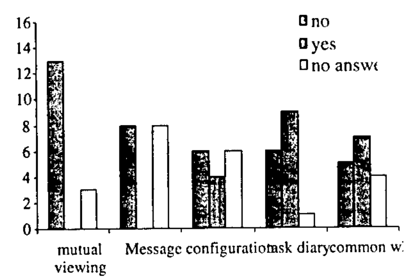

Figure 14: Answers of operators to the question "Does the assistance favour cooperation?"

The video picture and the exchange of written message are useful neither for mission completion nor for cooperation (cf. Figure 13 and 14). Hardly no crews used these tools. On the other hand, the shared diary of tasks and the common workspace are clearly useful for performing the tasks but opinions are divided about their effects on cooperation. Operators pointed out that they used these tools during low workload periods whereas during high workload periods they had not sufficient resources available (especially time) to do so. In these latter periods, operators returned to their usual work procedures probably because of a lack of motivation to use the assistance tools. Opinions are divided about the usefulness of configuration of the partner interface (for task completion as for cooperation).

Generally speaking, in this experiment, assistance were not much utilised. The main reason was probably a too short duration of training session. Crews did not have enough time to learn how to make use of the assistance and to embed the use of these assistance in their usual work procedures. Moreover, when they were used, assistance tools were never modified. It was probably due to a lack of resources to do so and to a lack of mastery of the voice commands.

However, crews evaluated positively two of our proposed tools. Then, we decided to make a second experiment where we tried to improve the training session (more time) and the motivation to use the tools. We also improved slightly assistance according to the commentaries of operators.

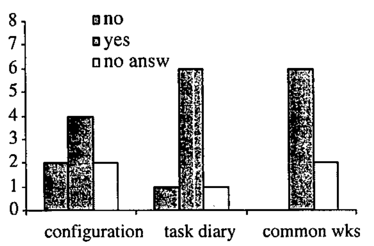

Figure 15: Answers of operators to the question "Is the assistance useful to operators for performing the task?"

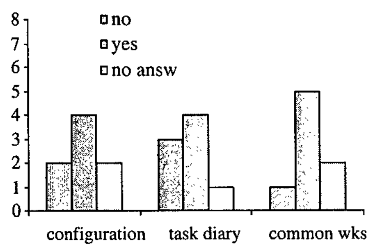

Figure 16: Answers of operators to the question "Does the assistance favour cooperation?"

Second experiment

The main results of this second experiment are that, on the one hand, operators used the assistance tools more often (which confirms our previous hypothesis), on the other hand the evaluation of the usefulness are similar to those of the first experiment (cf. Figure 15 et 16). Observations show a great difference between the crews regarding their easiness, speed and in a certain extend their willingness to integrate the use of assistance tools in their usual procedure of work. This result can explain the absence of difference between the questionnaire's results in experiment 1 and 2. Results seems encouraging.

12. CONCLUSION

From a theoretical framework of cognitive cooperation, through its application to an observed protocol of activity in the cockpit by the way of a protocol analysis method and relying on the CSCW literature, we were able to provide some proposals for the design of cooperation assistances. It lead to the demonstration of the usefulness of the framework from an ergonomic and design point of view. The usefulness of the framework from a psychological point of view had been previously demonstrated (Loiselet & Hoc, 1999).

Such a reasoning can provide invaluable information during the first steps of a design of a project. It provides a picture of the components of "existing" cooperative activity and then allow to identify:

– Cooperative activities operators favour in their everyday work;

- Cooperative activities that are the most likely to fail or to disappear (i.e. as soon as workload increase, some cooperative activities are no longer performed);
- The sufficient conditions for cooperative activities to be carried out.

In our work, we try to support existing work modes. However, two main weaknesses were identified in our study:

- Nothing allows us to assert that these modes are the best ones.
- Focusing on existing work, we remain dependant upon the specific constraints of the existing situation. Nevertheless these constraints can be modified in future systems.

These weaknesses could be avoided by assessing (when possible) during preliminary studies:

- Inter-crews variability in terms of performance and cooperative activity. It allows to make the connection between performance and cooperation modes.
- Inter-situation variability in terms of activity. It allows to evaluate the influence of specific constraints of the situation on cooperation modes.

Assistance evaluation faces some classical problems of design: Especially, the fact that operators lack of habit to use the assistance tools and that their use is sometimes not completely compatible with the usual procedure of work. Moreover, such assistances are supposed to be integrated in a future aircraft, but despite major trends already identified, what their cockpit will precisely look like is yet to be determined (aeronautical cycles are very long!).

Nevertheless the results seem very encouraging. Obviously some additional analysis are required. It is necessary to analyse how operators use the assistance in the course of their activity and the consequence of this use on their cooperative activity. We expect that the presence of assistance tools prompts crews to make more cooperative activities and that these activities would be more efficient. It is also important to evaluate the impact of assistance tools on the task related performance. For example, we expect that the shared task diary allows crews to efficiently follow flight instructions. These analysis are still in progress.

Faced with more and more cooperative operation requirements, involved by the use of data links or operation including un-inhabited air vehicles, the development of these new concepts will provide a significant additional theoretical and experimental background to be used to develop design guidelines that will guarantee the efficiency and lower costs of future air systems.

ACKNOWLEDGMENTS

This work has been done in collaboration with the "cooperative system" team of the LAMIH, we first thank M.P. Pacaux-Lemoine for her invaluable collaboration. We thank the Dassault Aviation Istres test base staff for its collaboration (especially Isabelle Farsy and Didier Ribot), the 2/4 and 1/4 Air Force squadrons from the Air Base 116 for their welcome and their cooperation, the Dassault-Aviation Saint-Cloud staff for their collaboration, and the IMASSA-CERMA staff for their help. We also thank H. Thuilliez and N. Leroy for their participation to the WoZ, and J.M. Hoc and R. Amalberti for their advices during this study.

REFERENCES

1. Amalberti, R., & Deblon, F. (1992). Cognitive modelling of fighter aircraft process control: a step towards an intelligent onboard assistance system. *International Journal of Man-Machine Studies, 36*, 639-671.

2. Bellorini, A., & Decortis, F. (1994). Régulation collective des activités basée sur une connaissance mutuelle de la charge de travail. In B. Pavard (Ed), *Systèmes coopératifs: de la modélisation à la conception* (pp. 253-270). Toulouse: Octarès Editions.
3. Castelfranchi, C. (1998). Modelling social action for AI agents. *Artificial Intelligence, 103*, 157-182.
4. Clark, H.H. (1996). *Using language.* Cambridge: Cambridge University Press.
5. Dahlbäck, N., Jönsson, A., & Ahrenberg, L. (1993). Wizard of oz studies - why and how. *Knowledge-Based Systems*, December Issue, Vol. VI.4, pp. 258-266.
6. Endsley, M.R. (1994). Situation awareness in dynamic human decision making: Theory. In R.D. Gilson, D.J. Garland & J.M. Koonce (Eds), *Situational awareness in complex systems* (pp. 27-58). Embry riddle aeronautical university press.
7. Ericsson, K.A., & Simon, H.A. (1984). *Protocol analysis: verbal reports as data.* Cambridge, MA: MIT Press.
8. Foulon-Molenda, S. (2000). Do people need to see each other to work together? A theretical contribution with reference to psycho-linguistics. *Le Travail Humain, 63*, 97-120.
9. Foushee, C. (1984). Dyads and triads at 35,000 feet: Factors affecting group process and aircrew performance. *American Psychologist, 39*, 885-893.
10. Gutwin,C., & Greenberg, S. (1999). *A framework of awareness for small groups in shared-workspace groupware.* Technical report 99-1, Department of Computer Science, University of Saskatchewan, Canada.
11. Hélie, P (1999) Trends and technologies for future fighter MMI (ATS1999)
12. Hoc, J.M. (1998). How can we evaluate the quality of human-machine cooperation? In F. Darses & P. Zaraté (Eds.), *COOP'98. Third International Conference on the Design of Cooperative systems* (pp. 121-130). Le Chesnay, F: INRIA.
13. Hoc, J.-M., & Amalberti, R. (1995). Diagnosis: Some theorical questions raised by applied research. *Current Psychology of Cognition, 14*, 73-101.
14. Jones, P.M., & Jasek, A.J. (1997). Intelligent support for activity management (ISAM): an architecture to support distributed supervisory control. *IEEE Transactions on Systems, Man and Cybernetics - Part A: Systems and Humans, 27*, 274-288.
15. Karsenty, L. (in press). Cooperative work: The role of explanation in creating a shared problem representation. *Le Travail Humain.*
16. Lemoine-Pacaux, M.P., & Grislin-Le Strugeon, E. (1998). *Multi agent system and human machine cooperation.* Paper presented at the *17th European Annual Conference on Human Decision Making and Manual Control.* Valenciennes, France, Dec.
17. Loiselet, A., & Hoc, J.M. (1999). Assessment of a method to study cognitive cooperation in fighter aircraft piloting. Communication présentée à *CSAPC'99.* Villeneuve d'Ascq, France, Sept.
18. Newell, A., & Simon, H.A. (1972). *Human problem-solving.* Englewoods-Cliffs, NJ: Prentice-Hall.
19. Olson, G.M., & Olson, J.S. (1997). Research on CSCW. In M. Helander, T.K. Landauer & P. Prabhu (Eds), *Handbook of human-computer interaction* (pp1433-1456). Amsterdam: Elsevier Science.
20. Salas, E., Prince, C., Baker, D.P., & Shrestha, L. (1995). Situation awareness in team performance: implications for measurement and training. *Human Factors, 37,* 123-136.
21. Schmidt, K. (1994). Cooperative work and its articulation: Requirements for computer support. *Le Travail Humain, 57*, 345-366.
22. Wiener, E., Kanki, B., & Helmreich, R. (Eds) (1993). *Cockpit resouces management.* New York Academic Press.

LIST OF ACRONYMS

A/C	Aircraft
AB3C	Airbone Battlefield Command Control & Communication
ATC	Air Traffic Control
APIS	Aide au Pilotage sur Imagerie Synthétique
C2	Command and Control
COFOR	COmmon Frame Of Reference
CNRS	Centre National pour la Recherche Scientifique

CSCW	Computer Supported Cooperative Work
DEW	Directed Energy Weapons
DGA	Délégation Générale pour l'Armement
DVI	Direct Voice Input
EO/IR	Electro-Optical/InfraRed
FLIR	Forward Looking InfraRed
HALE	High Altitude Long Endurance
HOTAS	Hands On Throttle And Stick
HDD	Head Down Display
HDTV	High Definition TeleVision
HLD	Head Level Display
HMD	Helmet Mounted Display
HMI	Human Machine Interface
HUD	Head Up Display
ILO	Inside Looking Out
MALE	Medium Altitude Long Endurance
MITL	Man In The Loop
MMI	Man Machine Interface
MLU	Mid Life Update
MOD	Ministry Of Defence
OLI	Outside Looking In
TACSIT	TACtical SITuation
UAV	Unmanned Air Vehicle
UCAV	Uninhabited Combat Air Vehicle
VR	Virtual Reality
WSO	Weapon System Officer

PART TWO

Industrial Ergonomics

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

An Assessment of Container Handling Performance Using a Two- and Three-Dimensional Remote Crane Display

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A local freight company has implemented a 2D camera-based remote crane system to pick-up and land containers from a yard onto a prime mover and vice versa. However, a two-dimensional (2-D) camera-based system deprives the operator of the depth perception required for container handling. In particular, the operator may encounter difficulties in judging the speed of container landing and the distance of the container to the prime mover chassis or to another container. To support depth perception, a three-dimensional (3-D) camera and display system may be developed to enable stereoscopic vision. A mock-up of such a system that includes basic crane controls has been built, to assess the efficacy of the proposed 3-D set-up in terms of performance time, accuracy and force of impact of container positioning and landing. The assessment involves performance testing with subjects. Initial test results show that depth perception supported by the 3-D stereoscopic display setup enhanced performance of container landing, while no significant positioning performance enhancement was observed between 2-D and 3-D displays.

1. BACKGROUND

In the last couple of years, a local freight company has implemented a new remote controlled camera-based system for container handling. In this system, a central computer allocates container-handling jobs to any available operator, whose task is to position and land:

- an empty spreader (i.e. the device used to grab a container) onto a container to be picked up; or
- a loaded spreader onto a prime mover or another container.

To perform these tasks, an operator needs to adjust the position of the spreader with or without a container, and occasionally dampen its sway before lowering it. By removing the operator from being physically in the crane (with its attendant poor working posture and vibrations) to a centralised air-conditioned remote control room (see Figure 1), the new system promises to improve the working conditions of operators and also enhance their efficiency and productivity. However, a 2-D camera-based remote control system deprives the operator of the depth perception required for efficient pick-up and landing of containers. Further, with cameras mounted directly above the spreader, the existing remote control display provides the operator with only a planar view of the 4 corners of the spreader and container (see Figure 2). Although this display may be useful for positioning of the container to the prime mover chassis, the operator may find it difficult to judge the speed of container landing and the distance of the container to the prime mover chassis (dispatch operation) and to another container (stacking operation). Close monitoring of these container-handling parameters would be necessary to maximise throughput, and to avoid damage to container contents and/or the prime mover chassis due to an unduly heavy container landing. In view of the above concerns, a system that can provide stereoscopic vision should be examined to ascertain its potential for enhancing remote crane control operation.

Figure 1. Remote crane control workstation (Lim, 1998)

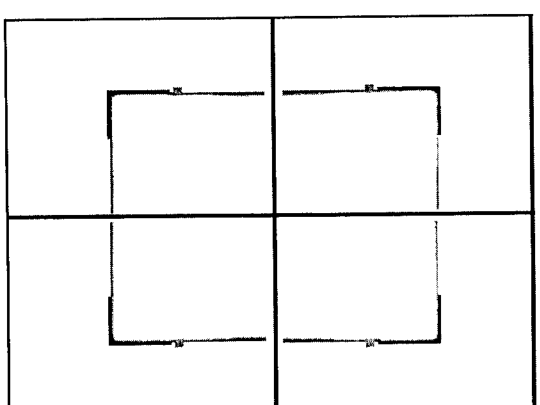

Figure 2. Planar display of the 4 corners of the container

2. STEREO-VISION

Stereoscopic vision is the ability to judge depth or position of objects accurately in a 3-D field. The human eye perceives depth stereoscopically via optic nerves from the two eyes, which come together at the optic chiasma near the brain (Pedrotti et al, 1998). The slightly different images that fall onto the left and right eye are sent to the brain, which integrates them into a single image. The fusion of the images is referred to as binocular vision. The slight differences in the images (i.e. retinal image disparity), provide additional information on the depth or distance of an object, and this forms the basis of stereoscopic vision (Schiffman, 1996).

Stereoscopic systems are more complex to work with, but with a good understanding of their working principles, they are flexible and easy to design. For images to be accurately projected onto a display to achieve stereoscopic vision, the camera or image position should comply with the formulae presented in table 1.

Table 1: Formulas Relating Lateral Retinal Disparity and Depth

To Calculate	**Given/Known**	**Formula Used**
Disparity	Depth	$\delta = id/(D^2+dD)$
Depth	Disparity	$d = \delta D^2/(i- \delta D)$

Where:
δ = disparity in radians
i = IPD (Interpupillary distance)
D = Distance of fixation point
d = distance from point of fixation positive for points before point of fixation (between eye and fixation point) and negative for point beyond point of fixation

The working principle of depth perception by the eye may be imitated by camera systems using the formulae in table 1. The main difference between a 2-D and 3-D display system is that the latter uses a pair of cameras to simulate the eyes. A 3-D system setup also includes a real-time image decoder and a pair of stereoscopically 'active' glasses (see Figure 3) or a 'passive' display screen with monitor (see Figure 4). The system simulates how the eyes perceive depth by alternately blocking the images projected into each eye synchronously with the monitor.

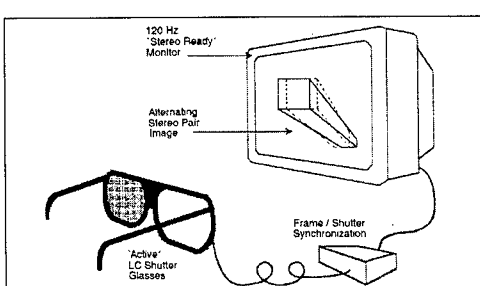

Figure 3. Occluding shutter display
(Bardsley *et al*, 1997)

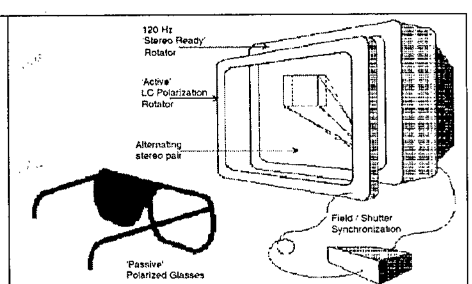

Figure 4. Polarisation rotating display
(Bardsley *et al*, 1997)

Although a 3-D stereoscopic display system appears to be better for the container-handling task, the extent to which task performance would be enhanced is unclear. Since monocular vision and 2-D display systems also provide indirect cues for depth perception, it is uncertain to what extent operators could adapt to and compensate for deficiencies when using such displays. In this respect, indirect visual cues that could possibly support some depth perception include parallax, shadows, relative size, and perspective views. Such visual cues are commonly used in computer games and CAD applications. Thus, to better argue a case for a 3-D system, it is vital to establish the extent to which such a system could enhance operator performance. Thus, an experiment rig is constructed to collect some data for such an assessment.

3. EXPERIMENTAL SETUP

To assess the effect of stereoscopic vision on operator performance, a model comprising crane hardware and software components needs to be developed. Thus, a mock-up crane is built as shown in figure 5. Test subjects control the mock-up crane by hand via monoscopic (2D) and stereoscopic (3D) displays.

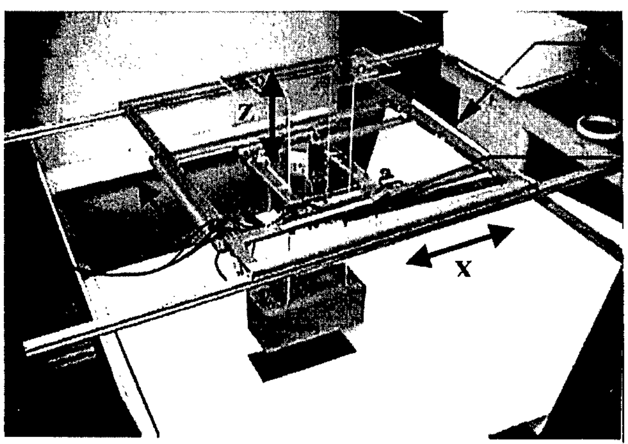

Figure 5. Remote crane mock-up

The subjects were grouped and balanced in respect of positioning and placement/landing tasks. 30 subjects with a male to female ratio of 3:1 were recruited for the experiments. The subjects were university students without previous experience of container handling. The performance factors examined included the:

- time taken to positioning and placement container,
- container positioning accuracy,
- container landing impact as an indicator of depth perception quality.

The results of the experiments were analysed using ANOVA. The results indicated that the stereoscopic display did not affect/improve positioning time performance. However, a stereoscopic display enhanced performance significantly in terms of landing time ($P < 0.001$) and impact ($P < 0.001$) container landing.

4. CONCLUSION

Although university students enhance the validity of the study to enable in an environment similar to those experienced by the remote crane operators. The visual background of the test environment was white and did not contain any other object other than the container and target area. A more valid background should include stacked containers and a prime-mover model. Other environmental factors may include lighting and weather conditions, and day and night operations. Finally, it should be noted that the remote crane is operating at a height of 25m and it remains to be demonstrated that the stereoscopic system proposed could be scaled up and operated at this height. However, according to Boff et al. (1988), a practical and effective distance for normal stereoscopic viewing would be approximately 65m for central vision and 9m for peripheral vision. Nevertheless, to be certain future tests should investigate any scale-up effects.

REFERENCES

1. Lim T.C.K., 1998, *Human Factors Study of Manual and Automated Yard Cranes,* School of Mechanical and Production Engineering, Nanyang Technological University.
2. Pedrotti L.S. and Pedrotti F.L., S.J., 1998. *Optics and Vision*, Prentice Hall International, Inc. 194-223.
3. Schiffman H.R.,1996, *Sensation and Perception, An Integrated Approach,* 4th edition, John Wiley & Sons, Inc. 215-245.
4. Boff K.R. & Lincoln J.E, 1988. Engineering Data Compendium: Human Perception and Performance. AAMRL, Wright-Patterson AFB. OH.
5. Bardsley T. and Sexton I., 1997. Evaluation Stereoscopic Displays for 3D Imagery. In MacDonald L.W. and Lowe A.C. (ed.), *Display Systems Design and Applications,* (John Wiley & Sons), 365-387.

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Design and Development of a Stereoscopic Display Rig for a Comparative Assessment of Remote Freight Handling Performance

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Many tasks are hazardous to human life such as bomb disposal, piloting a fighter aircraft and operation in extreme environmental conditions. With advances in technology, the human can now accomplish these tasks through teleoperation from a remote console. However, there is a need to ensure that the user interface between the human and machine is adequate for remote control. An example of this is the provision of stereoscopic 3-dimensional (3D) displays for remote operation in place of standard two-dimensional (2D) displays to facilitate depth perception tasks in remote freight handling. This paper reports a study on the effects of such displays on remote freight handling performance with respect to horizontal positioning and vertical placement of containers. A reduced scale simulation test rig was designed and constructed for the test. The results of the study revealed that stereoscopic displays enhanced significantly subject performance of vertical container placement in terms of task completion time and container handling accuracy. However, a stereoscopic display was found to be ineffective in enhancing task performance of horizontal container positioning.

1. BACKGROUND

Recently, the Port of Singapore Authority (PSA) implemented a new remotely operated crane system at the Pasir Panjang Container Terminal. The semi-automated system incorporates a computer that performs the task of shuttling containers between designated locations and its approximate horizontal alignment, before passing the job to an available operator who will perform the skilled component of manipulating the spreader (container grasper) horizontally and vertically to land or pick up a container. Thus, the mundane task of trolleying the crane to the designated location is eliminated for the operator.

To enable remote operation, a quad-screen is used to display four camera views to the operator. The quad-view displayed comprises a plan view of the four corners of the container/spreader. It should be noted here that container handling tasks (in particular vertical container landing) require depth perception, which in a human is perceived through both physiological and psychological depth cues (Goldstein, 1989). Physiological depth cues are related to the anatomy of the eyes and the physiological processes involved in vision. In particular, oculomotor cues and binocular disparity comprise the two categories of physiological depth cues (Hubel, 1998). Psychological cues, such as motion-based cues and pictorial cues, are extracted from the information associated with images that fall on the retina.

Since a 2D quad-display of camera views does not convey cues to support physiological depth perception, the visual information provided to operators by the existing remote control display does not match that obtainable from onsite manual crane operation. Physiological cues are absent as all the objects in the remote environment are presented on the same plane on the screen display. Thus, operators have to rely largely on psychological depth cues to manipulate the spreader/container; e.g. cues such as light and shade, occlusion (or interposition), size and height in the field of view, atmospheric and linear perspective, and relative and familiar size (Norman, 1988). Since physiological cues have been shown to be more direct and accurate (Merritt, 1988) than psychological cues, implications for container handling performance might arise.

To determine the implications of this reduction in depth perception cues for the new remote operation, a series of projects has been initiated (see also Quek et al (2000) and Ng et al (2000)) to investigate:

- the effect on operator performance due to the loss of physiological depth perception cues, and
- potential solutions to these problems presented by developments in virtual reality technology.

This paper reports a comparative study between a stereoscopic (3D) display set-up and a camera based (2D) display similar to the one currently in use at PSA. The stereoscopic display was assessed to determine its potential for providing cues for physiological depth perception lost in moving to a camera based remote control system. To this end, a reduced scale simulation test rig was designed and constructed to enable performance testing on freight handling tasks involving horizontal positioning and vertical placement of containers. Subject performance was assessed in terms of task completion time and container landing accuracy. Since PSA has plans to deploy female operators in the remote control system, gender effects on performance for the two classes of display were also investigated.

2. DESIGNING THE TEST RIG

To assess the potential of a 3D stereoscopic display for enhancing the performance of remote container handling, a reduced scale model of the crane system had to be designed and constructed to enable subject testing.

First, a simple and inexpensive stereoscopic display had to be developed. Common stereoscopic image generation techniques involve the dual optical path and filter separation techniques. Due to budget constraints, the dual optical path technique was selected. The technique mimics normal vision by presenting slightly different images to each eye, transmitted via two cameras separated at an appropriate horizontal distance apart. Figure 1 shows the set up used to generate stereoscopic video images using the dual optical path technique. Two CCD cameras channel video images via RCA cables to respective video cameras. As a head-mounted display with dual video channels was unavailable, the viewfinder of the two video cameras was used as display monitors.

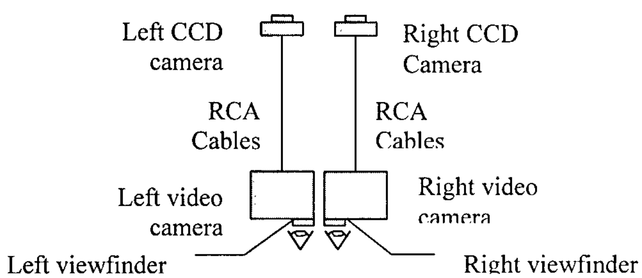

Figure 1 Stereoscopic video generation using the dual optical path technique

Figures 2 and 3 show the front and plan views respectively of the location of the CCD cameras used to capture video for stereoscopic video generation. The cameras were mounted above the longer edge of the "container" and spaced 6.5 cm apart with their principal axis converging onto the target (see Wickens, 1990). The "target area" simulating the prime mover chassis or another container, is represented by a black rectangle.

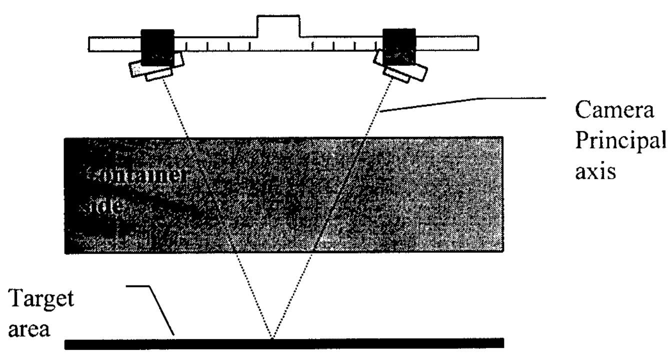

Figure 2 Front view of CCD camera arrangement for stereoscopic video capture

Second, a 2D camera based system similar to the one used presently for remote freight handling had to be constructed for comparative performance assessment. In this regard, a related study demonstrated that a 2-corner view of the container/spreader (as compared to the existing 4-corner display view) was more effective in enhancing container handling performance (Ng et al, 2000). Thus, the 2-corner display view was selected as the reference benchmark for this study.

Third, the test-rig had to include a motion and control module to simulate the movement of the crane and container. The rig had to support a suspended container model that may be positioned horizontally over the target area, and also moved vertically via a crank. The CCD video capture cameras were mounted onto this part of the test-rig, so that they would move together with the container.

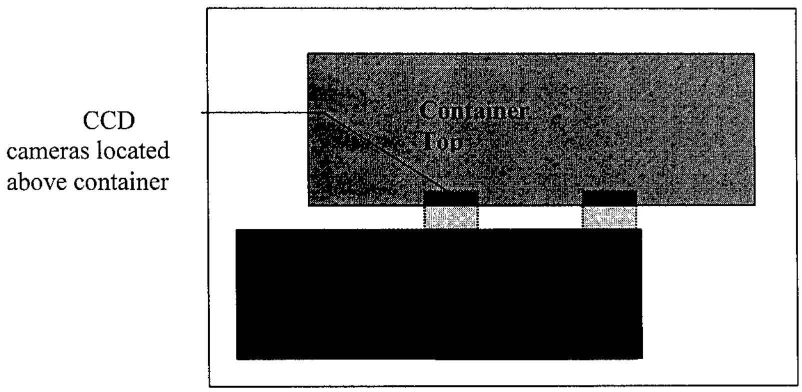

Figure 3 Plan view of camera arrangement for stereoscopic video capture

Finally, to enable assessment of container landing accuracy a simple vertical displacement platform was constructed to indicate indirectly the ability of subjects to gauge container height from a plan view (a depth perception task). The extent of displacement of the platform also served to indicate indirectly the impact of container landing. Budget constraints prevented the use of force gauges for direct measure of this aspect of task performance accuracy.

3. DESIGN OF THE TEST TASK

The horizontal positioning task required the subject to position a suspended container over a target area of the same size demarcated 20-cm below the container (superposition task from a plan view). The performance measurements taken comprised task completion time and container positioning accuracy. Positioning accuracy was represented as a percentage value computed from the area of intersection between the final position of the container and the target area (numerator) to the area of the target (denominator). Since, depth perception was not expected to be critical to the planar/horizontal container positioning task, it was hypothesised that providing a 3D stereoscopic display would not enhance subject performance.

The vertical displacement task required the subject to place a suspended container onto a depressible platform simulating the chassis of a prime-mover. The performance measurements recorded comprised task completion time and the magnitude of vertical displacement of the platform. Since the subject was only allowed to lower the container, he/she would have to use depth perception to accurately place the container onto the platform. This simple set-up was designed to assess how well a subject was able to gauge depth and the rate of container descent (and hence indirectly the severity of container impact against the target platform), from information presented by the two display views. It was thus hypothesised that a 3D stereoscopic display would enhance the performance of this task.

4. DESIGN OF THE EXPERIMENT

Thirty student volunteers of a female to male ratio of 1:2, were recruited from the university. A balanced within-group experiment design was employed; i.e. each subject is required to perform the task using both display conditions, the block presentation sequence of which was randomised to account for order effects (if any). The effect on performance due to gender was also analysed. To increase the reliability of the data, four repetitions of each task was done. At the start of the experiment, all subjects were given basic instructions on what to expect in the performance test. In addition, to account for effects due to unfamiliarity with rig controls, subjects were allowed to practice by direct viewing (i.e. without mediating displays), the test tasks of horizontal positioning and vertical placement of containers. Finally, to eliminate confounding sources of random variation, all tests were conducted indoors under controlled environment conditions.

5. TEST RESULTS

In this study, ANOVA was used to analyse the results to uncover any significant effects on task performance due to two factors; namely display type and gender. Specifically, subject performance in terms of task completion time and container handling accuracy was examined for the task of horizontal positioning and vertical placement of containers. Table 1 presents a summary of the results of this study.

Generally, the results followed predictions with respect to the nature of the two tasks. First, the 3D stereoscopic display did not enhance container positioning performance in terms of task completion time. Surprisingly, it degraded the accuracy of container positioning performance ($P = 0.01$). This performance degradation was most likely due parallax error attributable to the camera positions of the stereoscopic display set up. Second, as anticipated from the depth perception demands of the container placement task, subject performance of the task, was enhanced by the 3D stereoscopic display for both task completion time ($P<0.001$) and container landing accuracy ($P<0.001$).

Finally, the performance of male subjects were found to be generally better than female subjects. For the container positioning task, male subjects were quicker than female subjects for the same level of positioning accuracy ($P = 0.05$). In the case of container placement or landing tasks, male subjects were both faster and more accurate than female subjects ($P = 0.01$ and 0.05 respectively). The results seem to suggest that anecdotal reports of the higher spatial ability of males may have some basis in fact.

Table 1 Summary of ANOVA Results

Test Task	**Between 2D and Stereoscopic Displays**	**Between Male and Female Subjects**
Positioning Time	Stereoscopic display was generally ineffective in enhancing positioning time performance.	Male subjects were faster than female subjects at P = 0.01.
Positioning Accuracy	Stereoscopic display degraded subject performance in terms of positioning accuracy (P = 0.01).	No significant difference between the performance of male and female subjects (P = 0.05).
Placement Time	Stereoscopic display enhanced subject performance significantly in terms of placement time (P < 0.001).	Male subjects were faster than female subjects (P = 0.01).
Placement Accuracy	Stereoscopic display enhanced subject performance significantly in terms of placement accuracy (P< 0.001).	Male subjects were more accurate than female subjects (P = 0.05).

6. SUGGESTIONS FOR FOLLOW UP WORK

The results of this study indicated clearly that 3D stereoscopic displays deserve closer examination for their potential in enhancing the performance of container placement tasks. To advance this objective further, it is recommended that follow up work be commissioned to investigate any scale up effects that may thwart the exploitation of these displays. Operators should also be recruited for performance testing with a higher fidelity crane-container handling test rig. In addition, a light and unintrusive user interface for such a system should be designed to remove the need for operators to don cumbersome head gear (as in some 3D display systems). The latter would be very unpopular with operators, and such a system would most likely be rejected. Work in this direction is ongoing (see Quek et al, 2000).

REFERENCES

1. Goldstein, E.B., 1989, *Sensation and Perception*, Wadsworth Pub. Belmont, California.
2. Hubel D.H., 1998, *Eye, Brain and Vision*, Scientific American Library, New York.
3. Merritt, J.O., 1988, *Three Dimensional Imaging and Remote Sensing Imaging*, SPIE Journal Vol. 902.
4. Ng M.C. and Lim, K.Y., 2000, *An Assessment of Various Two-Dimensional Display Designs for a Camera Based Remote Freight Handling System,* In Lim, K.Y. (ed.), Proceedings of the Joint ASEAN Ergonomics/Asia Pacific CHI Conference, Singapore.
5. Norman, D.A., 1988, *The Psychology of Everyday Things*, Basic Books Inc, New York.
6. Quek, S.W., Lim, K.Y., Pang, T.K. and Chui, Y.P., 2000, *An Assessment of Container Handling Performance Using Two- and Three Dimensional Remote Crane Control Displays,* In Lim, K.Y. (ed.), Proceedings of the Joint ASEAN Ergonomics/Asia Pacific CHI Conference, Singapore.
7. Wickens, C.D., 1990, *Three Dimensional Stereoscopic Display Implementation: Guidelines Derived from Human Visual Capabilities*, SPIE Journal Vol. 1256.

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An Assessment of Various Two-Dimensional Display Designs for a Camera Based Remote Freight Handling System

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In recent years, the Port of Singapore Authority set up a camera based semi-automated remote freight handling system for yard operations. Operators are now located in a central control room where they control cranes to pick up and land containers. The computer is tasked with moving containers between pick up/landing locations and for scheduling container handling tasks to available operators. A human factors concern associated with such a system is the loss of physiological depth perception due to the inability of the quad-display of camera views to provide three-dimensional views. As such, operators have to rely largely on psychological depth cues to operate the crane and to manipulate the container/spreader. It is therefore vital that the position of the cameras is optirmised to present the most appropriate view to support psychological depth perception. This paper reports a study conducted to address this concern. Its objective is to assess whether the existing display view could be enhanced to better support psychological depth perception required by the operator's task. Thus, a computer simulation of five different display views was developed for subject testing, to enable a comparative assessment of their efficacy. The data derived was subjected to ANOVA and Least-Square Regression analyses. Of the display views investigated, the results indicated that a bi-camera display view of two corners of a container, enabled subjects to achieve the best container handling performance ($P = 0.001$).

1. BACKGROUND

The Port of Singapore Authority (PSA) built her fourth container terminal along the south coast of Singapore at Pasir Panjang. This new port features one of the most advanced freight handling systems in the world. Previously, yard cranes were controlled by operators on site. The operators were located in a cabin overhead where they can see the entire operation of container landing and pickup. With the new semi-automated freight handling system, operators are gathered in a centralized control room where they rely solely on camera display views to land and pick up containers remotely.

The screen display presently used for remote operation comprises a quad display showing four corners of a container/spreader. As the camera images are flat (two-dimensional or 2D), the new remote working environment inevitably reduces the "realism" afforded to operators by physical/onsite operation. This situation may lead to significant impairment of crucial perceptual judgments required for effective task performance. In particular, consider the depth perception required to determine container height and rate of descend. Depth perception is perceived by the human via visual cues which may be categorised into binocular and monocular cues. Binocular cues which support physiological depth perception involve retinal disparity, which can only be created on a 2D screen if the viewer wears special goggles. Monocular cues which support psychological depth perception are used extensively in 3D computer graphics to create the perception of depth on a 2D screen. There are basically six monocular cues, namely:

Retinal size:	larger images appear closer.
Familiar size:	a small image of a familiar car suggests that the car is far away.
Interposition:	an object that obscures another partially is located in front of it, but this cue would not tell the user how far apart the objects are.
Shading:	darker shades at the bottom of a region imply that the region is elevated, whereas the same shade located at the top of a region indicates that it is depressed.
Aerial perspective:	refers to the blue appearance of objects that are located far away.
Linear perspective:	parallel lines appear to converge when they are distant.

Of these monocular cues, familiar size, interposition, shading and linear perspective are more likely to be encountered in our daily lives.

For the present quad-display of camera views at PSA, physiological depth perception can not be supported. As such, operators have to rely largely on psychological depth cues to operate the crane and to manipulate the container/spreader. Thus, the container handling task may become more difficult. It is therefore vital that the position of the cameras is optimised to present the most effective view to support psychological depth perception.

This paper reports a study conducted to address this concern. Its objective is to assess whether the existing display view could be enhanced to better support psychological depth perception required by the operator's task. Thus, a computer simulation of five different display views was developed for subject testing, to enable a comparative assessment of their efficacy. The objective of the study was to determine the optimal display view and hence camera positions for remote freight handling operation. In this respect, the display view should enable operators to assess the:

1) position of the container/spreader.
2) height and rate of descend of the container/spreader.

Next, the design and development of simulated display views is presented followed by an account of the subject performance testing conducted.

2. EXPERIMENTAL SET-UP AND DESIGN

As budget constraints prevent the building of a physical model of the crane, a 3D software graphics programme was developed to simulate the various display views to be tested. Windows32, Visual C++ and OpenGL applications were used to generate the graphics and user interface.

Figure 1 shows the quad display view design similar to the one used presently at PSA. The design was thus used as the benchmark for assessing display efficacy. It can be seen from the figure that the quad display view was a 2D representation of the four corners of a container/spreader.

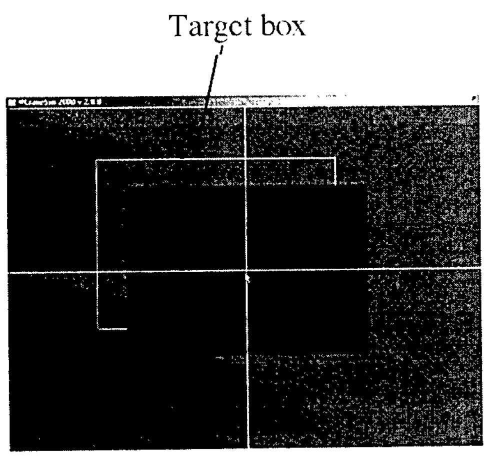


Figure 1. Design A: 2D quad display view

Figure 2 shows a second display view providing a perspective view of the container. In this design, depth cues were supported by interposition, size and linear perspective (the sides of the container).

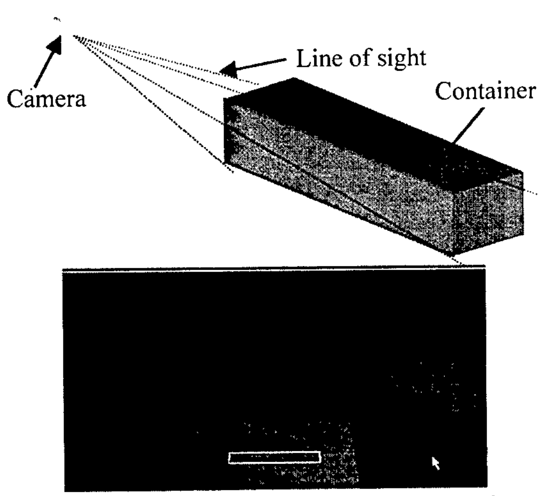


Figure 2. Design B: perspective 3D display view

Figure 3 shows a third display view providing bi-camera views of two corners of the container/spreader. This display view was a simplified derivative of the quad display view described earlier. The design was thus a 2D representation.

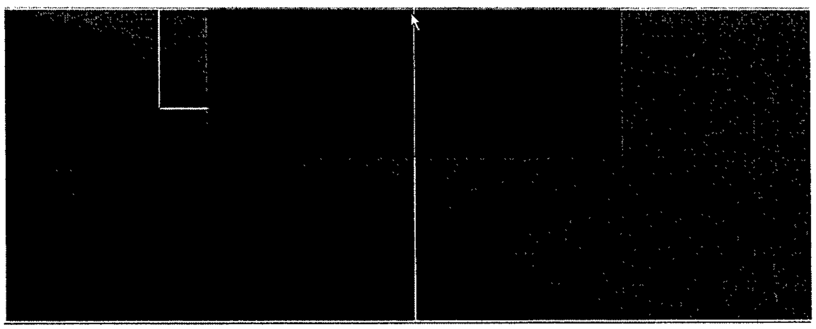


Figure 3. Design C: Bi-Camera 2D display view

Figure 4 shows a fourth display view providing virtual guides. In this design, two guide lines were drawn to connect the target area on the ground to the two corners of the container. A linear perspective cue to support depth perception was thus provided.

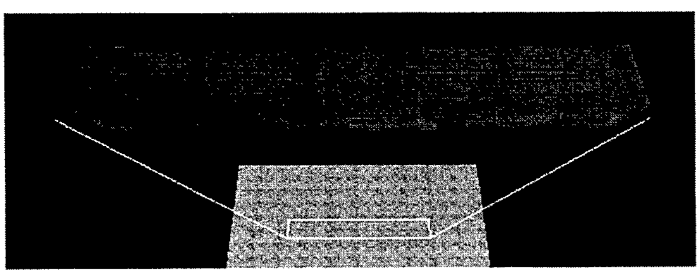
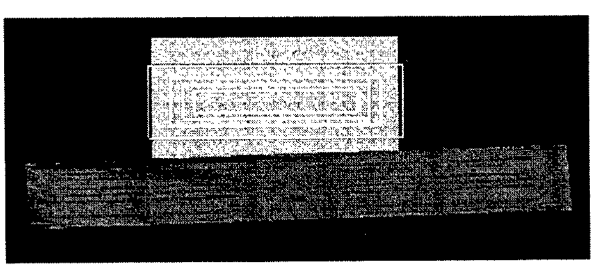


Figure 4. Design D: virtual guides display view

Finally, a bull's eye targeting display view was designed as shown in Figure 5. This display used converging rectangles to provide a depth cue to help subjects gauge the height and rate of descend of a container.



Using these simulated display views, a repeated measures subject performance test was conducted with 36 student volunteers. The task of the subjects was to land the container onto the target area in the shortest time and with the highest accuracy. The sequence of display views tested was balanced to account for order effects. To increase the reliability of the data, five repetitions of each task was done. At the start of the experiment, all subjects were given basic instructions on what to expect in the performance test. In addition, to account for effects due to unfamiliarity with the joystick controls, subjects were allowed a short practice. Finally, to eliminate confounding sources of random variation, all tests were conducted indoors under controlled environment conditions. A summary of the experiment design is given in Table 1.

Table 1. Summary of experiment design

Number of Subjects	36
Number of Pilot Test Subjects	10(5 for each sex)
Number of Experiment Design	5
Time for each Experimental Design	9 mins (including setup time)
Time for Trial Run	1 min
Number of Test Runs	5 attempts per design
Experimental Factors Studied	1) Number of Successful Attempts 2) Accuracy 3) Timing

The data obtained for time and accuracy of task performance was plotted and line fitted using Least-Square Regression. In this way, the trade off between performance time and accuracy may be established to enable an integrated assessment of subject performance in terms of task completion time for each of the display views. The performance data was also subjected to statistical analysis using Analysis of Variance (ANOVA).

3. RESULTS

The results of ANOVA analysis indicated that performance differences attributable to display view was highly significant for both landing accuracy ($P = 0.01$) and task completion time ($P = 0.01$). Further analysis of the results using Least-Square Regression revealed that the bi-camera 2D display view supported the best overall performance by subjects. Details of the results for all the 5 display views are summarised in Table 2. The results for the total number of successful landing attempts (success is indicated by landing the container within the target area at a minimum level of accuracy based on the requirements of actual container landing) also confirmed the superiority of the 2D display views (see Figure 6).

Table 2. Summary of overall performance for each of the display views

Design	Timing (secs)
A: Quad Camera Views	32.7
B: Remote View	45.9
C: Bi-Camera Views	23.8
D: Remote Virtual Guided View	40.0
E: Bull's Eye Targeting View	41.1

It appeared from the results that the 3D perspective views were considered cluttered and might have contributed to container manipulation problems associated with parallax error. The results also seemed to indicate that a two corner view was adequate for the task and that the provision of all four corners in the display view, may lead to unnecessary distraction. It may be that the subjects were subjected to a higher cognitive loading trying to focus their eyes unsuccessfully on multiple moving object in the displays associated with poorer subject performance (see also Bruce 1992; Gregory, 1997).

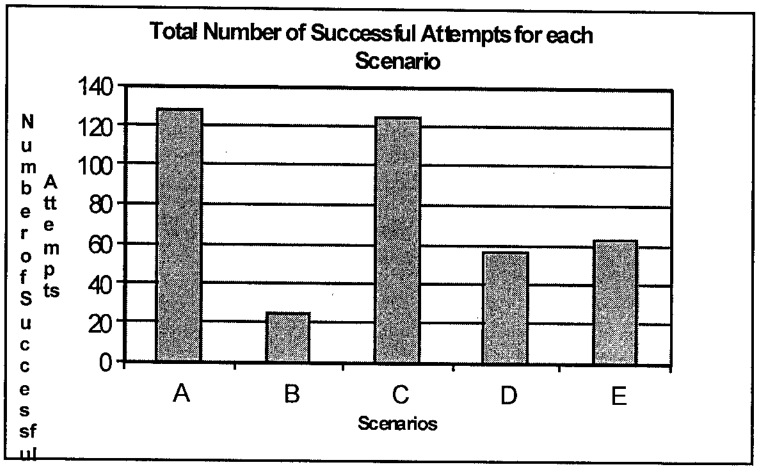


Figure 6. Total number of successful landing attempts for each display view

4. CONCLUSIONS AND RECOMMENDATIONS

This study on the efficacy of five different display views was conducted using university students as subjects. Although actual operators might have been more appropriate subjects, it should be noted that the study was concerned only with an assessment of the relative performance supported by each of the display views. Thus, the results should provide a good predictor of display appropriateness. In this respect, it may be concluded that task performance was significantly affected by the display view used. Of the display views tested, the 2D bi-camera display view supported the best overall performance in terms of the combined measure of time for task completion and landing accuracy, and the total number of successful container landing. If the use of 2D displays were to continue (and hence the reliance of operators on largely psychological depth perception cues), the results of this study point to a potential simplification of the existing quad display view in use at PSA. However, a further study using true 3D displays should be conducted to ascertain if such displays could provide operators with both physiological and psychological depth perception cues. Work in this direction is in progress (see Pang et al, 2000; Quek et al , 2000).

REFERENCES

1. T. K. Pang, K.Y. Lim and Roy S.M. Quek, 2000, Design and Development of a Stereoscopic Display Rig for a Comparative Assessment of Remote Freight Handling Performance, In Lim, K.Y. (ed.), Proceedings of the Joint ASEAN Ergonomics/Asia Pacific CHI Conference, Singapore.
2. Quek, S.W., Lim, K.Y., Pang, T.K. and Chui, Y.P., 2000, *An Assessment of Container Handling Performance Using Two- and Three Dimensional Remote Crane Control Displays,* In Lim, K.Y. (ed.), Proceedings of the Joint ASEAN Ergonomics/Asia Pacific CHI Conference, Singapore.
3. Vicki Bruce & Patrick R. Green, 1992. *Visual Perception*, Physiology, Psychology and Ecology, 2nd edition.
4. Richard L. Gregory, 1997. *Eye and Brain*, The Psychology of Seeing, 5th edition, Princeton University Press.

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Incorporating Ergonomics into an Integrated QFD/ DFX Approach for Concurrent Product Design Evaluation

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Good product value cannot occur without a carefully directed and documented product development program. Ergonomics, Economics and Technology have been defined as three basic areas, which are ultimately judged in evaluating a product. Very often good product value is lost when Economic and Technology constraints control a design. Therefore a good definition of Ergonomic needs is a key factor when designing new products. This paper reports a follow-up and extension of the feasibility study of integrating Quality Function Deployment (QFD) and Design for Excellence/ X-ability (DFX) for Concurrent Product Design Evaluation. The proposed methodology builds on the House of Quality (HoQ) presented in QFD process, by using not only Customer Preferences but also Preferences of Designers pertaining to lower level Design issues, to form constraints on design space. The extension to the feasibility study mentioned involves the incorporation of Ergonomics into the Concurrent Product Design Process.

1. BACKGROUND

The market place for interactive consumer products, demands products of higher quality with high levels of usability. To survive, manufactures must adapt new business strategies, which improves quality and customer satisfaction of the products while streamlining their product design into an ultra –efficient process. In the industry the process of product design and development is typically performed in isolation, separate from other functional departments. Within the design process itself designers consider each performance criterion independently. Manufacturers now agree that this type of sequential, isolated design process is inefficient and leads to less optimal products. Researchers are now examining new ways to understand and develop concurrent design processes to improve the science of design. Designers should be able to anticipate and address problems of the later stages of product development, such as manufacturability and usability earlier in the design stage. This sort of design strategy is called a "Design for X" or DFX approach, where X may be anything from manufacturability to recyclability [1].

2. OVERALL APPROACH

The methodology introduced in this paper goes beyond the current state of design theory and processes. The three most important concepts utilized were *Quality Function Deployment (QFD), Design For X-Ability (DFX) and Concurrent Function Deployment (CFD).* QFD provides a formal method of quality control for the product designer by converting the customer requirements defined in the product specifications into technical definition of the product in the design specification. A thorough explanation of the *House Of Quality (HoQ)* matrix used in QFD is provided in Hauser and Clausing [2]. Although DFX is a good first step toward integrating design with later stages of product development, it however only examines a single design criterion while engineering designs are evaluated with respect to various criteria. Furthermore, an important element, the customer, is still missing from this loop. CFD is a methodology that allows designers and manufacturing engineers to communicate early and work in parallel during various stages of a product design process. One critical tool to facilitate this early communication is house of values, which is a concept similar to house of quality. The term values ranges from quality to other values such as X-ability, Tools & Technology Cost, Infrastructure, etc. Figure 1 below shows the CFD matrix.

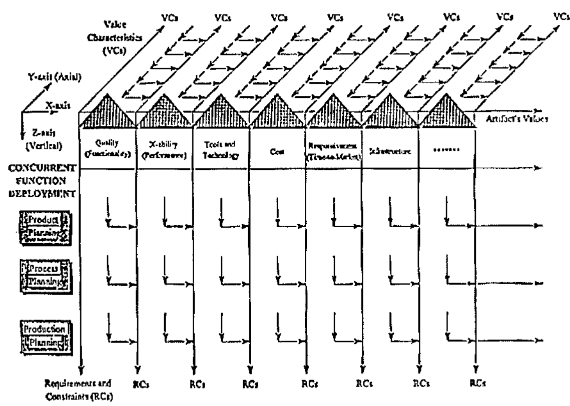

Figure 1 – CFD Matrix

The CFD methodology was adapted with some modifications. The House of Values utilized in CFD was integrated with the DFX methodology to incorporate 13 design attributes. Since the HoQ matrix remained the fundamental framework, the methodology allows us to model customers' preferences as well as multiple design attributes simultaneously, and also allows us to quantify trade-offs between design alternatives. These design alternatives include Customer Wants, Manufacturability Wants, Assembly Wants, Service & Maintainability Wants, Reliability Wants, Quality Wants, Cost Wants, Safety Wants, User-Friendly Wants, Physiological Wants and Psychological Wants. The following are some guidelines used for the 13 design attributes.

- **Design for Manufacturability**
  Simplify and improve the assembly, Minimize the number of parts, Standardize, Fit the design to the manufacturing process, Design each part to be easy to make etc.

- **Design for Assembly**
  Minimize number of parts, Once a part is oriented, never lose that orientation, Use subassemblies, Avoid the use of flexible parts if possible, Design parts to be self-aligning, Design parts so that they are easy to handle etc.

- **Design for Quality**
  Design the product, so that they can be easily tested, Utilize standard proven parts whenever possible, Design parts and set tolerances to reduce adjustments etc.

- **Design for Reliability**
  Simplify the design, Use standard or proven parts, Use redundancy, protect sensitive components and adjustments from accidental change etc

- **Design for Serviceability/ Maintainability**
  Increase the reliability of the product, Design all high mortality parts or those that may need replacement for easy detachment and replacement, Consider the use of modules, Design the product for easy testability etc.

- **Design for Safety**
  Design products to be fail-safe, Allow for human error, Avoid sharp corners, Provide guards or covers over sharp blades and similar elements etc.

- **Design for Environment**
  Eliminate environmentally unfriendly materials from the product and manufacturing processes, If elimination is not possible, reduce the quantity of such materials, Design the product so that such materials can be easily recycled etc.

- **Design for User-Friendliness**
  Simplify the structure of the user's tasks, Make the controls and their functions obvious, Provide feedback, Display operating information clearly etc

- **Psychological Factors**
  Provide visual or textile senses for discrimination of controls, Provide signal detection through visual or auditory displays, Use proper color coding etc.

- **Physiological Factors**
  Prolonged force exertion must be $< 15\%$ of muscular strength, Avoid exerting over 60% of muscular power, Avoid detectable range of vibration ($0.1 - 10^5$ Hz) etc.

Figure 2 below consists of a flow chart, which shows how the system works. The process is an extension to the HoQ matrix process flow and consists of the following steps :

1. Identification of requirements from the customer as well as various DFX attributes involved in the product design process.
2. Developing the horizontal portion of the matrix with requirements obtained instep 1.
3. Mapping of Technical Requirements to the above specifications (vertical portion).

3.1 Evaluation of Correlation Matrix.

4. Forming the relationships matrix between design attributes and technical specifications using simple weight factors.
5. Selection of important technical specifications by the user.
6. Development of conceptual ideas.
7. Evaluation and selection of product concept based on important technical specifications obtained in step 5.
8. Part Planning Stage.
9. Process Planning Stage.
10. Production Planning Stage.

The approach was also implemented into a software program (QFD Capture) to facilitate usability and also for the purpose of handling complicated products requiring large database. A suitable product (design of a coffee cup, adapted from Bossert [3]) was selected to test and verify the approach.

3. RESULTS

The approach allowed the user to design the Coffee Cup, not only based on Customer Specifications, but also based on lower level design alternatives as well. Most importantly, the approach allowed the designer to include ergonomic considerations early in the product development process, thus allowing ergonomics to play a greater part in the design of the product. By observing the total weightings given to each attribute, the user was able to identify the important Wants of each Attribute, to facilitate the development of a better design. Thus by giving high weightages to important ergonomic factors, the designer ensured that the final product would not be controlled by economic and technology constraints alone, thus maintaining good product value. Furthermore, from the Metric Tradeoff Chart, the user was able to distinguish the important Technical Specifications form the weaker ones. Finally, the introduction of an additional feature, The Concept Selection Facility, enabled the user to evaluate his Conceptual Designs based on crucial Technical Requirements, to identify the best concept.

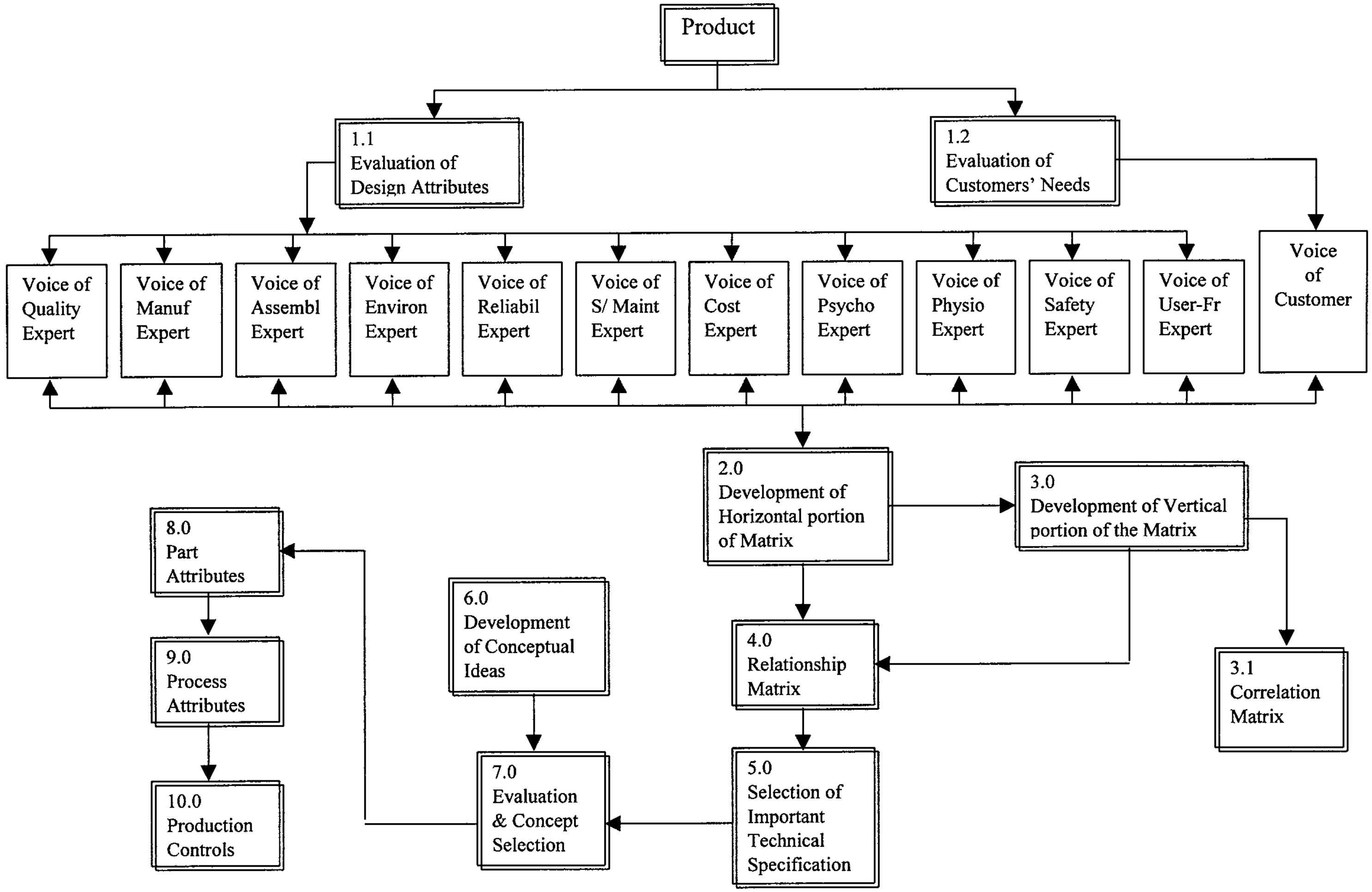

Figure 2 - Flow Chart

4. CONCLUSIONS

Current and future developments emphasize the need of integrating ergonomics more thoroughly into the design process. For this to be realized a more effective partnership between the designer and the ergonomist must be cultivated. Engineering through Technology must assist in developing ergonomic features at a reasonable cost. Therefore Engineering and Manufacturing must be selected primarily on the basis of their contribution towards achieving appropriate user value in product design. The approach presented in this paper aids the designer in doing just this. By incorporating Ergonomics into the new Concurrent Product Design Methodology which evaluates based on both higher and lower level design attributes, good product value can be maintained.

REFERENCES

1. James G. Bralla (1996), "Design For Excellence", McGraw Hill, Inc , USA.
2. Hauser, J.R, and Clausing, D., (1988), "The House of Quality", Harvard Business Review, May-June 1988, pp.63-73.
3. James L. Bossert (1991), "Quality Function Deployment, A practitioners Approach", ASQC Quality Press, Marcel Dekker Inc, Milwaukee, WI.

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Fuzzy Decision Approach for Electronic Industrial Work Induced Stress Analysis in Ergonomics

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This paper aims at investigating and exploring critical "work-induced-stress" for technicians working in a chip manufacturing industry to pinpoint the existing weaknesses in applying human factors to increase yield and productivity. Various work stresses ranging from environmental, physical and mental aspects were assessed by the technicians investigated, and the results are tabulated. In order to model the imprecision of human judgement and the uncertainty of consequences, fuzzy decision making approach was utilized. A single attribute (productivity) was considered and a fuzzy set of different alternative stresses was derived, where each alternative stress in the set was characterized by a grade. The alternative that corresponds to maximum grade was considered as the highest severity stress. To capture the optimistic and pessimistic attitude of technicians' judgements and to verify the typicality of result, maximax method was further verified by fuzzy Hurwicz rule, fuzzy regret principle and fuzzy expectation worth.

1. INTRODUCTION

Stress is defined as the reaction of organism to a threatening or oppressing situation. As stress is part and parcel of our life, it is necessary for all human beings to react to the threatening situations in an appropriate way. A life without stressors and stress would not only be unnatural, but also be boring or monotonous. However, if a person feels subjectively overloaded, he or she will be in distress [1,2].

Stress is on the rise and gaining attention as a costly workplace hazard. Employee turnover, unscheduled absenteeism, declining morale and all by-products of job-related stress have become extreme. It is essential to design a life that fits our values, aspirations, financial, emotional and spiritual needs [3]. The main causes of stress are lack of communication and consultation, increased workload in both physical and mental, job insecurity, lack of career path, organizational change and restructuring, etc. [4].

The present research aims at investigating relationship between subjective judgements, physiological and psycho-physiological variabilities, behavior and performance measures of technicians in order to increase company's yield and productivity with the lowest possible costs [5].

The objective of this paper is to explore and rank critical work induced stresses for technicians working in an electronic manufacturing environment. Various work stresses ranging from environment, physical and mental aspects were investigated. Semantic descriptions of specific consequences caused by work stress were described linguistically because their occurrence cannot be predicted accurately. A fuzzy decision making approach was utilized. A single attribute namely productivity was considered and a fuzzy set of alternatives was derived, where each alternative in the set was characterized by a grade. The alternative, which corresponds to maximum grade, was considered as the highest severity stress. Fuzzy regret principle, fuzzy Hurwicz rule and fuzzy worth expectation were used to verify and justify the decision obtained from maximax method to figure out the rank of stress suffered by most technicians.

2. STRESS ANALYSIS

In Ref. [6], direct observations on existing workload as subjectively perceived by the technicians: Quantitative or qualitative work overload or underload, their work roles or tasks, working conditions or environment, etc., are being studied as an ongoing project. Subjective rating of workload using NASA Task Load Index (TLX) assessment has been carried out and the result of the survey with regard to various environmental, physical and mental stresses are tabulated in Table 1. The percentage values in this table are not taken into consideration in fuzzy decision approach.

In short, despite the investigation of various types of environmental, physical and mental stresses, the results did not explicitly show the weight of severity for each stress in proper comparative analysis. This implicit presentation just implies the frequency distribution of each stress within its category. Thus, fuzzy decision making approach was utilized to further rank the stresses according to their respective importance, evaluated by the technicians with regard to productivity.

3. FUZZY DECISION MAKING APPROACH

Let S represents the set of all states (events) that may occur due to the consequences of various stresses. Associated with each alternative and the states of nature of production, there is a payoff value, P_{ij} which associating with the states of nature of production that are not known precisely. The semantic descriptions of consequences due to various stresses for each state are shown in Table 2. The possible states of nature of production are characterised by the following fuzzy set, S_1:

$$S_1 \quad = \quad \{(1, 0.80), (2, 0.40), (3, 0.20), (4, 0.60), (5, 0.50)\}\ . \qquad (1)$$

Table 3 illustrates the utility matrix based on single criterion namely productivity. The values of utility matrix are assigned subjectively by the technicians, based on the consideration and judgement of the states of nature of production, alternatives and criterions used. The weighted values range from 1 to 10. The fuzzy utilities associated with each alternative are shown in Eq. (5) in Appendix. The set of possible payoff values is given as:

$$X = \{1, 2, 3, 4, 5, 6, 7, 8, 9, 10\},$$
$$P_{max} = \sup_x(X) = 10. \quad (2)$$

Table 1 Environmental, physical and mental stresses and strains faced by the technicians

Categories of Stresses	Types of Stresses and Strains (Serially A1 to A12) (A1 – A12)	Technicians (%)
1. Environmental	• Felt cold chills when working in night shift.	57.1
	• Working in air-conditioned environment lead to dry mouth.	46.4
	• Working in noisy environment especially when the alarms or buzzers simultaneously turned on due to machine errors, stoppages, etc.	32.1
2. Physical	• Ordinary Visual Inspection or 100% Visual Inspection of rejects that causes eye problems.	89.3
	• Back pain and stiffness at neck due to frequent bending of body, to load and unload magazine, to attend to machine errors, etc.	25.0
	• Pain in leg due to long hours of standing and movements within assembly line.	53.6
3. Mental	• Arguments with superiors regarding the devices, packages or products, etc. to be processed.	28.6
	• Have to shorten the regular tea and lunch breaks, to address to machine problems to keep them continuously running.	46.4
	• Unable to sleep well with anxiety to explain to top management the root cause of rejects.	53.6
	• More support or assistance needed in handling mechanical and electronic problems of machine, etc.	28.6
	• Felt bored by repetitive and monotonous work and preferred to leave the job.	14.3
	• The top management did not show their appreciation of the work to solve machine errors or problems, complete the work or tasks in time, etc.	17.9

Table 2 States of nature of production

Possible State of Nature of Production	Semantic Description of Consequences Due to Various Stresses	Grade of Membership as Done by Experts
1.	Low Productivity	0.80
2.	Low Working Morale	0.40
3.	High Employee Turnover	0.20
4.	High Absenteeism	0.60
5.	High Accident Rates	0.50

Table 3. Utility matrix for productivity

State of Nature of Production	Utility Value (1-10) for **Alternative Stresses**											
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1.	4	2	5	7	4	5	8	2	7	8	7	9
2.	1	1	2	2	2	1	7	6	7	6	9	9
3.	1	1	3	4	3	3	9	6	8	6	10	7
4.	3	2	3	5	5	4	6	5	7	6	8	10
5.	7	7	8	9	9	9	2	1	6	1	2	8

The maximizing sets for various alternatives are determined as: Each payoff value is generalized by P_{max}, and the result is the grade of membership of the actual payoff values that shown in Eq. (6) in Appendix. Next, the fuzzy utility (decision making) sets are obtained as follows:

$$PS_l \quad = \quad f_{Pl} \wedge f_{XMl} , \tag{3}$$

where $\wedge$ is the minimum operator.

f_{Pl} and f_{XMl} are the grades of membership functions of P_l and XM_l respectively as shown in Eq. (7) in Appendix. The highest grade of membership for each alternative is determined as shown in Eq. (8) in Appendix.

Stress A7 and A12 have the highest grade of membership, therefore, it is the highest severity stress with regard to the consequences of stress with the consideration of productivity.

The fuzzy set of alternatives is given by:

$$A = \{0.50|A1, 0.50|A2, \ldots\ldots, 0.80|A7, \ldots\ldots, 0.80|A10, 0.70|A11, 0.80|A12\} . \tag{4}$$

This fuzzy set of alternatives indicates the relative severity of all the alternatives. From fuzzy utility sets (Eq. (6)), the lowest grade of membership for each alternative is determined as Eq. (9) in Appendix.

The Hurwicz values for $\alpha = 0.7$, which implies the surveyed technicians are more optimistic, can be determined as:

$$\begin{aligned} HV_l &= \alpha Hf_{ai} + (1-\alpha)Lf_{ai} \\ &= 0.7 * (0.50, 0.50, \ldots\ldots, 0.80, \ldots\ldots, 0.80, 0.70, 0.80) + \\ &\quad 0.3 * (0.10, 0.10, \ldots\ldots, 0.20, \ldots\ldots, 0.10, 0.20, 0.20) \\ &= (0.38, 0.38, \ldots\ldots, \mathbf{0.62}, \ldots\ldots, 0.59, 0.55, \mathbf{0.62}) . \end{aligned}$$

The largest Hurwicz value is 0.62. A7 and A12 are among the highest severity stress with/without regard to the attitude of technicians. From Eq. (6), the fuzzy regret matrix is derived as follows: Regret is found by deducting each grade of membership from the highest value in its column. Fuzzy regret matrix for this sample problem is shown in Table 4, where the maximum fuzzy regret for each alternative is found and the alternative with the minimum value is chosen. The alternative A12 is chosen as the most serious since it has the minimum value as compared to A7.

In the worth expectation criterion, the fuzzy belief vector is the subjective judgement of the events. The fuzzy belief vector is given as:

g_i = (0.80, 0.40, 0.20, 0.60, 0.50)

The expected worth for each alternative can be estimated and is shown in Table 5. Alternative A12 is preferred in all cases. Only the highest severity stress, A12 can be verified by maximax method, fuzzy Hurwicz rule, fuzzy regret matrix and fuzzy worth expectation, the following ranking of other stresses are not apparently sorted out consistently and verified by the above methods. If the maximax method, fuzzy Hurwicz rule and fuzzy regret principles were carried out, the three most severe stresses are A12, A7 and A10. Nevertheless, the fuzzy worth expectation shows that A12, A11 and A9 are among the serious stresses for the technicians. The variation of the results may originate from the non-specificity of assessment and judgements of technicians. Thus, to further justify the technicians' opinion, evidence sets [8] which model the fuzziness, non-specificity and conflict of human judgement may be used.

4. CONCLUSIONS

In this paper, statistical decision on various stresses was viewed in fuzzy manner and unique results were obtained. A single attribute (productivity) was analyzed and a fuzzy algorithm was utilized to choose the highest severity stress, namely, A12 - The top management did not show their appreciation of the work to solve machine errors or problems, complete the work or tasks in time, etc. The result was further verified by fuzzy Hurwicz rule, fuzzy regret principle and fuzzy expectation worth. The exploration of the highest severity stress would assist the production management to minimize the technicians' stress particularly to increase the yield.

Table 4: Fuzzy regret matrix

State of Nature of Production	**Alternative Stresses**											
	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**	**11.**	**12.**
1.	**0.4**	**0.6**	**....**	**....**	**....**	**....**	**0.0**	**....**	**....**	**0.0**	**0.1**	**0.0**
2.	**0.3**	**0.3**	**....**	**....**	**....**	**....**	**0.0**	**....**	**....**	**0.0**	**0.0**	**0.0**
3.	**0.1**	**0.1**	**....**	**....**	**....**	**....**	**0.0**	**....**	**....**	**0.0**	**0.0**	**0.0**
4.	**0.3**	**0.4**	**....**	**....**	**....**	**....**	**0.0**	**....**	**....**	**0.0**	**0.0**	**0.0**
5.	**0.0**	**0.0**	**....**	**....**	**....**	**....**	**0.3**	**....**	**....**	**0.4**	**0.3**	**0.0**
Max	**1.1**	**1.4**	**....**	**....**	**....**	**....**	**0.3**	**....**	**....**	**0.4**	**0.4**	**0.0***

* Minimum value

Table 5 Fuzzy worth expectation

State of Nature of Production	Alternative Stresses											
	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**	**11.**	**12.**
1. (0.8)	**4**	**2**	**5**	**7**	**4**	**5**	**8**	**2**	**7**	**8**	**7**	**9**
2.(0.4)	**1**	**1**	**2**	**2**	**2**	**1**	**7**	**6**	**7**	**6**	**9**	**9**
3.(0.2)	**1**	**1**	**3**	**4**	**3**	**3**	**9**	**6**	**8**	**6**	**10**	**7**
4.(0.6)	**3**	**2**	**3**	**5**	**5**	**4**	**6**	**5**	**7**	**6**	**8**	**10**
5.(0.5)	**7**	**7**	**8**	**9**	**9**	**9**	**2**	**1**	**6**	**1**	**2**	**8**
EW	**9.1**	**6.9**	**11.2**	**14.7**	**12.1**	**11.9**	**14.6**	**8.7**	**17.2**	**16.0**	**17.0**	**22.2**

* EW ≡ Expected Worth

REFERENCES

1. H. Seyle, The Stress of Life, McGraw-Hill, New York, 1978.
2. K. H. E. Kroemer and E. Grangjean, Fitting the Task to the Human – A Textbook of Occupational Ergonomics, Taylor and Francis, London, 1997.
3. C. Farren, "Stress and Productivity : What Tips the Scale ?", Strategy & Leadership, Chicago, 27 (1999) 36.
4. Anonymous, "Workplace Stress = Health Distress", The Worklife Report, Ottawa, 11 (1997) 10.
5. J. D. Stone, "The Relationship between Three Predictors of Mental Workload and the Information Content of a Task", University of South Dakota, DAI-B 42/05, (1981) 2117.
6. R. N. Sen and Y. H. Quek, "Ergonomic Evaluation of Work and Environmental Stresses on Technicians Working in a Multimedia Chip Manufacturing Industry in Malaysia", In : Contemporary Ergonomics 2000, P. T. McCabe, M. A. Hanson and S. A. Robertson (eds.), Taylor & Francis, London, ISBN 0-748-40958-0 (2000) 134.
7. C. W. Chong, C. Eswaran and V. Ramachandran, "Fuzzy Decision Analysis for Future World Wide Web Planning", 18th IASTED International Conference on Modelling, Identification and Control (MIC'99), Innsbruck, Austria, (1999) 89.
8. L. M. Rocha, "Interval Based Evidence Sets", Proceedings of the ISUMA-NAFIPS'95, B. Ayyub (ed.), (1995) 624.

APPENDIX

The fuzzy utilities associated with each alternative are:

P_1 = {(0.80, 4), (0.40, 1), (0.20, 1), 0.60, 3), (0.50, 7)}
P_2 = {(0.80, 2), (0.40, 1), (0.20, 1), 0.60, 2), (0.50, 7)}

.

P_{10} = {(0.80, 8), (0.40, 7), (0.20, 9), (0.60, 6), (0.50, 2)}
P_{11} = {(0.80, 7), (0.40, 9), (0.20, 10), (0.60, 8), (0.50, 2)}
P_{12} = {(0.80, 9), (0.40, 9), (0.20, 7), 0.60, 10), (0.50, 8)} (5)

The grade of membership of the actual payoff values:

XM_1	=	{(0.4, 4), (0.1, 1), (0.1, 1), (0.3, 3), (0.7, 7)}
XM_2	=	{(0.2, 2), (0.1, 1), (0.1, 1), (0.2, 2), (0.7, 7)}
		.
XM_{10}	=	{(0.8, 8), (0.6, 6), (0.6, 6), (0.6, 6), (0.1, 1)}
XM_{11}	=	{(0.7, 7), (0.9, 9), (1.0, 10), (0.8, 8), (0.2, 2)}
XM_{12}	=	{(0.9, 9), (0.9, 9), (0.7, 7), (1.0, 10), (0.8, 8)} (6)

f_{P1} and f_{XM1} are the grades of membership functions of P_1 and XM_1 respectively, i.e.,

PS_1	=	{(0.4, 4), (0.1, 1), (0.1, 1), (0.3, 3), (0.5, 7)}
PS_2	=	{(0.2, 2), (0.1, 1), (0.1, 1), (0.2, 2), (0.5, 7)}
		.
PS_{10}	=	{(0.8, 8), (0.4, 6), (0.2, 6), (0.6, 6), (0.1, 1)}
PS_{11}	=	{(0.7, 7), (0.4, 9), (0.2, 10), (0.6, 8), (0.2, 2)}
PS_{12}	=	{(0.8, 9), (0.4, 9), (0.2, 7), (0.6, 10), (0.5, 8)} (7)

The highest grade of membership for each alternative is determined as follows:

Hf_{a1}	=	$\vee$ (0.40, 0.10, 0.10, 0.30, 0.50)	=	0.50
Hf_{a2}	=	$\vee$ (0.20, 0.10, 0.10, 0.20, 0.50)	=	0.50
		.		
Hf_{a10}	=	$\vee$ (0.80, 0.40, 0.20, 0.60, 0.10)	=	0.80
Hf_{a11}	=	$\vee$ (0.70, 0.40, 0.20, 0.60, 0.20)	=	0.70
Hf_{a12}	=	$\vee$ (0.80, 0.40, 0.20, 0.60, 0.50)	=	0.80 (8)

The lowest grade of membership for each alternative is determined as follows:

Lf_{a1}	=	$\wedge$ (0.40, 0.10, 0.10, 0.30, 0.50)	=	0.10
Lf_{a2}	=	$\wedge$ (0.20, 0.10, 0.10, 0.20, 0.50)	=	0.10
		.		
Lf_{a10}	=	$\wedge$ (0.80, 0.40, 0.20, 0.60, 0.10)	=	0.10
Lf_{a11}	=	$\wedge$ (0.80, 0.40, 0.20, 0.60, 0.50)	=	0.20
Lf_{a12}	=	$\wedge$ (0.80, 0.40, 0.20, 0.60, 0.50)	=	0.20 (9)

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Using ACTA to Extract the Cognitive Demands of Preventive Maintenance Activities in a Wafer Plant

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Due to very high production volumes, wafer machines require frequent and regular preventive maintenance. At these times, ample opportunity exists for human error to occur. Because high electrical power and toxic gases are involved, the consequences of any human-error-induced machine failure have a very high impact on plant safety, production cost, and environment health. It is, therefore, necessary to analyze the preventive maintenance tasks so that the cognitive skills and mental demands imposed can be identified. The data from the task analyses can then be used in the design of task procedures and online support systems. The objective of this paper is to explore the use of ACTA (Applied Cognitive Task Analysis) -- an established framework for cognitive task analysis in supervisory control task -- for the preventive maintenance procedure of a plasma etch equipment. ACTA was used to extract the cognitive skills and mental demands of the preventive maintenance activities.

1. INTRODUCTION

Equipment systems in the wafer fabrication industry, which are mostly electro-chemical in nature, are regularly shut down for preventive maintenance. Such activities can be classified as supervisory control tasks where equipment parts are cleaned and replaced if necessary. The integrity of the equipment is examined also so as to uncover any risk of machine failure.

Human-error-induced machine failures are known to occur frequently during preventive maintenance where a great deal of high level human-machine interaction takes place. Cognitive task analysis is, therefore, useful in identifying the various cognitive demands and skills that are required in order to perform the task of preventive maintenance.

Various cognitive task analysis techniques have been developed. See, for example, Rasmussen's (1986) text on cognitive engineering. Militello and Hutton (1998) discussed an applied cognitive task analysis (ACTA) that is both easy to use and also provides clear output. Rouse (1984) looked at fault diagnosis tasks and its implications for training maintenance personnel.

In a wafer fabrication plant, the equipment and operation engineers have the responsibility of ensuring a high level of effectiveness and efficiency of the technical support teams in equipment maintenance and troubleshooting. Hence, the application of cognitive task analysis techniques in extracting various mental models can facilitate efforts to improve task performance on the part of the technical support team. The result may be the design of a robust support system, the installation of various maintenance infrastructures, or the dynamic allocation of tasks between humans and machines.

This paper proposes a cognitive task analysis procedure to study equipment preventive maintenance in a wafer fabrication plant. It is hoped that this technique will help minimise human-error-induced machine failures through task redesign and improvement. The proposed cognitive task analysis is referred to as PM_ACTA.

2. PM_ACTA (COGNITIVE TASK ANALYSIS IN PREVENTIVE MAINTENANCE)

PM_ACTA was designed based on Wickens' (Wickens, Gordon, and Liu, 1997, p. 147) model of human information processing and Rasmussen's (1986, p. 7) framework for cognitive task analysis. The main objective of PM_ACTA is to extract various mental models and data involved in the task of equipment preventive maintenance in a wafer plant.

In the extraction of mental demands, Wickens' model was used to classify and derive the various mental demands placed on a human operator. These are classified as either attention demands, perception loads, or memory stresses. A hierarchical chart of the various mental demands is shown in Figure 1.

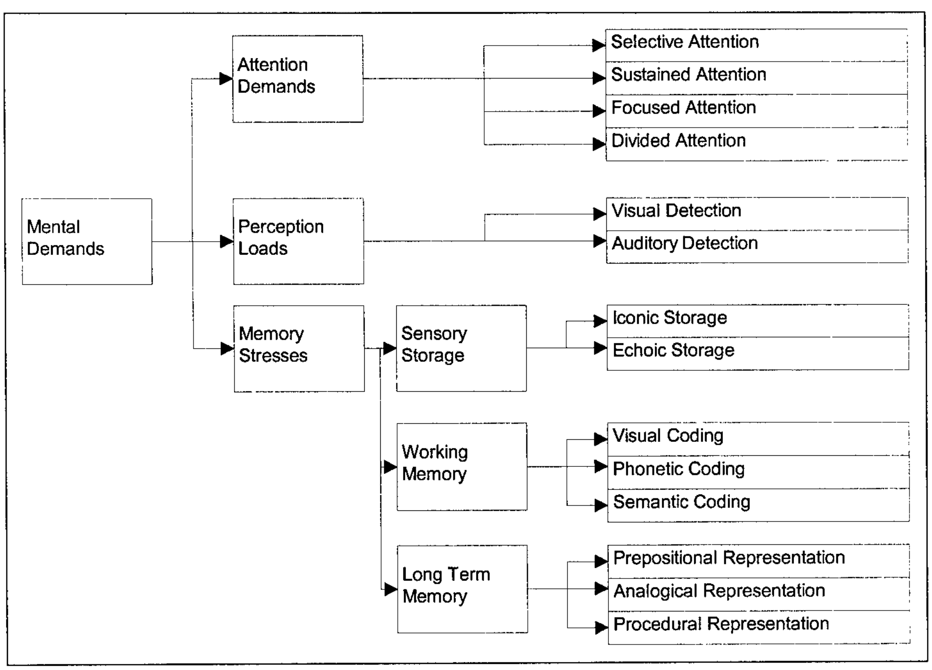

Figure 1. Hierarchical chart of mental demands

In the extraction of cognitive skills, Rasmussen's (1986) framework for supervisory control task is applicable. In this framework, a typical information processing sequence is where an operator first perceives the states of a task situation through: i) detecting the need of an action, ii) observing information and data, and iii) identifying the present state of the system. The operator then proceeds to diagnose the task situation through interpreting the consequences of intervention with reference to various constraints and policies. He evaluates the root cause of the situation observed, defines the probably target states, and formulates an action plan. The operator finally executes or coordinates the performance of the action plan. Depending on the level of cognitive processing involved (i.e., skill-based, rule-based or knowledge-based), the operator may cut short the information processing task at any stage. He may also communicate with various relevant parties at various points during task performance. Hence, perceptual, diagnostic, and communication skills are all important.

For the present study, having identified the elements of the mental model, a list of test statements can be formed to help complete each step in the preventive maintenance procedure. These statements can be formatted in the style of self-questioning. It will be used by the troubleshooter or equipment engineer who will likely be a subject matter expert (SME) in PM_ACTA. The list of test statements is used to help complete the preventive maintenance procedure. An example of a PM_ACTA worksheet is presented in Table 1 (Mental demand section) and Table 2 (Cognitive skills section). Refer to the first two columns of both tables.

Table 1 An example of a PM_ACTA worksheet (Mental demand section)

Mental Demand	**Test Question**	**Step**	**Remarks**
Attention			
Selective attention	I am required to monitor data from more than one source.	1	There are a few process parameter fields, namely Pressure, RF Power, Gas Flow Rate in Process Macro Page that I am required to check while the dry clean recipe is running.
Focused attention	I am required to work in the presence of distractions.	1 2, 3	The same recipe appears in several different sub-directories. I am required to activate the correct recipe in the correct sub-directory. The Pump/Purge and Pump/Vent fields are close to each other and the two look similar, I may activate the wrong field.
Sustained attention	I am required to remain alert over a long period of time.		
Divided attention	I am required to perform more than one task at a time.		
Perception			
Sensitivity (visual signal detection)	Do the items I have to see stand out from the background?		

Sensitivity (auditory signal detection)	Do the sounds I have to hear stand out from background?	2	Sounds generated by the opening/closing of valves during pump/purge are masked by the background noise in the clean room.
Memory			
Iconic sensory storage	I am required to remember what I just saw prior to a task.	1	I am required to record the process parameters into a checklist when the plasma clean recipe is running.
Echoic sensory storage	I am required to remember what I just heard prior to a task.		
Visual memory	I am required to memorize images for a task.		
Phonic memory	I am required to memorize sounds for a task.		
Semantic memory	I am required to memorize very long task sequences.	2	There are quite a few fields to be edited before activating pump/purge circle.
Prepositional knowledge representation	I am required to learn or recall some pre-learned concepts for a task.	1 2 3	I am required to evaluate the chamber condition and decide on the number of wafers to run. I am required to understand the operation of the pump/purge. I am required to understand the operation of the chamber vent operation.
Analog representation	I am required to learn or recall some pre-learned images or sounds for a task.	2, 3	The correct sound sequence generated when valves open and close is helpful to verify the correct operation of chamber pump/purge and chamber vent.
Procedural representation	I am required to learn or recall some pre-learned know-how in order to perform a task.	1 2, 3	I am required to know how to edit a process recipe. I am required to know how to edit and verify the chamber pump/purge and chamber vent related fields.

Table 2 An example of a PM_ACTA worksheet (Cognitive skill section)

Cognitive Skill	**Test Question**	**Step**	**Remarks**
Perception			
Action alert	I am required to detect the need for action(s).	1 2, 3	I am required to identify the starting and ending of the recipe. I am required to identify the starting and ending of the operation of chamber pump/purge and chamber vent.
Data observation	I am required to observe information and data.	1	I am required to check the process parameters in the Process Macro Page.
State identification	I am required to identify the present state of the system.	1 2 3	I am required to determine that the machine is in the process mode. I am required to verify that the machine is in the pump/purge mode. I am required to verify that the machine is in the venting mode.
Diagnostic			
Consequence interpretation	I am required to interpret consequences of action(s) in terms of various constraints and policies.	1, 2, 3	I am required to do this when there is an alarm.
Root cause search	I am required to search and evaluate root causes of current observations.	1, 2, 3	What I will do will depend on the alarm.
Goal setting	I am required to define the target state.	1, 2 3	It depends on the resources and constraints that I face.
Task formulation	I am required to formulate action plan(s).	1, 2, 3	My plan will depend on the root cause.
Plan execution	I am required to coordinate and perform the action plan(s).	1, 2, 3	It will depend on the resources and constraints.
Communication			
Verbal interaction	I am required to communicate with someone during the task.	1	I am required to confirm with the Process Engineer about the status of the process recipe. I am required to request wafers from Manufacturing Department.

2.1. Procedure of PM_ACTA

The PM_ACTA implementation steps are:

1. The subject matter expert is required to read the PM_ACTA worksheet in order to understand the classification and meaning of the mental model.

2. For each step in the preventive maintenance procedure, he is to extract the mental model using the PM_ACTA worksheet. He enters his thoughts into the "Remarks" column.
3. He is to specify the applicable procedural step(s) in the "Step" column.
4. Steps 2 and 3 above are repeated throughout the preventive maintenance procedure.

3. DISCUSSION

The feasibility of PM_ACTA was examined by applying it to analyze the task of preparing a plasma etch equipment reaction chamber for wet clean operation in a wafer plant. Figure 2 is a flow chart of the task sequence summarized from the actual preventive maintenance procedure.

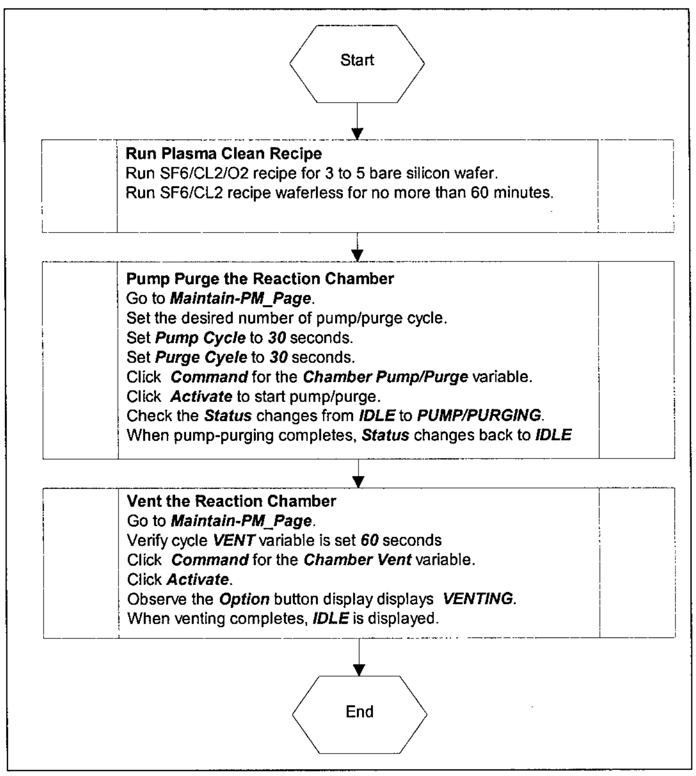

Figure 2. Task sequence for preventive maintenance procedure.

Each step in the above procedure was scrutinized for the mental model involved. The resultant PM_ACTA worksheet obtained is shown also in Tables 1 and 2 (see "Remarks" column). The worksheet presents information about the engineer's mental model at each step.

This is done in an organised, tabulated form. The data are now ready to be transformed into a frequency distribution. Statistical analysis can be performed also.

4. CONCLUSION

PM_ACTA utilizes a user-centric approach to cognitive task analysis. The information gleaned provides insights into the user's mental model during task performance. The exercise of filling out the PM_ACTA worksheet promotes awareness on the part of the user. Preventive maintenance exercises can be conducted more effectively with a view to reducing human-error-induced machine failures. A direct benefit of the PM_ACTA worksheet would be improvement in the safety standard of the wafer fabrication industry.

REFERENCES

1. Rasmussen, J. (1986). *Information processing and human-machine interaction: An approach to cognitive engineering*. New York: North-Holland.
2. Rouse, W. (1984). Models of natural intelligence for fault diagnosis tasks: Implications for training and aiding of maintenance personnel. *In Proceedings of the Joint Services Workshop, Report No. AFHRL-TR-84-25, pp. 193-212*. Colorado: AFHRL.
3. Wickens, C. D., Gordon, S. E., and Liu, Y. (1997). *An introduction to human factors engineering*. New York: Longman.

PART THREE

Process Control

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Eye Point-of-Gaze, EEG and ECG Measures of Graphical and Keyboard Interfaces in Simulated ATC

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To assess the utility of eye movement recording for the assessment of different ATC operating methods, its relation to other electro-physiological measures and their sensitivity to task difficulty, 8 controllers carried out four TRACON II exercises using a graphic and a keyboard interface in light and heavy traffic. An iView head-mounted eye-tracking device was used. EEG/EOG and EKG were also measured, and on-line observations recorded using the Noldus Observer System. Significant events during the exercises were also identified for detailed analysis. Subsequently, an ASL 504 remote eye-tracking system was evaluated using the same protocol, for the graphic interface only, and comparisons were made between the two eye movement recording systems.

1. INTRODUCTION

A series of small-scale Real Time (RT) simulations of Air Traffic control (ATC) has been carried out as reported previously (Cabon *et al,* 1997, 1998, David *et al*, 1998, 1999), to evaluate the use of psychophysiological measures to measure the effects of performing ATC on controllers. These simulations used a simple Wesson International TRACON II Autonomous ATC simulator. On the basis of the findings of these simulations, selected psychophysiological and self-assessment measures were applied to a RT simulation. (These studies are summarised in the companion paper by the same authors elsewhere in these proceedings.)

Continuing the Eurocontrol Experimental Centre policy of preliminary small-scale investigations, attention was turned to the measurement of eye-movement (Point of Gaze). This technique has been used on other occasions for investigations in real life ATC (Bouju and Sperandio, 1979, Leguillou *et al,* 1981) and in RT simulations, (David, 1985), but without corresponding measures of psychophysical strain.

2. AIMS

This study was undertaken in order to: -

1. Provide experience in applying Eye Point-of-Gaze measurement in a Real-time simulation.
2. Provide experience of the simultaneous application of electrophysiological measures.
3. Investigate the sensitivity of these measures to different control devices in light and heavy traffic.

4. Investigate the utility of the Noldus Observer system for ATC observation.
5. Investigate controllers' eye-movements prior to undesirable events.

3. METHOD

Eight experienced but not currently practising Air Traffic Controllers carried out simulation exercises using the TRACON II Autonomous Air Traffic Control (ATC) simulator at Eurocontrol Experimental Centre, (EEC), Bretigny, France. Each controller undertook four exercises, controlling 15 and 30 aircraft entering in 30 minutes, using graphic (trackball/pointer/windows) and coded keyboard input methods. The two lighter loaded exercises were carried out on one afternoon, following some preliminary training exercises, and the more heavily loaded exercises were carried out on the following afternoon, to minimise circadian rhythm problems. The orders of presentation of samples and input methods were permuted to minimise overall bias.

The traffic level for the heavier sample was deliberately chosen to exceed the controllers' expected capacity, in order to produce a significant number of 'errors': missed approaches (where an aircraft is not correctly positioned for landing), missed hand-offs (where an aircraft is not transferred to the next sector in time), conflicts (where aircraft approach within 3 NM without 1000 feet vertical separation) and even collisions.

4. MEASURES

The controllers' left/right frontal Electroencephalogram (EEG) and Electrocardiogram were recorded using a Vitaport psychophysiological recorder. The point of gaze was recorded using a Sensomotoric Instruments iView head-mounted eye-tracking device. Point-of-Gaze video recordings were obtained for all exercises. (No interference was experienced between the EEG and the eye-tracking helmet - in fact the lightweight cycle helmet helped to secure the EEG electrodes firmly in place.)

A preliminary analysis was carried out using the Noldus Observer on-line, an observer recording major shifts of attention. Significant events during the exercise were noted. The TRACON II simulator provided an overall score for each exercise, with numbers of the 'errors' mentioned above. (Unfortunately, the TRACON II simulator stops if a collision occurs, and destroys the records of the controller concerned.)

The Controllers filled in fatigue measurement instruments before and after exercises, and completed the NASA-TLX instrument after each exercise. They also completed a post-simulation questionnaire after the last exercise.

5. ANALYSIS

Eye Movements

Aircraft entered the simulation over a 30-minute period, and took about 15 minutes to complete their flights. There was an initial rise in activity, a busy period and a final tailing-off of activity. Eye-movement analysis was therefore confined to the busiest 20 minutes of each simulation. Initially, the location, duration and frequency of eye-movements were analysed on a minute-by-minute basis.

The TRACON II screen (400 mm x 300 mm) is divided into a Radar display (Top left, 275 mm square), flanked by a strip bay (Right, 125 mm wide), containing strips (15 mm deep). Pending strips, relating to aircraft not yet under the controller's control, appear above Active strips. Strips appear in the Pending list, are transferred to the Active list automatically on acceptance, and are removed automatically from that list when the aircraft lands or leaves the area. A communications window (25 mm deep), below the radar, shows in text form the verbal messages generated by the system from the controller's input and simulated pilots and adjacent controllers. When operating in the track-ball/pointer (Graphic) mode, pop-up windows of varying sizes and shapes (about 50 -80 mm in either dimension) appear, providing choices of instructions and complementary information.

The mean number of fixations per minute was approximately 15 per minute for the graphic mode, and 25 per minute for the keyboard mode. In keyboard mode, the controllers switched frequently between the keyboard, the active strip area and the radar. Controllers using the graphic interface spent about 57 percent of their time looking at the radar, 17 percent looking at the active strips and 17 percent looking at 'pop-ups'. Controllers using the keyboard interface spent about 47 percent of their time looking at the radar, 20 percent looking at active strips and 20 percent looking at the keyboard. Surprisingly, the traffic load made no significant differences in the duration or number of fixations, for either control mode.

Electroencephalography

The estimated theta-rhythm power rose for higher traffic load in the keyboard mode, as might be expected. In the graphic mode, however, it fell.

ECG- Heart Rate

For both modes, the variability of heart rate (sinusarythmia) fell for higher task loads. There was a significant negative correlation between sinusarythmia and the number of fixations for radar, active strips, and keyboard, and between sinusarythmia and the time spent looking at the radar.

NASA-TLX

There were significantly higher scores for the mental, physical and temporal demand and effort sub-scales of the NASA-Task Load Index for heavier traffic load.

Performance

The overall TRACON score was higher for higher traffic load, although the deliberate overloading of controllers in the high traffic load produced variable scores. Specific error frequencies showed a more complex pattern. There were more separation losses in the keyboard mode, suggesting less situational awareness. There were more handover errors in heavy task load conditions, suggesting that controllers may decide to 'shed' this task under time stress, and more missed approaches in the graphic control mode, which may be attributed to the lower precision of the graphic methods for height and speed allocation.

Controller Orders

There were no significant differences in the numbers of orders per minute - even between high and low traffic load conditions.

6. DISCUSSION

This was an initial feasibility study, which should be repeated with larger numbers of subjects. The observed results can only be regarded as tentative, but are indicative.

The only problems encountered with the head-mounted iView equipment were that the tracking was lost when the controller was looking downwards, as the upper eyelid tends to fall as he does so. This problem is exacerbated when bifocal or progressive lenses are worn, since these force the controller to tilt his head back to read print. EEG electrodes were applied with collodion, and the converted bicycle helmet used by the iView system helped to hold them in good contact. Only one controller expressed discomfort at this combination.

Calibration of the equipment presented some problems. A blank panel with a grid of reference points was presented to the controller, who was asked to look at these points while the computer-based calibration was carried out. Normally, this required about five minutes, but on some occasions calibration had to be repeated several times. It was important that the controller adopted his true working posture, rather than leaning back from the screen. (Controllers when working tend to lean towards the screen when solving problems, and to lean back after finding solutions.)

The I-view system presents the point-of-gaze as a point on a video image taken from a head-mounted camera. This permits free head movement but requires costly and slow manual analysis.

The video-records incorporating the controller's eye movements provide the opportunity to examine in detail exactly where the controller's attention was directed before significant events, such as failures to maintain separation, failures to hand over aircraft to the next sector and so on. These analyses are particularly laborious, and are currently being completed. An initial hypothesis, that controllers did not see that an aircraft was due to be handed over to the next sector, because they were looking at another part of the screen, does not appear to be supported. It appears that either they were too busy, or they had not realised that an attempt to hand over had been rejected.

The integration of psychophysiological, eye-movement and operational data on a minute-by-minute basis was practical and effective. It is not yet practical to identify which aircraft image or strip is being looked at, or to separate EEG signals according to the direction of gaze, so that no direct information on the lateralisation of brain functions has been obtained.

7. ASL 504 SYSTEM

Because the possibility of borrowing the ASL 504 system arose, at short notice, after the iView measurement campaign had been completed, it was not possible to produce a fully balanced experimental comparison. To maximise the available comparisons, given that only two of the original controllers were available, only the measures of the graphic presentation method were repeated. The two previously participating controllers experienced the heavy traffic samples that they had not previously seen, while the two controllers who had not participated in the previous exercise saw the same heavy and light traffic samples as were seen by two previously particiating controllers using the graphic interface. It was thus possible to treat the first two controllers as a within-subjects statistical analysis, and the other two as a four-subject between subjects statistical analysis, which will be reported in a later publication.

Initial observation suggests that the ASL504 system, which stores its results as coordinates relative to pre-defined screen areas, provides considerably more useable results, since it is not necessary, as with the iView system, to analyse each recording manually. It was possible to use the Noldus Observer to record the occurrence of significant events during the running of the experiment, and to isolate observations of eye-movements prior to these events.

The ASL system employs a motor driven eye-tracking camera ,aided by a Polhemus head-tracking device, which required the controller to wear a cloth head-band holding the sensor. This did not interfere with either the EEG/EOG electrodes or the controllers' activities. The ASL system experienced some difficulty where continouously-variable lenses were worn, and it was necessary to request the one controller who wore this type of lens to employ a different pair of spectacles. (No controller in either exercise wore contact lenses.)

8. CONCLUSIONS

1. Eye Point-of-Gaze measurement was successfully applied in this Real-time simulation.
2. Electrophysiological measures were applied successfully at the same time as these measures. Results of ECG, EEG and Eye Movement were combined (on a minute-by-minute basis.)
3. Eye Movement measurements were sensitive to the interface mode. Psychophysiological measures were sensitive to the interface mode, and to traffic load.
4. The Noldus Observer system can be usefully applied to the direct observation of a single controller, and to the analysis of video records. Some method of time-sharing or sampling should be developed for the observation of many controllers. .
5. The investigation of controllers' eye-movements prior to undesirable events is continuing, but initial observations do not support the hypothesis of 'over-concentration'.

REFERENCES

(Paper copies of EEC Notes and Reports are available from the address above. Recent Notes and Reports are available at the EEC Web-site (www.eurocontrol.fr))

1. Bouju, F. and Sperandio, J-C, 1979, *Analyse de l'activite visuelle des controlleurs d'approche*, Rapport C.O. 7911 R59. INRIA France
2. Cabon, P., Mollard, R., Cointot, B., Martel, A. and Beslot, P. 1997, *Elaboration of a method for the psychophysiological states of Air Traffic Controllers in Simulation* EEC Report No. 323 (Eurocontrol Experimental Centre, Bretigny-sur-Orge, France)
3. Cabon, P., Farbos, B., Bourgeois, S., R., Cointot, B. and Mollard, R. 1998, *Objective evaluation of the learning process of controllers adapting to a new HMI for ATC* EEC Note No. 16/98 (Eurocontrol Experimental Centre, Bretigny-sur-Orge, France)
4. David, H., 1985, *Measurement Of Air Traffic Controllers' Eye Movements in Real Time Simulation.* EEC Report No. 187 (Eurocontrol Experimental Centre, Bretigny-sur-Orge, France)

5. David, H., Cabon, P., Bourgeoise-Bougrine, S. and Mollard, R., 1998 Psychophysiological Measures of Fatigue and Somnolence in Simulated Air Traffic Control, In M.A. Hanson (ed.) *Contemporary Ergonomics 1998,* (Taylor and Francis, London) 427-433
6. David, H., Farbos, B., Bourgeois, S., Cabon, P., and Mollard, R., 1999 Psychophysiological Measures of Adaptation to an unfamiliar HMI in Simulated Air Traffic Control, In M.A. Hanson, E.J. Lovesey and S.A. Robertson, (eds.) *Contemporary Ergonomics 1999,* (Taylor and Francis, London) 12-16
7. Jasper, H.H., 1958, The 10-20 electrode system of the International Federation, *Electroencephalography and Clinical Neurophysiology*, 10, 371-376
8. Kramer A.F., Donchin E. and Wickens C.D. 1987, Event-Related Potentials as indices of mental workload and attentional allocation, In *Electrical and Magnetic Activity of the Central Nervous System: Research and Clinical Applications on Aerospace Medicine.* AGARD Conference Proceedings No. 432, pp 14-1 to 14-14
9. Leguillou, M., Halliez, B. and Nobel, J., 1981, *Etude du Travail du controleur Organique au CRNA/Nord Par Analyse de la saisie visuelle*, CRNA R 81/22 (DNA, Paris)

Psychophysiological Measures on Air Traffic Controllers in Simulated Air Traffic Control

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Three experimental studies were directed at the evaluation of measures of strain on Air Traffic controllers for potential use in Real Time Simulations. The first two studies evaluated a number of promising measures using a small autonomous ATC simulator, and the third introduced some of these methods to a full-scale Real Time simulation. Conclusions are drawn on the value, relevance and drawbacks of the various methods employed.

1. INTRODUCTION

The European Organisation for the Safety of Air Navigation (EUROCONTROL) is an international organisation, set up by treaty to which 28 European nations are signatories, to improve, standardise and facilitate Air Traffic Control (ATC) in Europe. The EUROCONTROL Experimental Centre, founded in 1962, evaluates ATC systems, in Europe and elsewhere, using a large-scale ATC Real Time simulator, which can simulate up to 40 working positions and several hundred aircraft. Large quantities (about 50 Megabytes) of data are recorded during each run, and analysed in considerable detail. The effects on the controllers are largely measured by the Instantaneous Self Assessment (ISA) system, (Jordan 1992) which requires the controller to press one of five buttons to record his self-assessed workload at regular intervals, by the NASA-TLX test (Hart & Stavelund, 1988) applied after the exercise, and by ad-hoc questionnaires. All of these 'subjective' measures may be thought to be biased, and the ISA in particular may be disruptive to the controllers' thought processes (David & Pledger, 1995). The amount of information derived from the most important part of the system, the controllers, is therefore very small compared to that available from the computer system.

The Experimental Centre therefore maintains a continuous survey of possible "objective" techniques for measuring the strain imposed on controllers by the practice of Air Traffic Control (David & Noonan 1983, Vanwonterghem & Rabit 1989). Recent developments in ATC (Brookings *et al*, 1996) and elsewhere (Fibiger *et al,* 1986 - hormonal responses to stress, Kramer *et al,* 1987 - Event-Related Potentials) suggested that sufficient progress had been made to justify a further study of the feasibility of measuring physiological and psychological correlates of stress in ATC. When we were contacted by the Laboratoire de l'Anthropologie Appliquee of the Universite de Paris V in 1997, it seemed a useful opportunity to re-examine electro-physiological measures, which had evolved significantly since the previous cycle of studies. It was decided to carry out initial trials using a TRACON II autonomous ATC simulator.(Wesson,1990) and to transfer selected measures to the main Real-Time Simulator subsequently.

2. EXPERIMENTAL EQUIPMENT

The TRACON II simulator is a PC-based RT simulator, displaying a simulated radar picture, with tables of strips for actual and expected traffic. Control orders were inserted via the keyboard, and a speech generator 'spoke' the controllers' orders and pilots' communications. A labelled map of the (London) TMA area employed, a table of data for the eight airports involved, and a table interpreting the keyboard orders were provided at all times. Exercises were nominally thirty minutes long, but continued until all the traffic had left the area, requiring up to 20 minutes after the last aircraft entered. The TRACON II simulator provides a summary of the controller's performance and a notional score. A similar simulator (TRACON Pro) which has voice recognition capabilities was used by David and Pledger to compare On-line Stress assessment measures and by Brookings *et al* (1996).

3. FIRST STUDY

Eight experienced, male Air Traffic Controllers carried out exercises separately. After a training and familiarisation day, the controller carried out four simulation exercises, two low and two high traffic load.

Measurements and Results

Sleep loss:

Controllers filled in sleep duration questionnaires before, during and after the experiment. They showed no significant changes in the time for which they slept, and felt less sleepy and tired on waking.

NASA-TLX

Controllers completed the NASA-TLX task after each exercise. They rated the higher loaded exercises to be more difficult. The mental demand component was rated highest for the high traffic session at the end of day one. Controllers rated their performance higher after the high load exercises, although objective performance, measured as the ratio of the TRACON score to the maximum value decreased.

Alpha Attenuation Test

The alpha attenuation test (Stampi *et al,* 1995), applied after each exercise, compares the proportion of alpha rhythm observed in the EEG when the eyes are shut with that when they are open. In principle, when a controller becomes sleepy, his alpha rhythm should decrease when his eyes are closed and increase when they are open. the ratio of alpha power eyes closed /open is the alpha attenuation coefficient (AAC). A high AAC implies high alertness and vice-versa. In this experiment, no significant effect was observed.

Subjective ratings of sleepiness and fatigue

Self-ratings of fatigue and sleepiness were carried out before and after each exercise. A clear circadian rhythm, with a marked post-lunch dip, was observable. Sleepiness and fatigue were generally closely related, although they diverged on the afternoon of the second day, where controllers felt less sleepy, but more fatigued.

EEG - Spectral Analyses

EEG was measured throughout each exercise. Theta rhythm (4-7 Hz) was high during the high traffic training session of day 1, consistent with the view that theta activity is related to learning processes. During the measured exercises, there was a shift from low frequency (Delta and Theta rhythm 1-7 Hz) to higher frequencies (Alpha and Beta rhythm 8-30 Hz) for higher workload samples, consistent with increased alertness.

ERP - Event Related Potential.

ERP (Kramer *et al*, 1987) was carried out before and after each exercise. It was also carried out during some exercises, although it was generally too intrusive and constituted a distracting secondary task for the controller. The relative amplitude of the P300 potential decreased significantly after high load exercises, suggesting a measured fatigue effect attributable to the higher workload. (P300 amplitude during the exercise decreases considerably, but the technique is not practically applicable in RT simulations.)

Cortisol

A sample of saliva was taken for cortisol analysis (Fibiger *et al*, 1986) before and after each experimental session.

Salivary cortisol normally shows a strong circadian rhythm, and did so here. Comparisons were therefore made in terms of the change in cortisol levels after an exercise compared with the level measured before. During the training day there was a significantly greater increase in cortisol for the high-load exercise than for the low-load exercise. During the measured day, no such effect was observed. The controllers, however, reported, via the NASA TLX, a higher subjective workload. This discrepancy may be attributed to the controllers, although they perceived a workload difference, being better able to cope with it.

Individual Cortisol Rates

There were significant differences between the four controllers having higher cortisol levels (HC)and the four having lower cortisol levels (LC). During the training day, the HC group performed significantly better, and tended to rate the workload higher. During the measured day, however, the HC group performed significantly better in low traffic, but showed a strong decrement in performance in high traffic. The HC group showed a marked increase in cortisol after the high workload training exercise, and after the afternoon high workload measured exercise, during which their performance deteriorated. Consideration of subjective and objective evidence of sleepiness and fatigue suggests that the HC group were more liable to fatigue than the LC group. They slept longer during and after the experiment, and felt more tired when they woke.

4. SECOND STUDY

Eight Air Traffic Controllers (four experienced male practising controllers and three male and one female trainee controllers) carried out four simulation exercises (one low, three high traffic load) during one afternoon, the morning being used for familiarisation and initial training. This experiment was particularly concerned to identify correlates of learning the unfamiliar interface.

5. RESULTS

Simulator Performance

Both groups of controllers obtained the same average performance (about 80% of the theoretical maximum) on the first (10 aircraft) simulation. On the three 20 aircraft simulations, the average overall performance of experienced controllers remained steady at about 60% of the theoretical maximum, while the average for trainees rose from 40% to 65%. The performance in terms of specific types of error showed some interesting variations. Trainees allowed more failures to maintain separation, and evoked more 'pilot requests'. (A 'pilot request' in the TRACON II system is a reminder by the system that an aircraft should have been required to perform some action, such as descending to the correct flight level for landing.) Experienced controllers maintained separation and evoked no 'pilot requests' in the fourth simulation.

Sleep log

Experienced controllers slept on average for 5H37m on the night before the experiment. (They were normally on shift-work, while trainees were not.) Trainees slept for 7H18m (1H41m more than experienced controllers), going to bed earlier.

Control Orders

Control orders were mainly headings. For both groups, the mean number of orders per aircraft in the first simulation was about 2.0, but the number of orders per aircraft in the following simulations increased for trainees from 1.2 to 1.5, while it diminished from 1.8 to 1.2 for experienced controllers. This suggests that experienced controllers adapted more rapidly than trainees.

NASA-TLX

Analysis of NASA-TLX sub-scales showed a sharp rise from the first (10 aircraft) to the second and later exercises (20 aircraft), except, as might be expected, for the (self-assessed) performance scale. The differences were less marked for beginners than for experienced controllers. It appears that experienced controllers learned the system more rapidly.

Salivary Cortisol

Although cortisol levels were generally higher in the older, experienced, group, comparisons of cortisol levels before and after exercises showed significantly greater increases (suggesting significantly greater strain) for experienced than for trainee controllers.

Electroencephalography

EEG Theta band activity increased significantly for the left hemisphere, reaching a peak at the third exercise for experienced controllers and the fourth for trainees.

Introduction to Full Scale Simulation

Selected psychophysiological and self-assessment measures were applied to a Real-Time simulation of a revised interface for adjacent Swedish and Danish Air Traffic Control (ATC) sectors (Eriksen & Harvey, 1999). (Because the Real Time simulation involved radical change in displays and operating methods, it was important to establish that the controllers had completed learning the system.)

Measures, with Significant Results

Electroencephalogram (EEG) and Electro-oculogram (EOG)

EEG and EOG were recorded on one controller per simulation session. Four different controllers were recorded in each of the two organisations. Sites corresponding to the frontal lobes (FP1, FP2) and median (Fz Pz Cz) (Jasper,1958) were employed. Data were initially recorded using a Vickers Medical Discovery system, and subsequently analysed using a DEC Microvax system to remove EOG artefacts from the EEG recordings and to perform spectral analysis for 30 second intervals,. A high level of theta rhythm was observed, dropping off only after the tenth day of simulation.

Event-Related potential (ERP)

ERP was to be measured before and after each exercise (using the 'odd-ball' paradigm (Kramer *et al*, 1987) on the controller whose EEG was measured). It was found to be too cumbersome in the RT simulation environment, and was discontinued.

Cortisol

Salivary Cortisol was measured before and after each exercise on eight controllers. No significant differences were observed, probably due to technical problems in sample transportation.

Sleep Logs

All controllers participating in the exercise filled in self-reporting sleep logs for the onset and duration of sleep, and self-assessed fatigue and sleepiness on sleeping and rising for each night of the simulation and for two weeks after the end of the simulation. (Sleep logs for the period following the simulation were returned by post. All controllers returned their logs.) - *Sleep* time rose significantly during the simulation, and fatigue at rising time decreased correspondingly. Sleep times during the two weekends spent in Paris were significantly lower than those during weekends at home after the simulation.

NASA-TLX

All controllers completed the NASA-TLX after each simulation. There was significantly more 'frustration' and lower 'self-assessed performance' with heavier workload. Performance (self-assessed) increased with time. Older controllers showed significantly higher ratings, particularly of 'physical difficulty'.

Self-rated fatigue and sleepiness

A self-rating of fatigue and sleepiness, with a four-point self-assessment of mental fatigue, physical fatigue, sensorial fatigue and mood was carried out by all controllers before and after each exercise. Fatigue was significantly higher in early morning and late afternoon sessions. Older controllers, male controllers and those with no previous experience of the system were significantly more fatigued.

Effects of Traffic Load

Although systematic traffic variations were not part of the simulation strategy, a 20% increase in traffic load, even in the early stages of the simulation, produced significant changes in fatigue, NASA-TLX, and theta-band EEG.

6. CONCLUSIONS

Carefully selected psychophysiological measures can be used to obtain useful information on specific aspects of the task of Air Traffic control. Electrophysiological measures require skilled personnel, and are subject to major individual differences, including age, experience and gender effects. Self-reporting methods are simple and easy to administer, but experience shows that it is absolutely necessary that participants should be convinced of the value of the methods. Methods should be chosen to address the specific aims of the simulation, taking into account the established relations between measures, performance characteristics and practical requirements.

REFERENCES

(EEC Reports and Notes are available on request from the EUROCONTROL Experimental Centre. Recent Reports and Notes are available at the EEC Website www.eurocontrol.fr)

1. Brookings J.B., Wilson G.F. and Swain, C.R. 1996, Psychophysiological responses to changes in workload during simulated Air Traffic Control, *Biological Psychology*, **42**, 361-377
2. Cabon, P., Mollard, R., Cointot, B., Martel, A. and Beslot, P. 1997, *Elaboration of a method for the psychophysiological states of Air Traffic Controllers in Simulation* EEC Report No. 323 (Eurocontrol Experimental Centre, Bretigny-sur-Orge, France)
3. Cabon, P., Farbos, B., Bourgeois-Bougrine, S. and Mollard, R. 1999, *Objective Evaluation of Air Traffic Controllers' Adaptation to an Unfamiliar Human-Computer Interface.* EEC Report No. 334 (Eurocontrol Experimental Centre, Bretigny-sur-Orge, France)
4. David H. and Noonan C., 1983, Potential Measures of strain on controllers, EEC Report No. 164
5. David, H. and Pledger, S. 1995, Intrusiveness of On-Line Self-assessment in ATC Simulation using Keyboard and Speech Recognition. EEC Report No. 275

6. Eriksen, P. and Harvey, A., 1999, *SweDen98 Real-Time Simulation*, EEC Report No. 335 (Eurocontrol Experimental Centre, Bretigny-sur-Orge, France).
7. Fibiger W., Evans O. and Singer G.1986, Hormonal Responses to Graded Mental Workload, *European Journal of Applied Psychology and Occupational Psychology,* Vol. 55, pp 339-43
8. Hart, S.G. and Stavelund, L.E. 1988, Development of the NASA-TLX (Task Load Index) In Hancock and Meshkati (eds.) *Human Mental Workload*, North Holland Publishing, Amsterdam
9. Jasper, H.H., 1958, The 10-20 electrode system of the International Federation, *Electroencephalography and Clinical Neurophysiology,* **10**, 371-376
10. Jordan C S, 1992, Experimental study of the effect of an instantaneous self assessment workload recorder on task performance, DRA TM (CADS) 92011 (HMSO London)
11. Kramer A.F., Donchin E. and Wickens C.D. 1987, Event-Related Potentials as indices of mental workload and attentional allocation, In *Electrical and Magnetic Activity of the Central Nervous System* AGARD Conference Proceedings No. 432, pp 14-1 to 14-14
12. Stampi, C., Stone P. and Michimori A. 1995, A new quantitative method for assessing sleepiness: the Alpha Attenuation Test , *Work and Stress*, Vol 9 (2/3), pp 368-376
13. Vanwonterghem K. and Rabit M. 1989, Activite Electrique Cerebrale et Charge Mentale chez les Controleurs du Trafic Aerien, EEC Report No. 228
14. Wesson International Inc., 1990, *The TRACON II Multi-player ATC Simulator*, (Wesson International, Dallas, Texas)

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Co-Ordination and Control in a Dynamic Environment

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A frame of reference is presented for conceptualizing work processes in complex dynamic environments. In dynamic situations, people have to co-ordinate their situation assessments, planning and decisions in order to control a situation that is changing autonomously as well as an effect of the actions. Therefore, the frame builds upon control theory and matches these concepts with co-ordination requirements. Some examples of how the frame may be applied are given from studies within a SOS co-ordination center, an underground co-ordination center as well as from a military command and control situation. It is proposed that the frame supports both researchers and designers in keeping track of important processes taking place in complex dynamic situations and thus serves a methodological purpose.

1. INTRODUCTION

The science of ergonomics has to follow the development of technology. It is apparent that this development leads to increasingly complex systems, where automated systems often aim at substituting people. It is as well obvious that people may not always be substituted. The need for people is particularly apparent when dynamic, unpredictable situations are concerned. In such situations, the tasks of the human operators mainly consist in restricting as far as possible the damage caused by deviations from the normal.

It is interesting to note that new organizations are developing to cope with the needs of controlling dynamic events. In particular, we see the nascence of so called "co-ordination centers", i.e. centers where several operators co-operate with the support of information technology to control events far outside of their own reach. The main example of such centers has for a long time been military command and control centers. Now, centers with similar functions are introduced for civil missions such as emergency management, industrial plant control as well as all kinds of traffic control: aeroplanes, trains and cars.

Dynamic situations provide a challenge for researchers and practitioners alike. It is difficult to "see the forest for all the trees" in the complexity of events and the speed of changes. Thus, there is a need for higher order frames of reference. Two frames have already been used to

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cover such situations before, i.e. one concerned with "distributed cognition" and one related to "activity theory". Both of these frames are abstract and are related to "cognition" or "activity" respectively. In Hutchin's writings, cf [1], people and artefacts are considered as a system, where information is processed. The main focus is on the functioning of the system, which is described in its processing details. The new developments of activity theory by Engeström [2] concentrate on the concept of "activity" that is different from cognition and information processing. In this concept, the idea of "mediation" is central. Subjects (usually people) work towards an object, with artefacts as mediators. Their collaboration within a community is mediated by rules and by distribution of work.

Researchers have complained that activity theory is not very useful for design purposes and that the results from studies with the perspective of distributed cognition only provide descriptive data on the situations studied. Thus, there is still a need for developing some kind of frame of reference, which can encompass the actions involved in controlling a dynamic situation where several people and artefacts participate. This paper is an attempt to offer such a frame.

2. CO-ORDINATION/CONTROL FRAME

Previous research related to the control of dynamic systems has emphasised control theory (e.g. Brehmer, 1991). For our purposes the following items of control theory will be considered: a goal to be reached, an opportunity to assess the state of the system, an opportunity to affect the state of the system and a model of the system to be controlled. In the frame of reference, three central concepts from control theory form three pillars. The pillars are related to the situation and its assessment, to goals and planning and to decision making. The frame is presented in Figure 1.

Although the items from control theory may be embedded in one single mechanism when a mechanical control system is concerned, a control system that relies on a combination of people and equipment has to distribute the control processes over the participants in an efficient and safe way. If we look at the items from the point of view of human beings, we see processes that require perception (assessing the state of the system), interpretation (a model of the system), planning (goal setting) and decision-making (affecting the system). A lot of research has already been concerned with how individual persons approach these tasks. This paper will consider how the tasks are distributed over individuals as well as how artefacts serve various tasks. In Figure 1, the central concepts of control theory are found in the middle row, corresponding to situation, goal and action respectively. The actions related to control are shown below this middle row, and concern situation assessment, planning and decision making. The actions of coordination and distribution are found above the middle row and correspond to those of the control processes.

In order to assess the state of the situation, information has to be shared between the participants. This sharing may take place with the support of information technology. In the situation there may be several competing goals, that have to be negotiated between the participants. Further, in order to take decisions leading to actions, the tasks to be performed require some distribution over the participants.

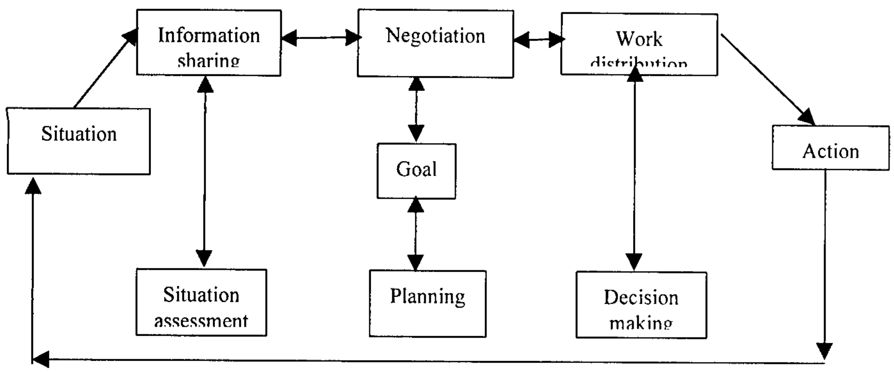

Figure 1. The coordination/control frame of reference

3. OBSERVATIONS RELATED TO THE FRAME

Three kinds of data will be related to the co-ordination/control frame. The intention is to show how complex situations may be analyzed with the help of the frame and how various approaches to solving the control problem may be compared. In this way, it will be easier to discern design trade-offs in these situations.

The data are taken from recent studies, of which only the first from the SOS-center has been reported before [3]. The other studies refer to one field study at an underground co-ordination center performed by Christer Garbis, [4] and an experiment that is currently underway and partly reported by [5]. The situations are characterized in Table 1.

Table 1.
An overview over studies illustrating the use of the coordination/control frame

Context	SOS-center	Underground control	Military command and control
Number of participants	2-4	2	4
Artefacts	Personal computers (PC), alerting signal	Public artefact, PC:s, radio	Public artefact, PC:s e-mail
Updating of artefact	Individual	Automated	Automated or manual
Organization	Parallel work	Parallel work	Hierarchic work

3.1. Situation assessment

In all settings, the artefacts offered and used are only supporting the task of situation assessment and information distribution. Of course, information technology of various kinds is important in all co-ordination centers for keeping in touch with the outer world, but information technology is also supporting the distribution of information within the centers. Let us therefore have a closer look at the observations made that refer to the use of the artefacts, the updating of the artefacts as well as the organization within the co-ordination centers.

The underground co-ordination center as well as the military command and control setting make use of a large, public display, giving some kind of map over the positions of the crucial units - trains in the underground control, troups and enemies in the military command and control context. Operators in both centers report that this display is very valuable for their work, by several reasons. One of the most important reasons is that they all can check the display and get an overall view of the events marked on the display.

The difference between the underground control setting and the military command and control concerns how the display is updated. In the underground control, the operators are not allowed to interact with the display. The display is uni-directional, providing information automatically as the trains pass sensor points. In the military setting - a micro-world experiment - we tried two different ways of updating the display. One was external, where the commanders at the field directly updated the positions on the common display in the command-and control room. Another was interactional, where the signal officer in the command-and-control room updated the display after interaction (via e-mail) with the commanders at the field. It might be believed that it would be more efficient to get the display updated automatically. This turned out not to be the case. Instead it seemed as though the automated updating made the command-and-control officers overconfident - during three trials their performance first increased and then decreased [5].

In the underground control, there was very little integration between the individual computer displays and the public screen. Changes made by the operators were not visible at the public screen. Therefore, they have to keep each other updated on exchanges of trains, as well as on changes in the routings of trains. In the observations and interviews it was observed that the value of the public display was much less during the night, where the trains did not run according to the timetable. Since the operators routed trains depending on other circumstances, and could not update the public display, it was much more difficult to keep track of the actions during the night, although there was much less action than during the day.

These observations indicate that it is not enough to observe the existence and nature of a public display. Instead, the updating of the display has to be considered. There seems to be a trade-off between external and internal updating of a public display. When it is important that participants have a common view of what is happening, it seems that they have to update it themselves. In this way, they attend to the changing events and may interpret as well as predict the development better than when a change just happens. A study by Artman [6] indicates that it is beneficial for a good joint assessment of the situation that participants negotiate a situation assessment together instead of working in parallel.

Such observations might be useful for the design of future co-ordination centers, for instance for the SOS service. The SOS center studied had not yet got any public display, but the operators expressed a desire to get an overview at least of where the emergency services were positioned. This would facilitate their finding suitable equipment that was both close to the accident and available. However, it is easily seen that somebody has to care for the need of ambulances and fire-trucks to keep track of one another as well. Thus, an automated updating of their positions that is only available to the co-ordination centers would not serve the needs of the emergency services.

Another aspect of a public device is the alerting signal used at the SOS-center. This signal is used when one operator needs support from another operator. Since the operators usually are busy with different incidents and accidents, they have to have some device to catch the attention of one another when something really important is at stake. Similar devices do not exist in the underground control or in the military command and control rooms. In the underground control settings, the operators call each other's attention by talking. In the military command-and control setting, the hierarchical organization requires that sub-ordinates attend to super-ordinates and vice versa. Thus, it may be concluded that the artefacts cannot be considered separately from the situation and organization.

3.2. Goal setting and planning

As to goal setting and negotiation of planning, there is no technology supporting these tasks in our studies. It might of course be possible to negotiate plans and test them via some kind of computer support, however time most often is too short to elaborate upon many alternatives. In a previous study related to military command and control, it seems as though operators perform less planning during periods of time stress than in periods where not much is happening. [7]. There may thus be a place for some support during less stressed periods.

3.3. Decision-making

Decision-making is a task for which support has been considered, since normative decision models are available. However, it has been proposed that normative decision making models are not very useful in most natural situations [8]. The proposal is instead that decision-makers rely upon prior knowledge of similar decisions. A 'recognition primed decision making' model is far more relevant to natural decision making. In a situation where several people participate in decision making it is obvious that a recognition primed decision is not favourable to co-ordination. People mostly have different prior knowledge and experience and it cannot be expected that they arrive at the same decisions. Most dynamic situations also rely upon a single decision-maker, particularly in the military, in fire fighting or in large emergencies.

Thus, it does not seem as though decision making had to be co-ordinated. However, decisions are made on several levels, which is also accommodated in dynamic decision making. Some decisions are far reaching, both in time and place, others have to be made for the moment and at the spot. A distribution of decisions thus takes place with respect to the time and geographical span [9]. It is also obvious that when people are geographically distributed, they have to take decisions that relate to their own immediate environment. Here it is important that people on a "lower level" tell the decision layers above them about both their intentions and their actions. In our study of military decision-makers, we observed that the participants discussed their communication between the sessions, particularly with respect to what to tell each other. We also observed that command and control team that performed well learned to leave the detailed decisions to the lower level commanders rather than making these decisions themselves [5]. This observation indicates that a possible decision support should take the level of decision into consideration.

4. CONCLUSIONS

We have used the frame in three studies and found that it helps us cover the complexities of the situations as well as compare the situations. It may give us some ideas about how to design organizations and artefacts to meet the challenges of dynamic situations. We find this frame more useful than the frames of "distributed cognition" or activity theory, presented above. In particular, the co-ordination/control frame covers the tasks that are crucial in the dynamic situations considered and matches these by co-ordination activities.

In these studies, the co-ordination centers have only had a couple of operators. This is one of the main ideas of a co-ordination center: that a few individuals should be able to control a large field of events and people "out there". There exist co-ordination centers with many more people. The present studies suggest that the artefacts and organization will have to be fitted to their particular requirements.

The frame has enabled us to combine various aspects of the control activity, i.e. see how activities are distributed over participants in various control settings and how various artefacts support the activities. We propose that these factors should be attended to in the design and evaluation of control centers.

REFERENCES

1. Hutchins, E., Cognition in the Wild. (1995). Cambridge, Mass.: MIT press.
2. Engeström, Y. and D. Middleton, eds. Cognition and Communication at Work. (1996). Cambridge University Press: Cambridge.
3. Artman, H. and Y. Waern, Creation and Loss of Cognitive Empathy., in Co-operative process management - Cognition and Information Technology, Y. Waern, Editor. (1998). Taylor & Francis: London. pp. 69-76.
4. Garbis, C. Communication and Coordination through Public and Private Representations in Control Rooms. In Proceedings from Human Factors in Computing Systems, pp. 67-68. (2000) The Hague: ACM Press.
5. Johansson, B., R. Granlund, and Y. Waern. The communicative aspects of distributed dynamic decision making in the ROLF environment. Presented at the conference on Naturalistic Decision Making (2000). Stockholm.
6. Artman, H., Team Situation Awareness and Information Distribution. Ergonomics, in press.
7. Waern, Y. and B. Johansson. Understanding communication in a dynamic situation- Argumentation in situation assessment and planning. Presented at the conference COOP 2000. (2000). Sophia Antipolis.
8. Zsambok, C.E. and G. Klein, eds. Naturalistic decision making. (1997). Erlbaum: Mahwah, NJ.
9. Brehmer, B., Modern Information Technology: Timescales and Distributed Decision Making., in Distributed decision making. Cognitive models for cooperative work, J. Rasmussen, B. Brehmer, and J. Leplat, Editors. (1991). Wiley: Chichester. pp. 193-200.

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Training of Leaders for International Relief Operations - Identifying the Effects of the Environment, Task Types and Cognitive Activities

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This paper reports on field research done at training facilities, which prepares team leaders for international humanitarian relief missions. 40 international relief operation leaders and veterans participated in providing information about the characteristics and demands of the environment and tasks. Questionnaires were presented to obtain information on relief operation environments, and the tasks performed. These were followed up with in-depth interviews in regards to opinions and experiences out in the field. In addition, observation methods were utilized during simulation exercises. Elements in the milieu that affects performance are categorized and the common tasks performed in the field are described. In addition, critical cognitive information processing activities of the relief leaders are presented and finally implications for training are discussed.

1. INTRODUCTION

Natural and war disasters occur in all regions of the world. These disasters have increased in the past few decades and various organizations and nations are involved in providing relief to those countries in need. Relief teams are sent to assist in giving aid with protection, food, shelter, etc. (1). These teams in many instances consist of members who have not worked and performed together in the past and who come together for the sole purpose of accomplishing a mission of relief.

In most scenarios, they find themselves placed in an environment that is unfamiliar, dynamic, event-driven, and multicultural in terms of organizations and people. The prevalence of these conditions in the environment described has incited a growing research interest in the characteristics and factors that contribute towards the leadership, performance and training (2).

The specific knowledge and skills and properties in order to yield optimal mission performance in such complex situations are not easily identified, and hence they are difficult to assess and improve. The primary limitations in identifying the types of competence training needed are the lack of conceptual grounding in the defining characteristics of the context in which the international relief leader functions (2). In order to recognize training needs for competence acquisition and application, it is crucial to identify the attributes of the environment and the demands placed on the leader.

This paper reports on field research done at training facilities, which prepares team leaders for international humanitarian relief missions. 40 international relief operation leaders and veterans participated in providing information about the characteristics and demands of the environment and tasks. Questionnaires were presented to obtain information on background, the types of missions participated, the relief operation environment, and the tasks performed. These questionnaires were followed up with in-depth interviews in regards to opinions and experiences out in the field. In addition, observation methods were utilized during simulation exercises.

Elements in the milieu that affects performance are categorized and the common tasks performed in the field are described. In addition, critical cognitive information processing activities of the relief leaders are presented and finally implications for training are discussed.

2. ENVIRONMENT, ORGANIZATION, AND THE INDIVIDUAL

Team leaders are expected to be highly focused on their competencies while on the field and must be oriented to demonstrate performance and capability to achieve goals within the formal requirements dictated by the organization (3). From a socialization point of view, individuals must first assimilate to the existing working environment. Table 1 depicts performance-affecting factors as described by relief leaders.

Table 1. Performance Affecting Factors in the Relief Environment

Physical Environment		
Characteristic	***Description***	
Mother Nature	Weather, geographical location	
Culture	History, way of life, language, etc.	
Working Conditions	Lodging, equipment, vehicles, etc	
Organization		
Characteristic	***Description***	
Purpose	Mission goal and function	
Working Culture	Ethics, law, morals, values	
Other Organizations	Coordinating activities	
Support	Type of encouragement and information given in context of carrying out tasks	
Training	Type, content, and method of training	
Individual		
Category	***Characteristic***	***Description***
Physiological	Food	Nutritional intake
	Illness	Disease and fatigue
Cognitive	Workload	Amount of work
	Time Pressure	Amount of time to carry out task or receive information
	Uncertainty	Ambiguous information
Psychological	Traumatic stimuli	Sights, sounds, and smells associated with disaster
	Security	Threat to person, body, and/or belonging
	Anxiety	Separation from family and friends

Different researchers have adapted this classification scheme for their particular industry of interest. Kontogiannis (4) used it in the classification of stresses in emergencies and Mumaw (5) utilized in the classification scheme of nuclear plant activities. The world that the relief leader performs in is complex. Woods (6), explains that a world is highly complex when an environment is dynamic, has highly interconnected parts, is filled with high uncertainty and when possible outcomes can have large costs.

Data from Table 1 indicates that the activities and actions in relief operations can occur in context of stress effects, uncertain evidence, ambiguous information, time pressure and delays, high physical and mental workload, goal conflicts, and a highly event-driven and chaotic environment.

3. PERFORMANCE TASKS

In order to continue the process of competence identification, it is also crucial to have knowledge of the kinds of tasks that the relief operator performs out on the field. The analysis allows us to understand the various responsibilities of the relief leader. The fundamental idea of task identification is to determine the composition of the kind of cognitive elements in the respective tasks (7).

In Table 2, we have categorized the common performance tasks of a relief leader that are prevalent in relief operations.

Table 2.
Common Performance Tasks

Task	Description
Communication	Sharing information in order to gain or give knowledge.
Conflict Resolution	Mediating behavior in situation that calls proper perception and understanding of environment and people.
Coordination	Having knowledge of existing organizations, their functions and bringing together the various factors and actors into joint action.
Decision Making	Selecting one of the number of options of actions when presented with the situation.
Negotiation	Communicating needs and requirements, conceiving new ideas and situations.
Situation Awareness	Facilitating the functioning of the team through providing accurate mental models of situation.
Risk Management	Assessing situation, determining threats to person, body, and belonging in terms of safety and security.
Resource Management	Managing resources available in terms of abilities, time, space, equipment, etc.
Stress Management	Establishing priorities, adapting behavior and actions to situation.
Team Management	Providing leadership efficiently and practically while fulfilling mission./

4. COGNITIVE DEMANDS

Relief leaders perform activities, which require them to utilize cognitive skills. In order to indicate the method of performing a task, a cognitive demands profile is utilized to illustrate the specific demands to cognition that are associated with a task segments or task steps of the relief leader. The modeling of cognition in Table 3 attempts to reproduce key phenomena of the task in practical terms . The current version of the list generally follows the Human Factors critical cognitive activities as similarly used by Hollnagel (8), Rasmussen (9), Rouse (10), and the Human Action Classification Scheme by Barriere et. al. (11).

Table 3
List of Critical Cognitive Activities

Activity	Description
Communication	Pass on or receive person to person, organization to organization information needed for operation by either verbal or electronic means.
Coordinate	Allocate or select resources in preparation for a task or job.
Decide	Make a decision on the situation at hand.
Diagnose	Recognize or determine the nature or cause of a condition by means of reasoning about signs or symptoms.
Evaluate	Appraise or assess an actual or hypothetical situation based on available information without requiring special actions.
Identify	Establish the state of the environment. This may involve specific actions to retrieve information and investigate details.
Monitor	Follow the development of a situation over time.
Plan	Formulate or organize a set of actions by which a goal will be successfully achieved. Plans maybe short or long term.
Record	Write or log down events.
Regulate	Adjust actions in order to achieve goal.
Resolve	Bring the team/s into the specific relation required to carry out the task or task step.
Scan	Quick review of situation state to obtain a general idea of situation.
Verify	Confirm the correctness of situation by certain actions and feedback from other operations.

5. DISCUSSION AND CONCLUSION

This paper attempts to provide a mental model of the performance environment and an understanding of the tasks a relief leader undertakes. There are two points to be made in regards to competence training being hierarchically organized as presented here in this paper. First, cognitive and/or physical activities described in Table 3 are gradually learned and assembled into tasks as described in Table 2. Second, the tasks in Table 2 are performed in context of the working environment listed in Table1.

This concept gives important implications for training. When one is acquiring knowledge and skills it is useful to identify what goals, sub-goals, and so on the relief leader should master since this will begin to delimit how such goals are achieved, which is fundamental to the development of training content (12). Training is a function of the extent to which it prepares relief leaders for the physical, cognitive and psychological demand that could emerge in the field. Training through careful analysis allows for the understanding of implicit knowledge (acquisition) as well as explicit knowledge (application). This also implies different learning objectives, processes, and performance specifications. One aim is to integrate the cognitive psychology with those of occupational /industrial psychology, human factors and ergonomics. The former contributes important notions concerning the acquisition, transfer and retention of skill and expertise whereas the latter provides many well established techniques for task analysis and evaluation.

Competence training is essential to attaining efficient leadership and performance. For dynamic worlds such the one described here, competence becomes the ability to adapt routines in the face of changing circumstances in the pursuit of a mission goal. Competence in this context includes having inert knowledge (acquisition), and exert knowledge (application). It also involves having practical and theoretical knowledge, cognitive, physical and social skills.

Currently, a large portion of the training concentrates on providing general information of the environment instead of actual knowledge and skills required to perform efficiently (13). This type of training does not provide for the congruent management and practices of teams which are made up of differing backgrounds. Competence training policies and methods need to be congruent with the dynamics and complexities, which exist in the environment, and the tasks. Attaining an accurate mental model of the context in which the leader performs in will allow us to define the level of knowledge and skill needed in executing a task (2).

From existing research we understand that training for disaster relief is a dynamic process requiring evaluation and adaptation (14). Adequate training cannot be provided without the identification of the characteristics of the environment, task type, and cognitive activities.

The data analysis, interviews, and simulation assessments that are presented in this paper could assist in the review and development of competence training that reflect theory, research, and practice. The hope is that the information provided here will assist researchers and trainers in understanding the functional context in which the relief leader operates.

The task for the researcher who is attempting to discover the context of functioning of a relief leader does not end here. There is much work to be done in the area of analyzing the level of competence needed. Further analysis of the tasks and the interaction of environmental, organizational, and individual factors needs to be performed. Also, questions relating to training objectives, methods to achieve those goals, the medium for training, and the assessment of the achievement of those objectives and goals are challenges that need to be undertaken. During all these undertakings, it is essential for the researchers and trainers to keep in mind that knowledge acquisition and application are two different aspects of competence training.

REFERENCES

1. D.A, McIntire. Issues in Disaster Relief: Progress, Perpetual Problem, and Prospective Solutions, Disaster Prevention and Management, Vol. 8 (1999),351-361.
2. S.W.J. Kowlowski, S.M. Gully, P.P. McHugh, E. Salas, J.A. Cannon-Bowers. A

Dynamic Theory of Leadership and Team Effectiveness: Development and Task Contingent Leader Roles, Research in Personnel and Human Resources Management, Vol.14 (1996), 253-305.

3. C. Ostroff & S.W.J. Kowlowski. Organizational Socialization as a Learning Process: The Role of Information Acquisition, Personnel Psychology, Vol45 (1992), 849-874.
4. T. Kontogiannis. Training Effective Human Performance in the Management of Stressful Emergencies. Cognitive, Technology, and Work, Vol. 1 (1999), 7-24.
5. R.J. Mumaw. The Effects of Stress on Nuclear Power Plant, Operational Decision Making, and Training Approaches to Reduce Stress Effects. 1994, NUREG/CR-6127. Nuclear Regulatory Commission, Washington, DC.
6. D.W. Woods. Coping with Complexity: The Psychology of Human Behavior in Complex Systems, 128-148, in L.P. Goodstein, H.B. Andersen, & S.E. Olsen (eds.), Tasks, Errors, and Mental Models, Taylor & Francis, London, 1988.
7. H. Luczak. Task Analysis, 340-416, in G. Salvendy (ed.), The Handbook of Human Factors and Ergonomics, 2nd Edition, John Wiley and Sons, New York.
8. E. Hollnagel. Cognitive Reliability and Error Analysis Method, Elsevier, 1998.
9. J. Rasmussen. Information Processing and Human Machine Interaction: An Approach to Cognitive Engineering, Amsterdam, North Holland, 1986.
10. W.B. Rouse. Human Computer Interaction in the Control of Dynamic Systems. ACM Computing Survey, Vol.13(1981), 71-79.
11. M. Barriere, W. Luckas, D. Whitehead & A. Ramey Smith. An Analysis of Operational Experience During Low Power and Shutdown and a Plan for Addressing Human Reliability Issues. 1994, NUREG/CR-6093, Nuclear Regulatory Commission, Washington, DC.
12. J.R. Anderson. Skill Acquisition: Compilation of Weak-Method Problem Solutions, Psychological Review, Vol. 94, 192-210.
13. R.T Sylves & W.L. Waugh Jr. Disaster Management in the U.S. and Canada: The Politics, Policymaking, Administration and Analysis of Emergency Management, 2nd Edition, Charles C. Thomas Publisher, Ltd., Springfield, Illinois, 1990.
14. Interviews conducted with Swedish Rescue Services Agency Mission Leaders. Winter, 1999/2000.

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Perception of Colors and Graphics in Process Control Workstations

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At Honeywell, an initiative has been embarked to enhance our Asia Pacific market share by understanding the needs and requirements of our product users in this region. In this study, thirty Chemical Engineering students from Temasek Polytechnic in Singapore were recruited to answer a computerized questionnaire regarding their perceptions of the colors, shapes, graphics and orientations used in Honeywell's Distributed Control System (DCS) products. The results showed that the color was not an effective feature for people to identify the equipment conditions. Compared to other common colors, the White was associated with the lowest hazard level. A circle and a square were associated with the normal condition, whereas a triangle was popular for representing the alarm or the caution condition. For the layout orientation, the majority of sequence patterns were more significant in the Line layouts than the layouts of Diamond and Square. Further research is necessary in the Asia Pacific region to extend the knowledge of user stereotypes and preferences about colors and graphics.

1. INTRODUCTION

Honeywell has been working in China and Southeast Asia to investigate user interface designs related to individual characteristics and cultures [4, 5]. One of these issues is regarding the use of color and graphic in user interfaces. Although colors and graphical symbols are essential components of user interfaces, related research focused on the Asia Pacific region is limited. The primary objective of this study was to evaluate the perceptions of colors, shapes, graphical symbols and layout orientations used in Honeywell's Distributed Control System (DCS) products in Asia Pacific market. This is one of Honeywell research projects toward better aligning our use of color and graphic with local preferences as well as improving the general usability of our process control workstation displays.

2. METHODOLOGY

This survey was designed in the form of computerized questionnaire. Thirty Temasek Polytechnic students majoring in Chemical Engineering were recruited as subjects.

Participation was voluntary and a gift was given to each subject for his/her participation in the study. The survey was conducted at the Usability Laboratory of Temasek Polytechnic. Subjects answered all the questions on the computer screen by clicking a mouse. In this questionnaire, some graphical symbols representing industrial equipment (e.g., valves, tanks, pumps, etc.) were displayed individually for participants to identify. The participants' perception of graphics in relation to the different conditions of certain industrial equipments was also tested. The questionnaire has also included ratings of associations between temperature and colors as well as safety levels and colors. Subjects were also asked for recognizing some symbols in a series of process schematic contents and associating a shape to a given process control term. Lastly, the layout orientation was tested where the participants were asked to click on the boxes with different layouts in their desired sequence. The completion time of the questionnaire was about 20 minutes for each participant.

A database structure was used to store texts in each question. This design enhanced the readiness of the questionnaire development for other languages such as Chinese, Japanese, Korean, Malay, Indonesian or Thai. By the time of writing this paper, a Chinese version of this questionnaire has been developed for the further survey in China.

3. RESULTS AND DISCUSSIONS

Demographics

Among the thirty subjects, eighteen were male and twelve were female. Twenty-three were in their second year of school (14 males and 9 females) whereas seven were in their first year (4 males and 3 females). The range of experience with computers was between 1.5 years to 10 years with the median at 5 years. All the subjects were between 17 to 22 years old with the median at 19 years old.

Color Association

The participants used a Likert scale from 1 to 5 to indicate how various colors showed temperature and hazard level. Based on the previous research [1, 3, 4], nine colors chosen for this test were Red, Orange, Yellow, Green, Blue, Purple, Grey, White and Black. The results from the Wilcoxon Rank Sum tests are shown in Figure 1.

← Higher Temperature Lower →

Red Orange Yellow Purple Black Green Grey White Blue

← Higher Hazard Level Lower →

Red Orange Grey Yellow Black Purple Blue Green White

An underline indicates that the means are not significantly different at $p < 0.05$

Figure 1. Color Associations with Temperature and Hazard Level

Generally, the color association with the temperature was similar to the one with the hazard level. The color associating the highest temperature and the highest hazard level were the same, e.g., the Red. From the results, the White represented the lowest temperature as well as the lowest hazard level.

For the hazard level, the association between the Red and the highest level is consistent with the results in previous research [1, 3, 4]. However, for the lowest level, the distinction between the White and other colors differs from the previous findings.

Shape Association

Based on the shapes used in Honeywell's DCS products, twelve shapes (Circle, Oval, Square, Rounded Square, Rectangle, Rounded Rectangle, Triangle, Diamond, Octagon, Plaque, Trapezoid and Star) were used to test subject's perception on the four general terms of industrial process control (Normal, Caution, Stop and Alarm). For each process control term, subjects were asked to select one shape that they thought was the best for associating with the term. The results are presented in Table 1. Note that only the shapes with the majority of percentages are listed in the table.

Table 1.
Percentage of Shape Association with Process Control Terms

	Normal	Alarm	Stop	Caution
Octagon	10%	7%	**47%**	10%
Square	**37%**	0%	7%	3%
Circle	**37%**	0%	10%	0%
Triangle	0%	**50%**	**17%**	**40%**
Star	0%	**33%**	3%	7%
Diamond	3%	0%	10%	**17%**
Others	13%	10%	6%	23%

Note: The percentages in bold indicate the first two highest percentages for each term

The results showed that the Square and the Circle were the two popular shapes to represent the Normal condition while the Octagon and the Triangle were the choices to represent the Stop. The Caution was highly associated with the Triangle and the Diamond, whereas the Alarm was strongly linked with the Triangle and the Star. Generally, the results were consistent with the psychological responses of these shapes [2].

Graphic

Figure 2 illustrating an operating blower was used for the tests of object identification and condition recognition. Four graphic features (Shape and Appearance, Color, Dash Lines and Circular Part) of the blower were listed. Subjects were asked to rank how important of these features to help them identify the blower and its condition. The results from the Wilcoxon Rank Sum test are presented in Figure 3.

Compared to other features, the Dash Lines feature was not the major factor for subjects to identify the symbol as a blower. However, the Circular Part and the Dash Lines features were more important than the Shape & Appearance and the Color when subjects tried to recognize the blower's operation conditions. The results indicated that the graphic features representing the movement were more critical than those representing more static features for recognizing the equipment conditions.

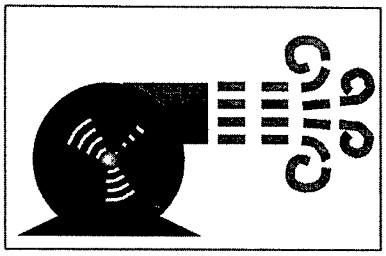

Figure 2. An Operating Blower

← More important Object Identification Less Important →

[Shape & Appearance] [Color] [Circular Part] [Dash Lines]

← More important Condition Recognition Less Important →

[Circular Part] [Dash Lines] [Shape & Appearance] [Color]

An underline indicates that the means are not significantly different at $p < 0.05$

Figure 3. Importance Ranking of Graphic Features on Object Identification and Condition Recognition

Layout Orientation

Four different layouts composed of four identical boxes were used to test subject's orientation perception. Subjects were asked to click on the boxes in a sequence they desired. These four layouts were Diamond, Vertical Line, Horizontal Line and Square.

For the Diamond layout, the majority of the subjects clicked the boxes in the direction of clockwise starting from the top (46%). The second popular sequence was from top to bottom then from left to right (17%).

For the Vertical Line layout, the dominant sequence was from top to bottom (83%) followed by the sequence from bottom to top (10%).

For the Horizontal Line layout, the most popular sequence was from left to right (80%). Other selected sequences were at the same preference level (3%).

Finally, for the Square layout, the major sequence was from left to right starting from the top two boxes then the bottom boxes (40%). The second popular sequence was the counterclockwise starting from the top left box (17%).

Compared to the Diamond and Square layouts, the higher percentages of selected sequences for the layouts of Vertical Line and Horizontal Line indicated that subjects had more agreement on the Line layouts than they did on either the Diamond or the Square layout.

4. CONCLUSION

This survey reveals some of the information about people's perception of colors, shapes, graphics and layout orientations. The color association between the white and the lowest hazard level is unique from the findings of previous research. However, compared to other graphic features, color is not an effective factor for representing the equipment conditions. Therefore, the possibility of virtually eliminating the use of color for this purpose should be considered. For the use of shapes, a circle or a square can be used for representing a normal condition while a triangle is suitable for an alarm or a caution condition. The strong association between an octagon and the stop condition might be due to the use of the octagon shape as the stop sign in Singapore. Finally, the orientation stereotypes will contribute our understanding of how to arrange important blocks of information on a screen for maximal effectiveness.

To determine how we should be using colors or graphics in our displays, further research is necessary to assess the color and graphic stereotypes and preferences in various regions of Asia Pacific.

REFERENCES

1. Courtney, A. J. (1996). Chinese population stereotypes: Color associations. *Human Factors*, 28(1), 97-99.
2. Holzschlag, M. E. (1999). Satisfying customers with color, shape, and type. *Web Techniques*, November, 4, 11, 24-29.
3. Luximon, A., Lau, W. C. and Goonetilleke, R. S. (1998). Safety signal words and color codes: The perception of implied hazard by Chinese people. *Proceedings of the 6th Pan-Pacific Conference on Occupational Ergonomics*, 30-33.
4. Plocher, T. A. (1999). Use of colors, symbols, and icons in Honeywell process control workstations in China. *Honeywell Internal Report*.
5. Plocher, T. A., Garg, C. and Chestnut J. (1999). Connecting culture, user characteristics and user interface design. *Proceedings of the 8th International Conference on Human-Computer Interaction*, 1, 803-807.

PART FOUR

Physical Ergonomics

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Anthropometric Design as a Mapping between Functional and Physical Domains

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Formulations of functional requirements and design parameters are helpful in conceptualizing design principles and selecting design parameters for anthropometric design. Uncoupled design solutions are preferred since they simplify the adjustability of workplaces. Two examples are given – design of car interiors and microscope workplaces.

1. INTRODUCTION

This mapping between functional requirements (FRs) and design parameters (DPs) may be represented by a design equation:

$$\{\boldsymbol{FR}\} = [A]\ \{\boldsymbol{DP}\} \qquad (1)$$

Where $\{\boldsymbol{FR}\}$ is a column vector that contains all the FRs of the design,
$\{\boldsymbol{DP}\}$ is a column vector that contains all the DPs of the design, and
$[A]$ is the "design matrix" that defines the relationships between FRs and DPs.

With an equal number (n) of FRs and DPs, $[A]$ is a square matrix of size n x n, which measures the effect of DP_j on FR_i. If the DP influences the FR, this element is non-zero. Otherwise it is zero. A design solution is uncoupled for a design matrix $[A]$ having all non-zero elements on its diagonal, indicating that the FRs are completely independent. However, complete uncoupling may not be easy to accomplish in a complex real world, where interactions of factors are common. Designs where FRs are satisfied by more than one DP are acceptable, as long as the design matrix $[A]$ is triangular, that is, the non-zero elements occur in a triangular pattern either about or below the diagonal. This is called a decoupled design. A decoupled design still satisfies the independence axiom, provided that the DPs are specified in a sequence such that each FR is ultimately controlled by one unique DP. Any other formation of the design matrix that cannot be transformed into triangular one represents a coupled design, indicating the dependence of the FRs. Therefore, the design may be unacceptable, as we will claim below.

2. ERGONOMICS DESIGN

In anthropometry, human body dimensions are used to design artifacts. The general principle is that the artifact must fit the size of the human body. But users vary in size.

Percentiles of body measures are commonly used to represent variability - from 5^{th} percentile small size to 95^{th} percentile large size. Several different body measures are used for design including stature, sitting eye height, forward reach, lower leg length, and so forth. These measures are listed in anthropometric tables for various populations.

2.1 Design of adjustability in a driver's compartment

To design a driver's compartment reach distances are usually dimensioned for 5^{th} percentile small user (large persons can overreach) and clearance dimensions for 95^{th} percentiles large users (small persons can always fit). There is a choice between a. *Seat adjustments* that puts the driver's seat in an advantageous position and b. *Car adjustments* that make the car adjust to the person. An example of the latter is a steering wheel that can be pulled out or pushed in. The top-level FR 1 and FR 2 and the corresponding DP 1 and DP 2 are given in Table 1.

Table 1. FRs and DPs for design of a driver's compartment. First iteration.

FR 1	Easy to Manipulate Controls	DP 1	Controls within Easy Reach
FR 2	Comfortable Sitting	DP 2	Ergonomics Design
FR 11	Reach Dashboard Controls	DP 11	Dashboard Close
FR 12	Reach Pedals	DP 12	Long/Short Pedals
FR 21	Clear Steering Wheel	DP 21	Push/Pull Steering Wheel
FR 22	Reach Floor (with feet)	DP 22	Up/Down Seat Height
FR 23	Clear Roof	DP 23	Up/Down Roof
FR 24	Comfortable Sitting	DP 24	Adjustable Backrest Angle

The top level FRs and DPs are then decomposed and their constraining influences are used to derive FRs and DPs at a lower level of abstraction: Given the top goal FR 1 - to make it easy to manipulate controls and given that we have decided to put controls within easy reach (DP 1), we proceed to formulate FR11 and FR12 at a lower level of abstraction and select DP 11 and DP 12, see Table 1. We may then derive the design equation as follows:

$$\begin{vmatrix} FR_{11} \\ FR_{12} \\ FR_{21} \\ FR_{22} \\ FR_{23} \\ FR_{24} \end{vmatrix} = \begin{vmatrix} A_{111} & 0 & A_{113} & 0 & 0 & 0 \\ 0 & A_{122} & 0 & 0 & 0 & A_{126} \\ 0 & 0 & A_{212} & 0 & 0 & A_{216} \\ 0 & 0 & 0 & A_{224} & 0 & 0 \\ 0 & 0 & 0 & A_{234} & A_{235} & 0 \\ 0 & 0 & 0 & 0 & 0 & A_{246} \end{vmatrix} \begin{vmatrix} DP_{11} \\ DP_{12} \\ DP_{21} \\ DP_{22} \\ DP_{23} \\ DP_{24} \end{vmatrix}$$

This is a de-coupled design, and therefore acceptable. For the operator, it is however difficult to learn to operate the different adjustabilities in a specific order (see also example 2 below). In this case DP 22 and DP 24 must be dealt with first, followed by the other adjustments. Assume a driver will first adjust the Backrest Angle (DP24) considering Comfort. He can then set the chair height (DP22) to reach the floor and then push the steering wheel back to accommodate his large stomach. He can then consider either of DP 12, DP 21 and DP 23. DP 12 satisfies the reach requirements to the pedals. DP 21 is to fit a large stomach between the steering wheel and DP 23 is to clear the roof. Finally the driver can set DP11, the distance to the dashboard.

The design matrix represents a simplified representation of user requirements. FR 24 - Comfortable Sitting, is assumed to be accomplished by a single design parameter, DP 24 – Adjustable Backrest Angle. From a biomechanics perspective this is indeed the most important variable, since a large hip joint angle has reduces the compressive force in the spine (Helander, 1995). We could also have considered additional design parameters, such as Adjustable Length Seat Pan. Fifth percentile users need a short Seat Pan to reach to the backrest with their back, whereas 95th percentile users need a long Seat Pan to support their thighs. An Adjustable Seat Pan would also affect some of the other FRs. Although this design solution was not explored here, it would be worthwhile to consider this and other design parameters.

One might argue that The Adjustable Roof and the adjustable Length Pedals are unconventional design solutions, and for the next exploration a more conventional design was chosen: High Roof and Adjustable Seat Forward/Backward. The following solution is obtained (see Table 2).

Table 2. FRs and DPs for design of a driver's compartment. Second Iteration.

FR1	Handle Controls	DP 1	Controls within Reach
FR 2	Comfortable Sitting	DP2	Ergonomics Design
FR 11	Reach Dashboard Controls	DP 11	Dashboard Close
FR 12	Reach Pedals	DP 12	Forward/Backward Seat
FR 21	Clear Steering Wheel	DP 21	Push/Pull Steering Wheel
FR 22	Reach Floor (with feet)	DP 22	Up/Down Seat Height
FR 23	Clear Roof	DP 23	High Roof
FR 24	Comfortable Sitting	DP 24	Adjustable Backrest Angle

$$\begin{vmatrix} FR_{11} \\ FR_{12} \\ FR_{21} \\ FR_{22} \\ FR_{23} \\ FR_{24} \end{vmatrix} = \begin{vmatrix} A_{111} & 0 & A_{113} & A_{114} & 0 & 0 \\ A_{121} & A_{122} & A_{123} & 0 & 0 & A_{126} \\ A_{211} & 0 & A_{213} & 0 & 0 & A_{216} \\ 0 & 0 & 0 & A_{224} & 0 & 0 \\ 0 & 0 & 0 & A_{234} & A_{235} & 0 \\ 0 & 0 & 0 & 0 & 0 & A_{246} \end{vmatrix} \begin{vmatrix} DP_{11} \\ DP_{12} \\ DP_{21} \\ DP_{22} \\ DP_{23} \\ DP_{24} \end{vmatrix}$$

This is a coupled design, and it is therefore not a satisfactory solution. The driver can first set DP 22 and DP 24, which are independent. DP 23 is then feasible to adjust. However, DP 11, DP 12 and DEP 21 are coupled, which makes it difficult to make the adjustments so as to reach the floor, reach the dashboard and clear the steering wheel. Obviously the previous design solution: Long/Short Pedals produced a more satisfactory design than Forward/Backward Seat. The latter design, although it is the conventional design found in all cars, creates unwanted couplings, which may be difficult to deal with for the user.

To summarize, this exercise demonstrates the use of AD for anthropometric design. The design matrix provides a conceptualization of dependencies in design that we would otherwise not have been able to consider. Guided by the results of this example we may suggest an uncoupled design, but it is unconventional: Dashboard controls on steering wheel (DP 11), Adjustable length pedals (DP 12), Push/pull steering wheel (DP 21), Height adjustable floor (DP 22), High Roof (DP 23) and Adjustable backrest angle (DP 24). Note that in this design the Car adjustments are used, and not seat adjustments.

2.2 Anthropometric design of microscope workstation.

Microscope work is generally taxing, since the operators have to assume a very static work posture – the eyes must constantly be positioned at the eyepiece and the hands on the focus controls. At IBM Corporation in San Jose, there were about 1000 microscope operators, most of who were Asian females (Helander, Grossmith, and Prabhu [3]). They were much smaller than the regular USA population. As a result many of them could not accommodate to the oversize work place. The seat pan of the chair was too long so that they could not use the backrest. The seat was too high so that their feet could not reach the floor. The eyepieces were too high so that the operators had difficulties looking through them and seeing the magnified items.

To understand the underlying design problem an anthropometric survey was conducted. Fifteen different body measures were recorded for 400 operators and 5th percentile (5 % smallest), 50th percentile (average) and 95th percentile (5 percent largest) were calculated.

In our report we recommended a conventional design solution using a height adjustable chair, a height adjustable table and a height adjustable microscope (Helander, Grossmith, and Prabhu [3). The use of height adjustable chairs is a conventional design recommendation and is without exception recommended in the literature [e.g. 4,5]. As we will see below the height adjustable chair is not necessary. It is possible to use Axiomatic Design to derive a better, albeit unconventional design solution

- *General analysis of the design.* In the daily work situation, a microscope operator must make the necessary adjustments so that the workstation is comfortable. There are several possible adjustability design parameters in a microscope workstation that may affect operator comfort, see Figure 1 [6].

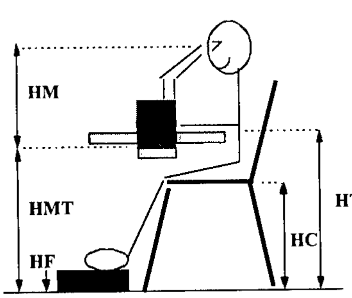

Figure 1: Design of a Microscope Workstation

Hardware manufacturers can supply all these height adjustabilities, including the microscope itself:

- The height of the table (HT) where the operator is sitting.
- The height of a special microscope table (HMT), which is additional to the worktable
- The height of the microscope eyepieces (HM)
- The height of the operator's chair (HC)

The height of the footrest (HF), We can now specify the top-level FR and its corresponding DP:

FR = Provide a good work posture for operators at a microscope workstation
DP = Provide height adjustable workstation

Using ergonomic design principles the top-level FR can be decomposed:

FR_1 = Support for feet
FR_2 = Table top at sitting elbow height
FR_3 = Eyes at microscope height

These FRs are reasonable, and they are commonly recommended, since they avoid many potential biomechanics problems. The top-level DP was decomposed using the conventional solution that was proposed to IBM in our study [3].

DP_1 = Adjustable chair height
DP_2 = Adjustable table height
DP_3 = Adjustable microscope height

Analysis of independence of the design: The design equation is given as:

$$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} A_{11} & 0 & 0 \\ A_{21} & A_{22} & 0 \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \begin{bmatrix} DP_1 \\ DP_2 \\ DP_3 \end{bmatrix}$$

Although this decoupled design is acceptable in the conventional sense of Axiomatic Design, a close examination indicates that the operator is required to remember the sequence of adjustments to bring about the best sitting posture. In this case, the chair height needs to be adjusted first, then the table height, and finally the microscope height. If this sequence is not followed, repeated iterative adjustments will be necessary. Even though this decoupled design is good enough for axiomatic it is not good enough for ergonomics, since it would be necessary to train the operator.

Reducing coupling in design. To improve the usability, and thus the design itself, other design solutions were tried. An adjustable footrest could be used instead of a height adjustable chair to satisfy FR_1 (Support for feet), and DP_1 was changed:

DP_1' = Adjustable footrest
DP_2' = Adjustable table height
DP_3' =Adjustable microscope height

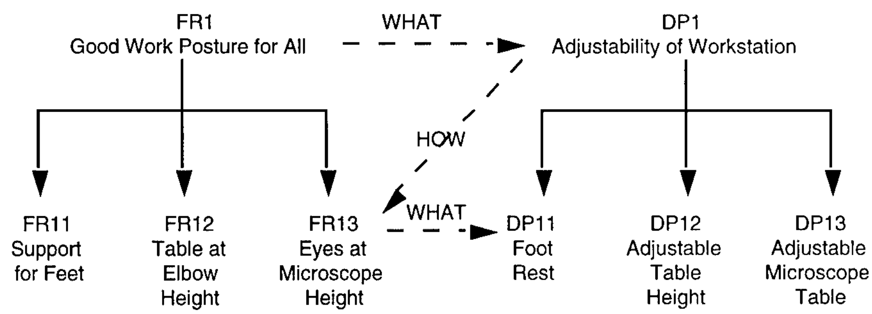

Figure 2: Hierarchical Structures and Decomposition of FRs and DPs. Note the zigzagging

The resultant design equation, with the modified design matrix [*A'*], is:

$$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} A_{11}' & 0 & 0 \\ 0 & A_{22}' & 0 \\ 0 & A_{32}' & A_{33}' \end{bmatrix} \begin{bmatrix} DP_1' \\ DP_2' \\ DP_3' \end{bmatrix}$$

This improved solution uses an independently adjustable footrest, which replaces the adjustable chair in satisfying FR_1 (Support for feet). Obviously a non-adjustable chair is then necessary, and it should be sufficiently high to accommodate tall operators.

Since the coupling is reduced this is a better design solution. The operator will still, however, be forced to set the adjustabilities in a certain sequence. DP_2' (Adjustable table height) must be set before DP_3' (Adjustable microscope height) otherwise repeated adjustments will be necessary. (This is simply due to the fact that the microscope is placed on the worktable). To further improve the design, we provided a separate adjustable microscope table, standing free from the worktable, see figure 2. Thus the modified DPs are

DP_1'' = Adjustable footrest

DP_2'' = Adjustable table height

DP_3'' = Separate adjustable microscope table

The resultant design equation, with the further modified design matrix [*A''*] is:

$$\begin{bmatrix} FR_1 \\ FR_2 \\ FR_3 \end{bmatrix} = \begin{bmatrix} A_{11}'' & 0 & 0 \\ 0 & A_{22}'' & 0 \\ 0 & 0 & A_{33}'' \end{bmatrix} \begin{bmatrix} DP_1'' \\ DP_2'' \\ DP_3'' \end{bmatrix}$$

By now we have achieved an uncoupled design that does not require any specified sequence to make the adjustments. Clearly, this is the <u>best</u> solution of all the ones proposed. It is however very unconventional, since it does not use a height adjustable chair. We have not seen this design solution documented in the literature.

3. DISCUSSION

This paper used domain mapping to arrive at good design solutions for adjustability. In the drivers compartment we provided examples of how decoupled design parameters simplify adjustments. It does not seem to be possible to find an uncoupled solution, unless design of vehicles is altered extensively. For example, the controls on the dashboard are in conflict with the steering wheel. An individual with a 5th percentile reach distance and a 95th percentile stomach girth may have difficulties to reach the dashboard controls.

It may have been informative to explore how design parameters affect the extremes of the driver population. Usually the average driver has no problems, but the 5th and the 95th percentile drivers do. However, their problems are different and individual treatments of the 5th and 95 the percentiles may suggest new de-coupled solutions.

The design of the microscope workstation was different in that it was possible to suggest a practical, uncoupled design. An unconventional design solution was accepted: the height adjustable chair was replaced by a footrest and an extra table was for the microscope was positioned inside the regular worktable. We discovered that height adjustable chairs were ineffective, since they impose a predetermined sequence of adjustability corrections that is difficult for the user to learn.

The design equations and some figures in this paper gave examples of the zigzagging between the functional domain and the design domain. The zigzagging procedure has a great advantage in that it can visualize how the choice of FRs and DPs at a high level of abstraction constrains the choice of FRs and DPs at the lower levels of abstraction. The zigzagging therefore introduces a method for constraint propagation, which is useful in delimiting the design space, and helps designers to arrive at reasonable solutions.

Domain mapping offers interesting solutions in anthropometric design because:

(1) A clear framework for the identification of functional requirements and the corresponding design parameters that may be evaluated with respect to user requirements.

(2) An analysis of the design matrix can reveal independence/dependence of functional requirements and point to possible ways of improving the design.

(3) The decomposition through the hierarchical structures of FRs and DPs by the zigzag process offers a procedure to constrain design solution.

Further research is necessary to formalize the use of top-down design procedures in ergonomics.

REFERENCES

1. Helander, M.G., Grossmith, E. & Prabhu, P., "Visual and Postural Ergonomics in Design of Microscope Workplaces", *Applied Ergonomics, Vol.* 22, pp.36-42, 1990.
2. Suh, N., *The Principles of Design*. New York: Oxford University Press, 1990.

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Anthropometry of Filipino Female Workers

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This paper[1] gathered anthropometric data of female workers in different industries in Metro Manila. Anthropometric data of 394 female workers in four (4) industries were studied. The initial results showed that anthropometric data of female workers among industries considered in this study vary. Comparison with some guidelines using American data was also done.

1. INTRODUCTION

The study of anthropometry has generated considerable interests during the past century. The fascination of people on the human body has always been evidenced by recorded studies. Different hypotheses have been generated through the years. The human body, especially that of women, has been the subject of interesting debates and enormous design guidelines.

Changes in the body anthropometry have been identified to be determined by sex, age, occupation, racial origin, and historical trends (Oborne, 1996). The sources of variability in measurements indicate that one cannot generalize a basis for design purpose.

Considerable number of studies on anthropometry has been compiled. The most extensive compilation has been done by the military. Extensive studies on the anthropometry of the US Air Force and US Military personnel have been conducted for design of aircraft, clothing requirements, equipment and control panels (Roebuck, 1995). Pheasant (1986) compiled anthropometric data for British adult and children, as well as anthropometric data from Germany, Sweden, Switzerland, Poland, Japan, Hong Kong and India. Damon, Stoudt, and McFarland have compiled data of civilian and military for equipment design (Roebuck, 1995).

Very few studies have been done to measure the anthropometry of workers in different industries. Most studies conducted were data of military personnel in the United States and in different countries in Europe and America. Some studies were done on adult male and female population. Velasco (1997) measured anthropometry of Filipino workers. Maras and Kim (1993) studied American industrial workers. Both studies presented the results in the traditional 5^{th}, 50^{th}, and 95^{th} percentile. Very few studies on the anthropometry of industrial workers have been conducted.

[1] This paper is part of the research project entitled, " Filipino Workers Anthropometry" funded by the De La Salle University Research Coordination Office, Manila, Philippines.

2. METHODOLOGY

The study measured the body anthropometry of subjects in static position. Subjects were measured with very light clothing and barefooted. The Martin anthropolometer was used as the measuring device.

A total of 394 female subjects were measured. The subjects work as clerks, sewers, sales persons, food servers, cook, and managers. The workers represent the garment industry, retail trade, fast food business, ceramics industry, and furniture and handicraft industries.

Body dimensions critical in the design of workspace were measured. Anthropometric data are presented in the traditional 5^{th}, 50^{th}, and 95^{th} percentile. Data were measured critical for standing and sitting work postures. Definition of anthropometric data measured was based on ISO guidelines on anthropometry.

The subjects were measured in two basic positions: standing and sitting. The following guidelines were used in measuring the subjects in the two positions mentioned. The subject's body should be in defined upright position, with body segments either in line with each other or at 90 degrees. The subjects were required to stand erect, heels together, buttocks, shoulder blades and back of head touching a wall, arms and fingers straight and vertical. For seated subject, the flat and horizontal surfaces of feet and foot support were so arranged that the thighs are horizontal, the lower legs are vertical, and the feet flat on the floor. Subject wears light summer clothing. Subject does not wear shoes or any footwear. Data were gathered from September 1996 to August 1997.

Workers from the manufacturing and service industries were measured. Workers were selected based on their availability and willingness to be measured. Both manual and blue-collar workers were measured.

3. RESULTS OF THE STUDY

A total of 394 female workers participated in this study. These workers came from different industries engaged mostly in manual tasks. The list of participating industries and the number of participating subjects are given in Table 1.

Table 1
Profile of Female Subjects in Participating Industries

Industry	Number of subjects
Garments	136
Office	56
Retail	82
Fast-food Service	65
Others	58
Total	394

Workers in the garment industry are mostly engaged in cutting, sewing, and packaging activities. Clerical activities are the main job assignments of subjects coming from the office industry. Workers in the retail industry are mostly sales clerks and attendants. Subjects from the fast-food industry are assigned as cooks, servers, and cashiers. Most of the work done assumes sitting posture. The average age of female subjects is 26.311 years with a standard deviation of 7.561. Weight of female subjects averaged 49.97 kg and a standard deviation of 7.75 . The female workers have a mean height of 151.69 cm. Anthropometric data in 5^{th}, 50^{th}, and 95^{th} percentiles are given in Table 2.

Table 2
Anthropometric Data of Filipino Female Workers in Metro Manila (cm)

Anthropometric Measurement	Standard Deviation	5%	50%	95%
Stature	6.77	141.14	152.32	163.50
Vertical reach	9.36	173.55	188.99	204.43
Eye height, standing	7.14	129.47	141.25	153.02
Thumb tip reach	7.35	55.08	67.21	79.34
Forearm-hand length	2.08	37.87	41.30	44.73
Arm span	7.40	140.56	152.77	164.98
Shoulder height	6.39	114.89	125.44	135.98
Elbow to floor	5.43	87.33	96.29	105.26
Hip breadth, standing	2.10	26.83	30.29	33.75
Sitting height	6.74	68.43	79.56	90.69
Eye height, sitting	4.99	59.79	68.03	76.27
Hip breadth, sitting	4.31	27.67	34.78	41.90
Knee height	3.68	39.71	45.61	51.52
Popliteal height	4.63	31.37	39.01	46.65
Buttock to popliteal	4.08	34.94	41.59	48.23
Buttock-knee length	4.04	44.10	50.77	57.43
Thigh clearance	6.77	9.51	12.98	16.44
Shoulder-elbow height	2.47	26.85	30.92	34.99
Elbow rest height	3.57	16.20	22.10	28.00
Shoulder to seat height	3.45	46.75	52.45	58.15
Head circumference	3.36	47.56	53.10	58.64
Chest depth	1.86	13.98	17.04	20.11
Shoulder breadth	3.28	33.16	38.56	43.97
Elbow to wrist	2.11	21.41	24.89	28.36

Anthropometric data of female workers in different industries included in the study were summarized in Table 3. Some anthropometric data for other industries were not presented due to the very small number of sample size. Data that are often used in the design of workstation for the industry are considered in the above summary. There is an indication that some data considerably differ among workers in the different industries.

Height of female workers in the garment industry is considerably shorter than that of other workers. Garment workers can also reach the lowest in term of vertical reach. Garment workers also register the shortest height measurements namely: eye height, standing, shoulder height, elbow to floor height, sitting height, knee height, popliteal height, and shoulder elbow height. This finding is important in the design of workstation like seat and table heights and clearances especially for the garment industry where work is done mostly in sitting posture.

Table 3
Summary of Anthropometric Data of Female Workers in Different Industries (cm)

Anthropometric Data	Garments	Office	Retail	Fast-food	Others
Stature	149.49	153.78	154.70	153.01	153.52
Vertical reach	184.09	190.20	192.43	190.03	
Eye height, standing	138.31	142.81	143.00	141.52	
Thumb tip reach	67.90	65.93	62.75	67.29	
Shoulder height	121.69	126.11	128.26	126.19	
Elbow to floor	93.05	97.23	98.49	96.95	
Sitting height	78.72	79.36	80.41	78.69	81.56
Eye height, sitting	67.97	67.68	69.77	65.85	68.52
Hip breadth, sitting	35.07	39.17	32.48	34.96	32.71
Knee height	44.79	46.26	46.61	47.45	43.37
Popliteal height	38.33	40.12	39.14	40.16	38.01
Buttock to popliteal	40.31	45.73	40.21	43.69	41.07
Buttock-knee length	50.74	50.98	49.79	51.34	51.38
Thigh clearance	13.50	13.98	13.39	11.65	
Shoulder-elbow height	30.37	30.31	31.35	30.95	32.23
Elbow rest height	22.89	20.91	22.47	20.22	32.23
Shoulder to seat height	52.42	51.38	53.19	50.62	54.64
Head circumference	53.73	54.76	50.74	53.82	
Shoulder breadth	38.69	40.73	37.43	38.69	37.80

On the other hand, workers in the retail trade like supermarket and department store salesclerks registered the tallest stature and can reach higher than other workers. This is evidenced by the data on stature and vertical reach. Their data on eye height standing, shoulder height, elbow to floor height, sitting height, and eye height sitting are also higher than other workers included in the study.

Fast-food workers have the smallest thigh clearance and shortest elbow rest height. Office workers registered the longest buttock to popliteal measurement. Office workers have bigger head circumference and shoulder breadth compare to other workers included in the study.

The data gathered were compared with the guidelines for VDT furniture design standards presented by Roebuck (1995). The guidelines presented are measures of U.S. civilian adults in the age range of 20-60 years old. The buttock-popliteal length came from U.S. military personnel. The comparison can be seen in Table 4. The data show that the guidelines being used by the ANSI/HFS 100-1988 is considerably bigger than the data gathered for Filipino workers. The guidelines, if used in the Filipino workstation for female should result to some adjustments due to the smaller size of the Filipino worker. The difference between the data ranges from a low of one centimeter for buttock-popliteal length (95%) to a high of seven centimeters for buttock to knee length (5%). This points to the idea that there should be a different standard set for Filipino workers or maybe for certain cultural groups due to some pronounced differences in body size. The data being considered in the Table 4 are basic data needed to design chairs and working table heights to name a few.

Table 4
Filipino Women Data and VDT Furniture Design Standard (ANSI/HFS 100-1988)*

Anthropometric Data	5th Percentile Female (cm)		95th Percentile Female (cm)	
	Filipino	ANSI/HFS	Filipino	ANSI/HFS
Buttock-knee length	44.1	51.8	57.43	62.5
Buttock -Popliteal length	34.94	40.9	48.23	47.2
Elbow Rest Height (sitting)	16.2	18.1	28.0	28.1
Eye Height (sitting)	59.79	67.5	76.27	78.5
Hip breadth	27.67	31.2	41.9	43.7
Knee height (sitting)	39.71	45.2	51.52	54.4
Popliteal height	31.37	35.5	46.65	44.3

*Source: Roebuck, 1995 p. 139.

4. CONCLUSION AND RECOMMENDATIONS

The paper presented the anthropometric data of female workers in Metro Manila, an urban center in the Philippines. These data were presented in 5th, 50th, and 95th percentile. Initial analysis of data show that there is variation in the measurement of female workers in the different industries studied. Comparison was made on some critical body dimension used in the design of workstation like chairs and tables Between Filipino female workers and the ANSI/HFS standard. Analysis has shown that one cannot just use this standard for Filipino due to considerable difference in the dimension. The differences in some data among industries considered in this study are also worth noting.

The difference in the forearm-hand length and the arm span among female workers in the different industries points out to the consideration of the anthropometric data of the workers in different industries in setting guidelines for clearance and reach purposes. The buttock to knee length is a critical anthropometric data used in the design of seats particularly the clearance between the knee and the obstacles in front of the knee. This is a critical dimension for seated work like the jobs being done in the garment industry. The thigh clearance determines the height of the working table or surface and its clearance from the thigh while the worker is seated. Thus, it is imperative that data to be used for design guidelines should be taken from subjects representing different industries.

Aside from using the anthropometric data for workplace design, they can also be used to describe the characteristics of sex, age and body type. The data can also be used to design tools and work implements used by the workers. These factors are very important in the design considerations of different products due to the fast changing technological developments. These data can also be used as basis for the approximations of body segment's length and mass, two important data in the study of biomechanics. Since body movement is inevitable in the day to day performance of work, anthropometric data will greatly help understand the capabilities and limitations of Filipino workers. The result of this study can be used as a good input in the design of workplaces that are predominantly used by women.

Further studies must be done to gather more anthropometric data for workers in the Asia-Pacific region. Initial comparison show that there is a considerable difference between the data of Filipinos and the Americans. This can also be true for other Asian nationals. This study suggests that anthropometric data for Filipinos and other Southeast Asian nationals should be gathered to establish guidelines or standards for design purposes. The economic progress in technology and manufacturing processes results to more women being needed in the workforce. This study aims to start to address the ergonomics philosophy of comfort and safety in the workplace. Further study should be done to fully document and understand the workers' need in the design for better productivity and efficiency.

REFERENCES

1. Alexander, David C., The Practice and Management of Industrial Ergonomics, Prentice Hall, USA. (1986)
2. Burgess, J. Designing for Humans: The Human Factor in Engineering. Petrocelli Book. USA. (1986)
3. Fraser, T.M. The Worker at Work. Taylor and Francis. UK. . (1989).
4. Kantowitz, B. H. and R. D. Sorkin. Human factors: Understanding People-System Relationships. John Wiley and Sons. USA. (1983).
5. Kroemer, K., H. Kroemer, and K.K. Elber.). Ergonomics. McGraw-Hill Book Co.. Singapore.
6. ISO Ergonomic Design of Control Rooms, 1981.
7. Lund, R.T., A.B. Bishop, A.E Newman, H. Salzman. (1993). Designed to Work. Prentice Hall. New Jersey, USA. (1994
8. Maras, W.S. and J.Y. Kim Anthropometry and Industrial populations, Ergonomics. Vol. 36. No. 4. (1993).
9. Pheasant, S. Bodyspace. London. Taylor and Francis. . (1988).
10. Pulat, R.M.. Fundamental of Industrial Ergonomics. Prentice Hall. New Jersey, USA. (1992)
11. Sanders, M.S. and E.J. McCormick Human Factors in Engineering. McGraw-Hill Book Co.. Singapore. . (1987).
12. Selan, J.L. The Advance Ergonomics Manual. Advance Ergonomics, Inc., USA. (1994).
13. 1993 Occupational Injuries and Work Accidents. Department of Labor and Employment. Philippines.
14. Thurman, J.E., A.E. Louzine and K. Kogi.). Higher Productivity and a Better Place to Work. International Labor Office, Geneva. (1994
15. Velasco, A.L. Anthropometric Data of Filipino Workers. DLSU Engineering Journal. DLSU Press. Philippines. . (1997).

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Analysis of Vertical Multiplier (VM) of NIOSH Recommended Weight Limit Formula: an Indonesian Perspective

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The NIOSH's Recommended Weight Limit (RWL) formula was developed at an American working environment which among others consists of a worker population of Caucasians origin. Therefore, its direct application for Indonesian worker population which is physically different from the Americans is not reasonably accepted from ergonomic point of view. This article reports a study on testing one of the formula's constant, i.e. VM, the Vertical Multiplier at an Indonesian environment. The result showed indications that the formula should be corrected.

Modern industries still use a lot of human power for material handling activities for several reasons although back injuries are the big consequence. If a tested standardized method to precalculate some of the influential variables of manual material handling are available, it can reduce the negative effect of material handling on human worker. It means that the cost of production losses and the workers' recovery can be minimized which means efficiency in industry.

1. BACKGROUND

Low Back Pain (LBP) is a common injury in industry, especially where Manual Material Handling (MMH) characterizes major activities of the movements of material.
In the US, according to the Department of Labor's Bureau (DOL) report, back injuries accounted for nearly 20% of all injuries and illness in the workplace, and nearly 25% of the annual worker's compensation payments.

In Indonesia, because a lot of human power is used in most industries, the corresponding figure here must be higher. A report by Syllabi (1991) noted that 25% of worker's injuries in this country are caused by error in material handling design and operation.

In relation with this, NIOSH recommended lifting equation, named RWL (Recommended Weight Limit) which is defined for specific set of task conditions with the weight of the load that nearly all healthy workers could perform over a substantial period of time (e.g. up to 8 hours) without an increased risk of developing lifting-related low back pain (NIOSH, 1991).
The equation is:

$$RWL = LC \times HM \times VM \times DM \times AM \times FM \times CM \qquad (1)$$

which LC = *Load Constant*
HM = *Horizontal Multiplier*
VM = *Vertical Multiplier*
DM = *Distance Multiplier*
AM = *Asymmetric Multiplier*
FM = *Frequency Multiplier*
CM = *Coupling Multiplier*

The complete form of the formula which expresses constants related to the multipliers is mentioned in Revised NIOSH Lifting Equation (1994).

The formula was certainly developed for Americans workers, i.e. mostly Caucasians who are anthropometrically different from some other races such as the Indonesians. Table-1 suggests that while the formula provides the general idea of what variables should be considered, the constants should be evaluated if the formula is to be applied for Indonesian workers. Some corrections to the constants might be needed.

The purpose of this research is to study the importance of considering racial differences in developing RWL. In this study, the focus is on VM using biomechanical, epidemiological, physiological, and psychological approach.

2. PREVIOUS RESEARCH

To develop RWL, three criteria were used by NIOSH to define components of lifting equation: biomechanical, physiological, and psychophysical (Putz-Anderson and Waters, 1991). The biomechanical criterion limits the effects of lumbosacral stress, which is most important in infrequent lifting task. The physiological criterion limits the metabolic stress and fatigue associated with repetitive lifting task. The psychophysical criterion limits the workload based on the worker' perception of their lifting capability, a measure applicable to nearly all lifting tasks, except high frequency lifting (above 6 lifts per min).

❖ The biomechanical criteria

In general, biomechanics determine what a person can do physically. The ultimate goal of the biomechanical approach is to set limits on physical stresses imposed on the musculoskeletal system during a lifting action and then to determine the load-lifting capacity based on the limits. These physical stresses include reactive forces and torques on various joints of the body, and compressive and shear forces on the lower back (Chaffin 1975).

In the case of manual material handling, biomechanics focus is in vertebrae's stress. The vertebrae is grouped in four parts :

a. Cervical
b. Thoracic
c. Lumbar
d. Sacro iliac

Lumbar region is the most important part. It consists of 5 lumbar joints (Li), and between each joints, there are intervertebral discs (Si).

In manual material handling, the biggest stress happened in L5/S1. According to Jager and Luttman(1989), the compression at L5/S1 must not exceed 3,4 kN.

Table 1
Anthropometrical differences between Americans and Indonesians (50 percentile)

Anthropometry Data	American *	Indonesian **	Ratio (%)
Body weight	92.6 kg	54,85 kg	0,59
Body height	175.5 cm	163,47 cm	0,93

*mannequin version 1.1
** Widyanti, 1998

❖ The physiological criteria

The physiological approach is concerned with the physiological stress on the body. It is based on work physiology principles. This approach selects physiological criteria such as energy expenditure and its upper limit. One of the physiological approach is energy consumption, which is usually reflected, for practical measurement purposes, by the heart rate of the worker.

Worker's heart rate is measured before and after doing his job. Heart rate after performing a task is always higher than before performing the task. Energy consumption can be calculated with this formula (Astuti and Sutalaksana 1981) :

$$Et = 1{,}80411 - 0{,}0229038D + 4{,}71733.10^{-4}\,D^2 \qquad (2)$$

Et = energy consumption to perform a task, measured during work (kCal / minute)
D = steady state heart rate when performing the task (beats / minute)

Heart rate is then converted into energy consumption to perform the particular task with this formula :

$$Ke = Et - Ei \qquad (3)$$

Ke = energy consumption (kCal/minute)
Eo = energy before work (kCal/minute), measured before work starts

In other words, energy consumed for a specific manual material handling task is the difference between energy after and before work. Heart rate after work must not exceed 120 beats/minute (Barnes, 1980).

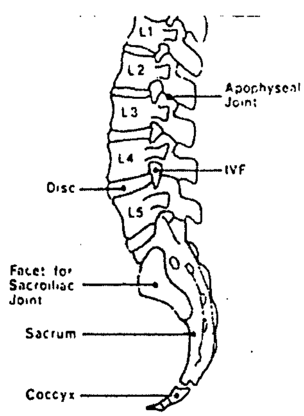

Figure 1. The position of L5/S1

❖ The psychophysical criteria

Psychophysics deals with the relationship between human sensations and their physical stimuli. The psychophysical approach focuses on the individual's perception of exertion, pain, or discomfort when performing a manual task. There are some methods used to quantify psychophysical stress: ordinal, interval, and ratio. One of the interval scale methods, the RPE (Rating of Perceived Exertion) is among the popular ones in industry. RPE is an individual subjective perception about his physical work (Borg, 1962). If the scale is multiplied by 10, it approaches the heart rate of a healthy worker to do the same level of job.

❖ The epidemiological criteria

The three criterions above are used by NIOSH to developed the RWL formula mentioned above. There is another criteria which might be used in relation with RWL, i.e. the epidemiological criteria (Work Practice Guide for Manual Lifting, 1981). It deals with the identification of distribution and control of injury and disease at the population of workers. The criteria are :

- job risk factors :
  weight lifted, location/site, frequency, workplace geometry, environment
- personal risk factors :
  gender, age, anthropometry, lift technique, attitude, training

3. RESEARCH METHODOLOGY

The research reported here is on the study on the Vertical Multiplier (VM) as influenced by anthropometrical measures. In other words, the term $VM = 1 - (0{,}003\,|V - 75\,|)$ [NIOSH,1991], is to be assessed whether the constants should be corrected. If there is any correction should be made, it's effect on RWL formula of NIOSH is to be found out. The study is performed experimentally with material handling workers in a metal manufacturing factory in Bandung. They consist of six healthy male workers aged between 26 and 34 years old, well motivated, and anthropometrically representative of the general workers population as shown in Table 2. These subjects characteristics along with the task to be experimented (as will be explained below), the workplace design and environment which are standardized, ensure that the epidemiological criteria are fulfilled.

These subjects were asked to perform lifting task as shown in Figure 2. Type 1 lifting consists of lifting loads from the floor to knuckle height. In Type 2 the subject lifts loads from knuckle height to shoulder height, and in Type 3, from shoulder height to normal arm reach height.

Table 2
Data of subjects

Subject	Age (years)	Experience (years)	Height (cm)	Weight (cm)
1	26	6	165	60
2	34	6	178	60
3	26	6	162	60
4	24	4	164	58
5	29	4	165	56
6	26	4	162	52

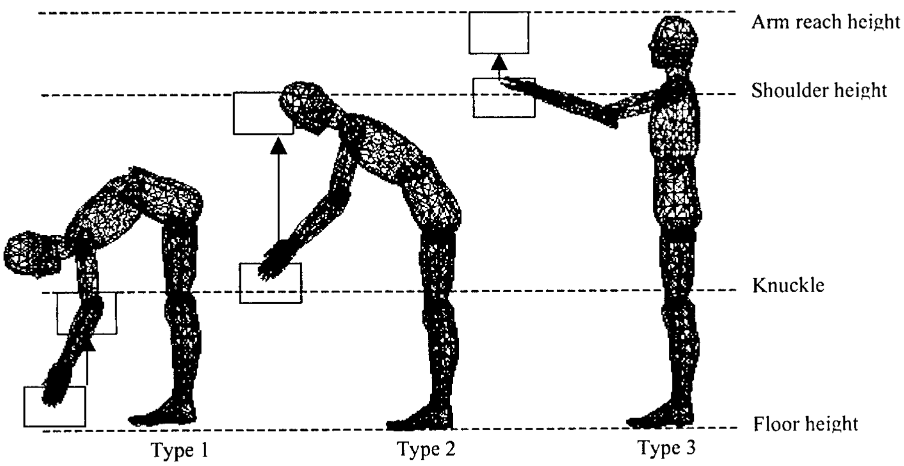

Figure 2. The lifting task

Different loads were arranged for each subject starting from small loads. For each load, the subject performs the lifting task at 5 lifts/minute rate continually. The heart rate is then measured using NSSG pulse monitor. The task is repeated with a heavier load until the weight of the load which gives heart beats of close to 120 times/minute was found (to fulfill the physiological criteria, based on Barnes (1980)). All this will result in the average physiologically accepted weight limit from the subjects for each type of task, namely WPh_1, WPh_2, and WPh_3 for Types 1,2, and 3 consecutively.

After workers do their job, they were asked to fill in a questionnaire which expressed their perception about their job. All workers state their perception on scale 12 – 13 at RPE ratings, which indicated medium work load.

These average are to be used to calculate the required discount values. Discount value is the percentage of decrease in worker's capability to lift loads from any initial position as compared to the assumed optimal initial position of load, which is at knuckle height (acknowledge by NIOSH (1991)). Type 1 and Type 3 tasks are thus compared to Type 2 task. The discount values for these non-optimal positions are calculated as follow:

Discount value for type 1 : $DV_1 = (WPh_1 - WPh_2)/WPh_2$ (4)

Discount value for type 3 : $DV_3 = (WPh_3 - WPh_2)/WPh_2$ (5)

Having the discount values on hand, VM, the Vertical Multiplier in the NIOSH's RWL formula is determined with

$$VM = 1 - DV \quad (6)$$

$$DV = a(V-b) \quad (7)$$

where a = constant

b = knuckle height

V = load height

Aside from this, the compressive force at L5/S1 is calculated using the mannequin software with the Physiologically Accepted Weight Limit (PAWL) values serve as inputs to accommodate the biomechanical criteria.

4. RESULTS

Table 3, 4, and 5 show the results of heart rate measurements from types 1 through 3 lifting tasks.

Table 3 : PAWL for type 1 task (floor – knuckle)

Subject	Physiologically accepted weight limit / PAWL (kg)
1	31
2	28
3	26
4	28
5	33
6	49
Average	32,5

Table 4: PAWL for type 2 task (knuckle - shoulder)

Subject	Physiologically accepted weight limit / PAWL (kg)
1	17
2	17
3	13
4	16
5	18
6	21
Average	17

Table 5: PAWL for type 3 task (shoulder – arm reach)

Subject	Physiologically accepted weight limit / PAWL (kg)
1	15
2	17
3	14
4	17
5	18
6	18
Average	16.5

The compressive forces at L5/S1 (the averages of PAWL) are calculated at table-6

Table 6: Compressive force at L5/S1

Lifting Position	Load Weight (kg)	Compressive force at L5/S1 (N)
Floor – knuckle	32,5	665
	17	373
	16,5	364
Knuckle – shoulder	32,5	353
	17	195
	16,5	189
Shoulder – reach	32,5	546
	17	279
	16,5	270

The discount value are then $DV_1 = 91,17$ %
$DV_3 = 94,11$ %
It is further obtained the VM values to be

$$VM = \begin{cases} 1 - 0,0132(69 - V) & \text{For floor – knuckle lift} \\ 1 - 0,0145(V - 69) & \text{For shoulder – arm reach lift} \end{cases}$$

If we compare NIOSH's RWL and RWL with new VM, the comparison as follows :

Table 7: The comparison between NIOSH's RWL and new RWL with proposed VM

Vertical Distances (cm)	VM		RWL (kg)		
	NIOSH	New	NIOSH	New	Difference (%)
10	0,81	0,22	18,52	5,09	72,52
20	0,84	0,35	19,21	8,12	57,73
30	0,87	0,49	19,90	11,16	43,92
40	0,90	0,62	20,59	14,20	31,03
50	0,93	0,75	21,28	17,23	19,03
60	0,96	0,88	21,97	20,27	7,74
69	0,98	1,00	22,59	23,00	-1,81
70	0,99	0,99	22,66	22,67	-0,04
75	1,00	0,91	23,00	21,00	8,70
80	0,99	0,84	22,66	19,33	14,70
90	0,96	0,70	21,97	16,00	27,17
100	0,93	0,55	21,28	12,66	40,51
110	0,90	0,41	20,59	9,33	54,69
120	0,87	0,26	19,90	5,99	69,90
130	0,84	0,12	19,21	2,66	86,15

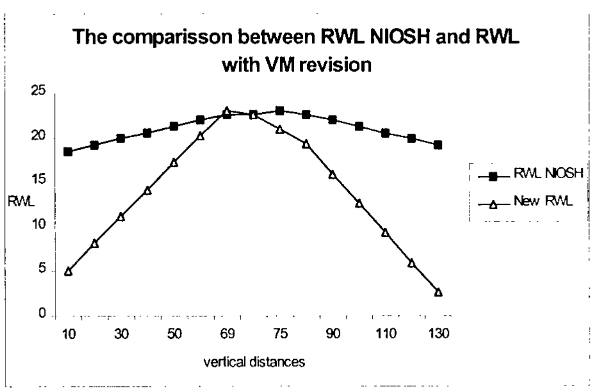

Figure 3. The comparison between RWL NIOSH and RWL with VM revision

5. ANALYSIS

The VM formulas found here agree with the formula from NIOSH in terms of the decreasing effect in VM value from the initial position of the loads in both direction (below and above knuckle height). But this study found out that this effect might not be symmetrical since the values are unique for each direction as shown in the above expressions and as also depicted in Figure 3.

It is also interesting to note that for other constants of NIOSH formula (LC, HM, DM, AM, FM, CM) assumed to be the same, significant difference of RWL's are found as shown by the figures at the last column of Table 7, especially when the vertical differences from knuckle height is large. This lead to an indication that the constants for a population is unique and therefore the existence of the uniqueness of RWL values should not be undermined.

6. SUGGESTION

More research about RWL must be done to analyse all the multipliers for the RWL formula of NIOSH if it is to be applied at working environments with workers other than from Caucasians origin. The scopes of analysis must include all criteria: biomechanical, physiological, psychological, and epidemiological.

REFERENCES

1. Silalahi, Bennet N.B, et al. Manajemen Keselamatan dan Kesehatan Kerja. PT. Pustaka Binaman Pressindo, Jakarta, 1991
2. NIOSH. Work Practices Guide For Manual Lifting. Ohio, 1981.
3. Waters, Thomas R., Ph.D., Vern Putz-Anderson, Ph.D., Arun Garg, Ph.D. Application Manual For The Revised NIOSH Lifting Equation, 1994.
4. Widyanti Suryono, A. and Sutalaksana, IZ. Analisis Manual Material Handling serta Faktor Pengali Vertikal dan Jarak pada Persamaan Pembebanan NIOSH. Tugas akhir Jurusan Teknik Industri ITB, 1998.
5. Chaffin, D.B,. Manual Material Handling And Low Back Pain. In Occupational Medicine : Principles and Practical Applications. Chicago, Year Book Publishers, 1975.
6. Jager, M. and Luttman. Biomechanical analysis and assessment of lumbar stress during load lifting using dynamic 19-segment human model. Ergonomics,32,93-112, 1989.
7. Astuti, B. and Sutalaksana, IZ. Beberapa segi faal kerja yang berhubungan dengan kecepatan denyut jantung dan konsumsi oksigen serta pendekatan kuantitatifnya, kertas kerja, hlm.29, 1981.
8. Barnes. Motion and Time Study Design and Measurement of work. John Wiley & Sons, Singapore, 1980.

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Ergonomics Consequences of Assistive Technology for the Disabled

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An assistive technology is a certain form of technical system which is generally used for assisting people with a disability. The ergonomics of assistive technology means to achieve the maximum level of benefits concentrating the safe manipulation of a technical system for people with low mobility. Assistive technology is increasingly gearing towards the user's satisfaction and socio-technical systems which are also interactive. An increasing number of reports have noted the mismatch between assistive technology and disabled people's actual needs and, thus, an analysis of a user's requirements is one of the most important factors. On the basis of ergonomics design and development, this paper explores a user's involvement that might come up in the everyday use of assistive technology. Aiming to find a scientific basis through which a technical system can match with an individual's specific needs, some initial areas of assistive technology are likewise described to show its importance and advantages on ergonomics. How an assistive technology can be truly beneficial for people with disabilities, ergonomics applicability is emphasised.

1. INTRODUCTION

Technology is some king of device, product, technique or service that helps us in many ways. In today's societies, it is commonly used to make our lives enjoyable and comfortable. It has enabled us to do our day-to-day jobs easier and faster. According to Webster's dictionary, technology is the totality of the means employed to provide the objects necessary for human sustenance and comfort. For most people, many of such technologies such as computers, video-electronics, automated appliances, telecommunications, biomedical appliances, etc. makes things easier, and help to maintain a sophisticated life style. From information technology to virtual reality, telemedicine to robotic diagnosis, new technology is always beneficial to everyone. All technology is innovative and assistive since it is useful for everyone from elderly to young people, from the disabled or handicap person to normal people. A recent development in assistive technology (AT) has also made the life of disabled people easier, offering freedom of choice for mobility and accessibility (LaPlanate et al. 1992, Cook and Hussev 1995). It has become progressively beneficial to many of them to get access in different places, manipulate home devices and so on.

In the conventional view, assistive devices are added to, substituted for, or used in conjunction with traditional technology. For using computers (checking electronic mail or Internet surfing), special keyboards or ergonomic joysticks, for instance, are being supplied to the people with disabilities. They can even call for a taxi using a whistling system (i.e., multi-devised wireless systems). A telecommunication device is designed to permit the use of a phone for people who are hard of hearing. In a similar way, disabled people can turn on a television, operate video systems or a cassette recorder with the help of AT. When we speak about AT, the uniformity of defining the difference between conventional technology and rehabilitation engineering is of vital importance in terms of its responsiveness and utilisation of devices. The main reason is that disabled persons usually have difficulties to move their body members easily, or get access to all public places, for instance. In developing AT, a user requirement is important to adapt with the environment for safe and reliable use of technical systems. Ergonomically illuminated lightening strips with acoustic signals, for instance, are better in the case of vision impaired disabled people. The variety of prosthetic and orthopaedic devices, for instance, are designed to replace or substitute for the function of numerous body organs, sensory, motor or cognitive functions (Mendelsohn, 1996).

In spite of the consumer-responsive rehabilitation offered by professionals, AT however remains a problem. An appropriate device and service remains an arduous task for both individuals and professionals, since the question of the match and/or mismatch of a disabled person and the technology requires much attention. AT may not be designed correctly for all people, and there could be a mismatch or non-satisfaction between the user and the device. In many cases, the design of such devices and technical systems does not permit the use of add-ons or substitutions. Such devices can be problematic for some aspects of the environment in which the technology will be used. The reason is perhaps accessibility and usability issues, which are a growing concern of AT. An array of electronic devices, for instance, has yet to be approved by whether they are designed and developed according to the principles of inclusiveness or universal access for disabled or handicapped people. Hence, it is of vital importance that the needs, choice and preferences of the specific user should meet with the functions and features of AT. If the match is not a quality one from the viewpoint of the disabled users, then AT will not truly be useful and beneficial. The interaction between the individuals delivering the technical systems, and the individuals receiving the service should therefore be considered carefully. How AT provides true benefits for people with a disability is the authors' speculation in this paper.

2. WHAT IS DISABILITY OR IMPAIRMENT?

The people with disabilities is one part of our society. World statistics show that increase in number of disabled and elderly people will lead in the future to disturbances in demographic distribution and will be a serious problem in many countries in the world (Molenbroke, 1987, Nowak, 1990, Kumar, 1992, Jarosz, 1993). A disabled person is however defined who has a record of impairment, or being regarded as having other symptoms of impairment(s). As such, a person who has physical or mental impairment that substantially limits one or more of the major life activities of such individuals. LaPlante (1991) assessed the variation both in terms of severity of disability, and in the identification of persons as having a disability. To define impairement and disability, a characterisation of impaireemnt and disability, and graditations of the functional capabilities of the disabled will have to begin to provide in the workforce (Kumar 1996). A disability usually defines a health condition(s) that significantly impair his or her major life activity (ADA, 1990, 1994). Under this definition, nearly one-fifth person in the USA has some sort of a disability, for instance (Fulbright and Jaworski 1990). However, all people classified as disabled do not necessarily have a work disability, which differs significantly from the general disability definition. Work disability (generally called handicap) describes condition(s) that prevents a person from working or limits the kind of work he or she can do for a periods of more than 6 months. There are several major categories of work disability. For instance, sensory impairments (visual, hearing or other sensory problems); mobility impairments (mobility, strength, manipulation or other mobility problems); and intellectual or psychiatric or psychological impairments (brain damage, generic intellectual impairments, psychiatric diseases, and learning and behaviour disabilities). Most people with work disabilities have a combination of two or more types of impairments (Blumkin 1997). However it is important that people reporting more than one type of impairment will have a greater level of severity of disabling conditions. By defination, disability refers to the interaction between a physical imarirment and an environmental demand. However many people with disabilities are wheelchair bound. Providing rehabilitation services outside the environment that defines the disability places undue emphasis on the physical impairment component of the disability. The emphasis on physical impairment in the management of disabilty-related difficulties also reflects a strictly bio-medical view of disability that is no longer cosidered viable (WHO, 1981). The instruments based on the international classification of Impairments, disablities and handicaps (WHO, 1980) defines 21 activities in 5 domains such as communication, mobility, personal care, occupation, and relationships. The fisrt four domains focus on two aspects of each activity: the difficulty in performances, and the amount of help needed to perform the activity (disability), and secondly, the perceived problems of patients. The fifth domain measures the changes in relationships in comparison to before a serious health problems may occur.

3. ASSISTIVE TECHNOLOGY AND ITS ADVANTAGES

An assistive device is defined as technology that can help people go through their day-to-day activities with less difficulty. ATs are some kind of sophisticated tools, devices or systems that can be distinguishable from other forms (e.g., traditional or conventional) of technology. AT differs according to their static model, their operation and maintenance criteria. There are various types of AT on the market. The hand controls, for instance, are used to operate an automobile, or the speech synthesiser is employed to capture the output of a computer screen. Similarly, the eye-gaze computer input system is designed to operate an environmental control unit (Galvin and Caves 1995). Alarm system, auto lightening, cordless telephone talking, or an answering machine is also a special feature of AT (Figure 1).

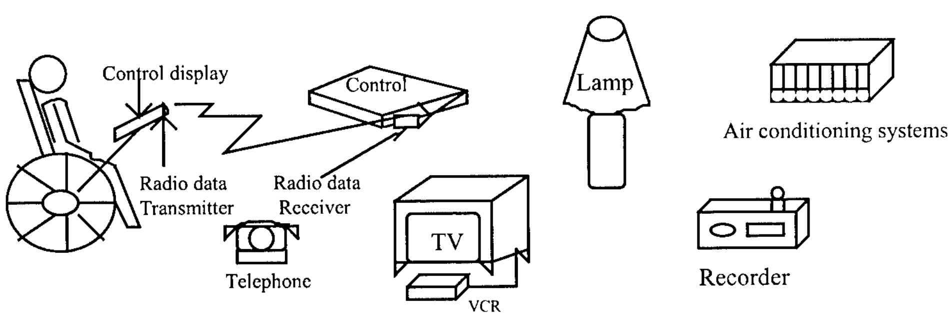

Figure 1. An example of multi-devised AT to operate various home appliances.

AT can also be a device, an integrated service, or a piece of equipment. It can be a product, an item, or a system that is modified or customised to increase, maintain or improve the functional capability of a disabled person. It helps to increase mobility and functional abilities (e.g., greater freedom of movement) in the job market. It increases self-esteem and reduces cognitive stress (Wright 1980). It facilitates development perspectives for disabled people's access to different places and in different situations. Individuals with disabilities use an assistive device [e.g., remote controls, electric ramps, power doors, etc.] for a variety of reasons such as to provide abilities to disabilities (Cook and Hussev 1995). An automated teller machine, for instance, may be an assistive device if it is a built-in speech output system to facilitate its use by the blind persons. The persons who are deaf can treat a new TV set as AT if it has built-in decoder chip to facilitate access to an audio system. It enhances independent functioning for the people with limited or restricted mobility by providing easier communication with each other (Scherer and Galvin 1997). It helps to clear obstacles, or reduce barriers to physical, behavioural or cognitive performance confronted by individuals with disabilities. It enhances the safe interactions or strategies among person, technology and the environment. It combats the stereotype of rehabilitation instead of promoting institutional or artificial rehabilitation. It is an important part of the rehabilitation process with the understanding or matching of common facilities in our modern society (Ahasan 1998). It also facilitates to ensure social and family oriented services are more accessible. In the understanding and awareness of what we mean by AT, further clarification is needed (Cook and Hussev 1995, LaPlanate et al. 1992). However AT can be high or low technology. High technology usually refers to complex tools or electrical or electronic devices [e.g. computers, robots, laser optics, spy satellites, augmentative communication boards, environmental control systems, etc.]. It is often assumed that high technologies [e.g., in the form of newer and more sophisticated means] are better than low technology. We should tend to look at high technology solutions for every situation, which is to be simple, easier to use, and less expensive (Galvin and Caves 1995). Low technology generally refers to similar interventions [e.g., custom-designed hand tools, workstation modifications, etc.] which often involves the application of traditional methods. As such, low technology alternatives can be seen in the workplace (or domestic environment) designed to fit the person. AT is just an effective means that could be easily integrated into a person's lifestyle (Galvin and Phillips, 1990). The outcome of services rendered by AT is expensive, while it is used for only a short time (Scherer 1991). Premature AT are costly both in terms of money and outcome achievement (Menelsohn 1996).

With the use of appropriate assistance (Rubin and Roessler 1987), disabled people should have control over a technical system on an individual basis, regardless of age, gender, culture or type of disability. It should represent a system that let disabled persons manage themselves doing something in respective environment [e.g. at home school, work and in the community]. By doing so, it should meet with an individual's specific needs. Within the context of someone's daily life, AT is consistent with his or her skills and accomplishes unique functions. The concept of rehabilitation engineering in this context is closely related with the proper use of assistive devices. AT devices can significantly benefit individuals with disabilities of all ages. AT can empower individuals to live independently, enjoy self-determination, make choices, pursue meaningful careers, and enjoy full inclusion and integretion in the economic, political, social, cultural and educational mainstream of our society. AT can often reduce expenditures associated with involvement in activities of daily living (ADL). People with disabilities can have the full access to modren society through the availablity of AT. Assistive devices helps to enable someone to live independently and enjoy full inclusion in society.

4. WHAT ARE THE USER'S SYSTEMS AND PHYSICAL ENVIRONMENT?

A disabled person's living (physical) environment should be barrier free (i.e., easily accessible). It has been noted that the living environment designed by the "European Institute for Design and Disability" (Philippen 1994) has neutralised the segregating effects, while using AT. Levon (1994) emphasised transparent technology and continuity principles where extra space has to be provided for future needs, so that assistive devices can be installed without basic or structural change. Physical environments should ergonomically be developed so that use of AT is effective. Special markings, clear direction of signs and ergonomic information also provide a way to perceive (cognitive ability) one's direction clearly. Residential premises such as stairs, corridors, entryways, vertical access, courtyard or car parking and other areas [e.g., WC-lifters, grab bars, adjustable commode seat, shelves, etc.] need to be easily accessible, while using assistive devices. Public buildings, transports, recreational park should be usable and suitable for disabled people. All those should be located at a standardised height and visible from various locations and distances (Dawson et al. 1987, Gongxia 1992). Utility spaces are to be clearly specified for AT because uniform manoeuvring space is generous for barrier-free mobility. Hence, occupational biomechanics (Chaffin and Andersson 1984) may be an important subject for the design of AT.

Introducing user systems, ergonomics principles (Ahasan 1998) also consider socio-technical perspective of technical aids through physical, cognitive and the psychosocial interface of the users (Zinder 1994). It dominates the functional efficiency of AT along with its ease of use. Ergonomics deals with the promotion of health and safety (Ahasan 2000), fostering the design of good devices that are the prerequisites for managing safe and convenient living. Ergonomic tools and devices also mean flexible, dynamic and compatible constructions. Ergonomics information is needed for specific solutions followed by certain checklist, codes, and guidelines, which are proactive rather than meeting only the physical specifications of AT. With the user's comprehension, ergonomics principles enhance new ways of co-operation on user-friendly services. It considers interface issues for the suitability of AT. Disabled people should be integrated into the rehabilitation process (Scherer and Galvin 1997), and be assisted without discrimination of sex, age, domicile, education or the type of disability. In order to improve the outcome of AT, design criteria should be evaluated considering various factors (Scherer 1991, Scherer and Galvin 1997), so that it looks for the benefit of the disabled people. Both the responsiveness and utilisation of devices has to be facilitated in such a way that it compares with various strategies and development. Where AT is concerned, ergonomics codes and special legislation should be regulatory so that fixtures and fittings are placed or fixed at optimum height, for instance, because too low or high sleeves may contribute to a loss of balance (Faletti 1993), for instance. Prevention and anticipatory care have to be enhanced (Williams 1992, Nissinen 1994) before ambulatory care. Ergonomics criteria should be checked when AT is introduced, and it is important before the system delivered (Philippen, 1994). Ambient environmental conditions must be pollution free and non-hazardous. Residential units should be usable and matched from an anthropometrical point of view with broader environmental and technical facilities. Checkout counters or inspection points are to be spacious without steps or elevation (Gongxia 1992).

The location, position and arrangement of AT are to be suitable for special needs. Ergonomic elevators like stairway-caterpillars, stair climbing, attachments beneath wheelchair, are used in emergency situations. Automatic sprinkler systems reduce the danger in a hazardous section along with emergency exits. Doors and corridors are to be larger, power actuated and more massive than necessary. An ergonomic mirror opposite to the door to monitor wheelchair motion can minimise accidents, for instance. The prime concern in evaluating a product is to find out the extent to which the product is convenient to use by people with special needs. Our approach to usuability can best be described by Figure 2 where it is shown that the level of success in use is dictated by four main things. The value of this approach to the evaluation process can best be illustrated by Figure 2 which outlines the basic elements. These elements from the basis of detailed convenience checklists which are used to measure the usability of each product for a range of people with especial needs. Another important stage in evolving the final checklist is to examine all tasks necessary to use the assistive device and the overall evluation criteria as shown in Table 1. Depending on the type of device, and the range of models which need to be tested, and eveluation.

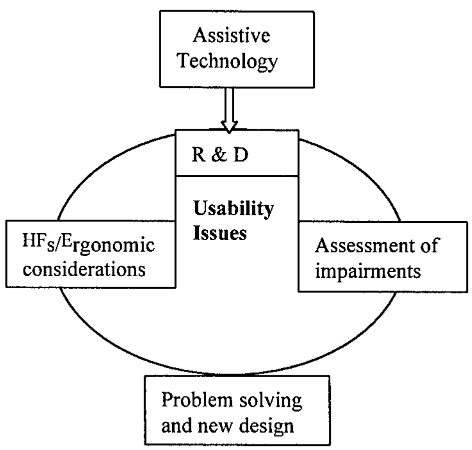

Figure 2. Factors affeccting successful use of assistive technology.

The direct involvement of users provides important guidance during the design process towards a user-friendly and effective device. The concept of evaluation and assessment together with the end users is a driving force for the development and use of AT. However it should start with a user-based analysis. Adaptations of homes and workplaces for disabled people can vary substantially in complexity and in resources required. Consequently, planning for such adaptations can also vary as to time, effort and people involved (e.g., therapists, construction engineers, architects). Eriksson and Johansson (1996) has developed a computer based tool to support the planning of adaptions for physically disabled people. This tool was found useful in the design and evaluation of ergonomics aspects such as accessibility, clearance, and reach considering individual's size and abilities. The therapists are able to answer more explicity about the efficiency and user-interface behaviour since they have had direct experience in operating the tool.

5. SERVICE DELIVERY SYSTEMS

What sort of services are rendered for the disabled? AT agencies and service providers have proven to be effective means of transferring information to persons wirth disabilities living in our society. It is imperative that outreach be effective if its include: indefication and assessing the needs of disabled people; providing activities to increase the accessibility of services to such populations; training representatives of such populations to become service providers; and training staff of the consumer-responsive comprehensive statewide program of technology-related assistance to work with such puopulations. Outreach actvities may also include the promotion, creation, maintenance, support, or provision of assistance to, statewide and community based organisations, or systems that provide AT and similar services. At services are provided to the individual with a disability in a number of different ways, depending on the specific delivery systems, i.e., a school-age child or a disabled veteran. A person may have to access more than one system to acquire all the services he/she need. Often, there is a gap in the service systems, or geographic area, or type of disability. However service delivery settings include following.

Rehabilitation setting is to support the other support of the rehabilitation settings. There is usually multidisciplinary team involvement in this setting. Typical populations served are usually spinal cord injuries, head injuries, cerebral vascular accidents and/or amputations. AT services is a part of comprehensive rehabilitation program. They may be a part of one of the therapy departments or its own departments. University based programs have largely evolved from a research component and it may provide direct consumer services as well as education and training. The professional involved in the team will depend upon the functional areas addressed by the settings those are the components of based on regionally oriented. State agency-based programs are usually a part of vocational rehabilitation departments or special education departments, which are state-wide programs developed for the purpose of providing AT services to individuals who need it for attaining or sustaining employment. It is to facilitate the education of school-age children. In other cases, there may be a team that covers the entire state. Private practice is usually seen when a small number of AT providers have gone into rehabilitation services. They may provide consultation to state agencies or rehabilitation centres. The population and functional services area varies and depends upon the professional backgrounds of those in the commercialisation. Operated as a non-profit, small business venture with fees for services charged in this program, which are usually based in one local area.

Durable medical equipment supplier is usually a non-profit agency that addresses a range of equipment needs. It provides walking aids, bathing and toileting aids wheelchair and seating systems. Some suppliers may provide communication and environmental control equipment. Third-party payers reimburse the supplier. This supplier also known for its technical resources and ability to provide repair and maintenance services. Volunteer programs can provide AT services that include groups as the volunteers for medical engineering and the rehabilitation volunteer network (Smith 1987, Hobson and Shaw 1987). Most of these groups have developed out of private industry and have as their purpose the provision of a philanthropic service. These groups usually provide services on a local or regional basis.

Veterans' administrative provides AT services at many veterans' administration hospitals. This organisation significantly contributes with service related disabilities, such as veterans with spinal cord injuries have been a major group served by Veterans administrations. Local affiliate of a national non-profit disability organisation is available through their local affiliates. The purpose is to serve individuals with a particular disability. Therefore, the populations served and the functional areas are geared primarily towards that disability group. Programs of local centres are usually administered at the local level may have a complete AT team to provide services, whereas others may only loan equipment. Funding for these agencies is through grants, contracts, donations and fundraising events.

6. ERGONOMICS CONSEQUENCES

Designing for people with disabilities, including the infirmities that flow the process of impairment, means the functional requirements of the user determine which design criteria must be met in the final service or environment. The ultimate objective of design is to develop AT that will maximize the use of a person's functional abilities. How can this be done? One approach to problem identification and problem solving, which can be applied disabled people. Rehabilitation traditinally endouvers to bring people to the level of ADL and ergonomics is largely based on a complementary discipline (Kumar 1989, 1992). The application of anthropometry for the needs of ergonomics in designing for the disabled were discussed by Nowak (1996).

Ergonomists are traditionally non-traditional (Ahasan 2000). Ergonomics principles correspond with human anatomy and physiology especially for the correct selection of assistive devices. Ergonomics configuration provides greater contribution to the overall satisfaction of the user in assessing the user's preferences and predispositions to the use of particular devices. When disabled people's impairment give rises to disability, ergonomists (i.e., human factor engineers) help to compensate these problems by providing special assistance. Ergonomics application is also very important for the intuitive development of appropriate assistance. By the designing, fitting, customising, adapting, applying, maintaining, repairing or replacing of a technical system, ergonomics design and development means to facilitate easy access or functional mobility of disabled people (Ahasan 1998). To improve the effectiveness of AT, ergonomics applications, along with engineering design (Phal and Beitz 1988), is of vital importance because it considers the interactions between the assistive device and the individual user. It directly assists an individual with a disability in the selection, acquisition, or use of a correct device. To enhance a consumer's satisfaction, ergonomics techniques are undoubtedly useful to simulate different approaches and perceptions. AT is to be patient, simple and visible and be marked correctly. AT should be designed in such a way that it induces long-term results and reduces institutional cost. Assistive devices such as door intercom system, electronic control devices, facsimile machines, etc. have to be specially designed so that there is traceable and usable (Grady et al. 1991). People with a progressive disability may not be able to manipulate many complex devices (WeiBmantel et al. 1994) and thus, AT should be easily accessible, safe, reliable and prospective for the people with disabilities.

Ergonomics of AT means to arrange a suitable device with various facilities. The central concern of this concept is that disabled people should be able to manage themselves independently, while using assistive devices (LaPlanate et al. 1992.) The basic needs are supposed to be solved when assistive tools are ergonomically designed and planned. By selecting the ergonomics codes and commands (anthropotechnological data, human factor characteristics), assistive devices must be flexible and tailored to suit the special needs of intended users. Social policy analysis and institutional feature is also important for the ecology of AT. Ergonomically designed design tools and equipment complies with the user's stature and posture, to suit the physiological need of rest, relax, or sleep. Ergonomically designed systems are therefore simple, well suited, modular and extendible rule-based. It is good for the safe handling of assistive devices and guarantees for continuous control. In the selection of proper devices or systems, ergonomics principles are to provide better solutions. Considering the accessibility of assistive devices, ergonomics deals with a consumer's involvement, motivation and its performance (Ahasan 1998). Ergonomics techniques provide correct information about the user's anthropotechnical data, and deals with the repair and maintenance of service delivery systems. Are the selected tools and devices correct for an individual user, how much its costs and how to re-use the device, ergonomists are able to provide all the answers. In the decision making process, ergonomic issues also give proper data and information for correct selection of assistive devices and systems (Table 1).

Table 1. Selective criteria and ergonomic issues

Aims and tasks	Abilities and preferences
Have we identified the actual need of assistive tools according to the tasks? Can we change the activities so that disabled people do not need the assistive devices?	What is the disability? Is it stable or changing? Do we know the physical and mental abilities to suggest for the devices? What type of tools he is currently using?
Will he/she need such an extra assistance (helper, other support, and additional aid) to use the services? What is the easiest and cheapest way to use the devices?	How does he manage daily activities? Is it important to do things as independently as possible? Does the tool help him to be more independent or dependent?
Situation and circumstances	Assistive technology, tools and devices
Where (at home, work or community) will the disabled person use the device? Is the environment physically accessible? Is the transportation available? Can the environment support the device? Are people available to assist the disabled person if needed ? Could the environment disrupt the performances of the devices e.g., in the case of an electronic interface? How would the device affect other people in that environment?	What types of devices do the disabled person prefers? Does the device reflect his/her lifestyle, gender, age, personality or values? Have we considered all the devices, which are available and low cost? How well do other alternative devices work? How much will it cost? How long is it likely to last? Will it be available and easier to buy? How much will it take to care of? Will it be easy to use, maintain, and be taken care of?

7. DISCUSSION AND CONCLUSION

Disabled people are highly susceptible or acutely sensitive. Educating disabled people and teaching them to maintain a healthier and happy life is not easy. And thus, a clear and fairly extensive explanation of providing technology types and its user-involvement is necessary. While using AT, it may be much more cost-effective if it is not suitable for the user. In this context, the role of ergonomists may be too high to improve the user's usability. With the existing local resources, continuous support is needed in the design and development (Sander and McCromick 1987). A partial, reluctant or inappropriate use of technology deserves assessment and intervention. AT becomes wasteful when it does not enhance the person's quality of life. Ergonomics principles must define AT broadly enough to include accessible technology, compelling access needs in the lives of those they aspire to serve. For individuals, the non-use of an assistive device may also lead to a decrease in their functional abilities, restrict freedom and increase their monetary expenses. A better understanding is thus necessary of how and why technology users decide to accept or reject an assistive device.

Disabled people need help to manipulate these technologies properly, and thus for users it is important to understand the type of devices and their actual use. Without his/her expectation of normality, and passive adjustment of AT, there can be continuous uncertainty and changing situations. Difficulties may also arise due to legitimate experimental and subjective aspects of failure of AT. An excessive use of technology could result in the worst quality of life if disabled people's rights and obligations are not sustained in the process of quality and quantity. Disabled people prefer to live in the community they are familiar with, or in their own (or parents) houses as long as they can maintain safe and sound living.

However, we should not think that only prolonging the life expectancy of our disabled friends and relatives, what is worthwhile. From a more optimistic outlook, social and community supports should be considered using moral judgement so that disabled people's lives are happy. Supportive and vocational employment could be a successful way to ensure social integration and to provide an integrated community or special settings. They should meet with the functional specification of AT including its safe and reliable use. There should be a dynamic relationships and a need of vocational rehabilitation in which AT is concerned. Understanding the design implications of disabled people can not be complete without further consideration of economic and commercial factors. Ergonomists have a long-standing interest in this subject, especially on AT which will require an extensive ergonomic assessment of assistive devices if they are to match the needs and aspirations of their users. Physiological and psychological factors are also important for the design of AT. In both ergonomic research and design applications, there are opportunities for innovative work towards meeting needs of disabled people now and the needs of our future selves (Coleman and Pullinger 1993).

For AT to be effective, ergonomics consequences (Ahasan 1998) should be emphasised for a user's satisfaction. A significant human aspect (Sander and McCromick 1987) is also important to consider in the design and development of AT. A user's involvement is to be prioritised in the experiences of long-term benefits, and developed through the use of technology prototype testing by disabled and handicapped users. AT should work well and be simple to regulate. It should be modular based, unique and easily accessible in all situations (Philippen 1994). AT should be based on ergonomics principles so that there is no problem for its application. Professionals should evaluate AT (Galvin and Scherer 1996, Menelsohn 1996) on a case by case basis. Ergonomics applications are also needed in all the stages concerned to teach new skills for using technical tools, devices and systems, rather than merely the testing or evaluation of design and disability (Ahasan 2000). Since ergonomics data in all the aspects of rehabilitation engineering (Scherer and Galvin 1997) are still limited, therefore, co-operation between designers, planners, servicemen and rehabilitation authorities are of prime importance. To minimise for unexpected input, technical systems have to be established with the co-operation of all the parties concerned. Opportunities could, and should be utilised widely, when there is collaboration between family members, social workers, healthcare workers, medical professionals, social workers and/or technicians. Engineers, architects and rehabilitation professionals must be in direct contact with the correct choice of technical devices (Ahasan 1998) so that it encompasses the actual need of disabled people. AT must focus on the basis of client support rather than technology-support. AT must be statuary or voluntary in the sense that contemporary development is effective. The service of rehabilitation counsellors is to be available for these interventions through empowering and advocacy in lobbying on behalf of disabled people. Ergonomic measures should be based on the performance specific design of AT through strategic planning. With adequate quality of supporting devices, AT should be adaptable to the existing environment and enable communication with each other's. To find easy and effective rehabilitation services, the design and development of AT is to be ergonomic. For user satisfaction, AT is to be made for both a user's choice and environment friendly. In any case, a clear and fairly extensive explanation must be considered in the adaptation of an individual user where AT is concerned. An adaptable living environment is to be built for changing personal situations.

This study presents a scenario of AT, where ergonomics applicability is concerned. To foster its priority on ergonomics principles, some initial areas of ATs are described. The hypothesis and the comments however came from the authors' own ergonomic view of suggestions for AT. How people with disabilities can maintain a sophisticated life while using AT, the validity of information and applicability is yet to be satisfactorily known. However the key concepts are to emphasise the importance of the implementation of ergonomics principles. For a user's satisfaction, the author also emphasised the sociotechnical aspects and ergonomics principles of designing AT. It is of vital importance that the rehabilitation process should be unique and truly beneficial for disabled persons. It is left to future researchers to find the comprehensive framework of AT through further studies and research.

REFERENCES

1. Ahasan, M.R., 1998. Ergonomics consequences in the rehabilitation program–with especial reference to the technical aids for disabled people. Paper presented in the International Conference on Open Care (23–25 September 1998), Finland: Oulu Deaconess Institute (In: abstracts, pp.23).
2. Ahasan, M.R., 2000. Ergonomics of rehabilitation–a non-traditional approach. Journal of Prevention,Assessment and Rehabilitation. [accepted to be published].
3. ADA, 1990. Americans With Disability Act 1990. Public Law 42 USC–12111.
4. ADA, 1994. Technology-Related Assistance for Individuals With Disabilities Act (Amendents, PL 103–218).
5. Batavia, A.I. and Hammer, G.S. 1990. Toward the development of consumer-based criteria for the evaluation of assistive technology. Journal of Rehabilitation and Development. 27 (4), 425–436.
6. Benkton, M. 1993. Design for our future selves: the Swedish experience. Applied Ergonomics, 24 (1), 19–24.
7. Blumkin, E.A., 1997. Ergonomics in vocational rehabilitation. In: S. Kumar (ed.) Perspectives in rehabilitation ergonomics. Taylor & Francis, pp. 145–165.
8. Buhler, Ch. And Schmidt, M., 1993. User involvement in evaluation and assessment of assistive technology. In Proceedings of the ECART2 (Stockholm 26–28.5 1993).
9. Chaffin, D.B. and Andersson, G.B., 1984. Occupational Biomechanics. John Wiely & Sons, NY, USA.
10. Cook, A.M. and Hussey, S.M., 1995. Assistive Technologies: Principles and Practice, St Louis: Mosby.
11. Coleman, R. and Pullinger, D.J., 1993. Designing for our future selves. Applied Ergonomics, 24 (1), 3–4.
12. Corso, J.F., 1984. Human Factors in medical rehbilitation: some major problem areas. In: proceedings of the Human Factors and Ergonomics Society. Santa Monica, CA: Human Factors Society. pp. 649–652.
13. Corso, J.F., 1985. Communication, presbycusis, and technological aids. In: H.K. Ulatowaska (ed.), The aging brain: communication in the elderly. San Diego, CA: College Hill Press. pp. 33–51.
14. Dibner, A.S., Lowy, L. And Morris, J.N., 1982. Usage and acceptance of an emergency alarm system by the frail elderly. Gerontechnologist, 22, 538–539.
15. Friis, S., 1987. Use developed prototype systems. In: J. Rasmussen and P. Zunde (eds.), Emperical Foundations of Information and Software Secince III. NY: Plenum Press.
16. Galvin, J.C. and Caves, K.M., 1995. Computer assistive devices and environmental controls. In: R.L. Braddom (ed.), Physical Medicine and Rehabilitation, Philadelphia: W. B. Saunders, pp. 493–501.
17. Galvin, J.C. and Phillips, E., 1960. What is Appropriate Technology? Rehabilitation Engineering Center, Washington, DC: National Rehabilitation Hospital, USA.
18. Galvin, J.C. and Scherer, M.J. (eds)., 1996. Evaluating, selecting and using appropriate assistive technology. Gaithersburg, MD: Aspen Publishers Inc.
19. Grady, A., Kovach, T., Lange, M. and Shannon, I., 1991. Promoting choice in the selection of assistive technology devices. In: H. Murphy (ed.), Technology and Persons with Disabilities (The 6th Annual Conference), Los Angeles: Office of Disabled Student Services, California State University, Northridge, pp. 8315–8324.
20. Gongxia, Y., 1992. Ergonomics of home. Impact of Science on Society, Ergonomics, 165, 23–34.
21. Gould, J.D. 1988. How to design usable systems. In: M. Helander (ed.), Handbook of Human-Computer Interaction. Amsterdam: Elsevier Science, pp. 757–789.

22. LaPlanate, M.P., Hendershot, G.E. and Moss, A.J., 1992. Assistive technology devices and home accessibility features: prevalence, payment, need & trends. Advance Data (National Center for Health Statitics), 217.
23. Field, W.E. (ed.), 1993. Assistive technology needs assessment of farmers and ranchers with spinal cord injuries. West Lafayette, IL: Breaking New Ground Resource Center.
24. Faletti, M.V., 1993. Human factors research and functional environment for the aged. In: I. Altman, J. Wohlwill and M.P. Lawton (eds.), Human Behaviour and the Environment.
25. Fulbright, and Jaworski, 1991. Americans With Disability Act. Special Report, 42USC-12111, PL-101-336.
26. Haigh, R. 1993. The agening process: a challenge for design. Applied Ergonomics 24 (1), 9–14.
27. Higgins, K.T., 1990. Handicapped rights: good intentions, bad policy? Building Supply Home Centres, 159 (7), 20–24.
28. Hogan, P., 1994. Towards an inclusive design philosophy. In: S.-L. Kivelä (eds.), The 2nd postgraduate course on Gerontechnology (7-8th November), Finland: Oulu University.
29. Hobson, D.A. and Shaw, C.G., 1987. Programs development and implementation. In: Rehabilitation Technology Service Delivery: A Practical Guide. Washington DC: RESNA Press.
30. ILO, 1996. Ergonomic checkpoints: practical and easy to implement solutions for improving safety, health and working conditions. Geneva: International Labour Organisation.
31. Kumar, S. 1989. Rehabilitation & ergonomics complimentary disciplines. Canadian Journal of Rehabilitation, 3, 99–111.
32. Kumar, S. 1992. Rehabilitation: an ergonomic dimension. International Journal of Industrial Ergonomics, 9, 97–108
33. Kumar, S., 1996. Preface–Rehabilitation Ergonomics. International Journal of Industrial Ergonomics, 17, 77–79.
34. Jarosz, E., 1993. Anthropometrical data for designing workspace for wheelchair users (In German). Prace I Materialy IWP, 146.
35. Jarosz, E., 1996. Determination of workspace of wheelchair users. International Journal of Industrial Ergonomics, 17, 123–133.
36. Light, E. and Lebowitz, B.D., 1990. Alzheimer's disease treatment and family stress. Hemisphere Publishing Corporation, NY, USA.
37. Nevala-Puranen, N., Simola, A. and Elo, J., 1997. Ergonomics of disabled workers in Finland. In: P. Seppälä, T. Luopajärvi, C.-H. Nygård and M. Mattila (eds.), From Experience to Innovation, Finnish Institute of Occupational Health: Helsinki, pp. 457–459.
38. Levon, B.V. (1994). Housing, elderly and dementia. In: S.-L. Kivelä (ed), The 2nd postgraduate course on Gerontechnology (7-8th November), Finland: University of Oulu.
39. Mann, W.C. and Lane, J.P. 1991. Assistive technology for persons with disabilities. Bethesda, MD: The American Occupational Therapy Association Inc., 2nd ed.
40. Menelsohn, S., 1996. Funding assistive technology. In: Galvin, J.C. and Scherer M. J. (eds). Evaluating, Selecting and Using Appropriate Assistive Technology. Gaithersburg, MD: Aspen Publishers Inc.
41. Molenbroek, J.F., 1987. Anthropometry of elderly people in the Netherlands: research and applications. Applied Ergonomics, 18 (3), 293–301.
42. McKeown T., 1976. The role of medicine; dream, mirage and nemesis. London: Nufflied Provincial Hospital Trust, UK.
43. Mattingly, S., 1981. Rehabilitation today in Great Britain. Update Books, London, UK.
44. Mathews, R.M. and Seekins, T., 1987. An interaction model of independence. Rehabilitation Psychology, 3 (1), 12–14.
45. Menlove, M., 1993. Training teachers to use assistive technology in the education of students with disabilities. In: proceedings of the Rehabilitation Engineering Society of North America.
46. Montana Independed Project, 1993. Seminar Flier, Helena, MT.
47. Nissinen, A., 1994. Prevention in Gerontechnology; what are the possibilities. In: S.-L. Kivelä (eds.), The 2nd postgraduate courses on Gerontechnology, University of Oulu.
48. Nowak, E. 1989. Workspace for disabled people. Ergonomics, 32 (9), 1077–1088.
49. Nowak, E. 1996. The role of anthropometry in design of work and life environments of the disabled population. International Journal of Industrial Ergonomics, 17, 113–121.
50. Orpwood, R., 1990. Design methodology for aids for the disabled. Journal of Medical Engineering & Technology, 14, 2–10.
51. Phal, G. and Beitz, W., 1988. Engineering design: a systematic approach. Berlin: Springer-Verlag.

52. Pheasant, S., 1986. Body space: anthropometry, ergonomics and design. Taylor and Francis: Philadelphia, USA.
53. Pirkl, J.J., 1991 Transgennerational design: a design strategy whose time has arrived. Design Management Journal, pp. 55–60.
54. Philippen, D.P., 1994. Housing, information and communication mobility. In. S.-L. Kivelä (ed.), The 2nd postgraduate course on Gerontechnology, Finland: Oulu University.
55. Peterson, W.A., 1996. Transportation. In Galvin, J.C. and Scherer, M.J. (eds). Evaluating, Selecting and Using Appropriate Assistive Technology. Gaithersburg, MD: Aspen Publishers Inc.
56. Russell, M.L. and Williams, M.R., 1993. American Disabilities Act Handbook. United States: Dearborn Financial Publishing Inc.
57. Rubin, S.E. and Roessler, R.T., 1987. Foundation of vocational rehabilitation process. Texas: Pro-Ed Inc, 3rd ed.
58. Scherer, M.J., 1991. Assistive tecnology use, avoidance and abandonment: what we know so far. In: H. Murphy, H. (Ed.). Technology and Persons with Disabilities (The 6th Annual Conference), Los Angeles: Office of Disabled Student Services, California State University, Northridge, pp. 815–826.
59. Scherer, M.J. and Galvin, J.C., 1997. Assistive tecnology. In: S. Kumar (eds.), Perspective in Rehabilitation Engineering, Taylor & Francis, pp. 273–310.
60. Scherer, M.J., 1993. Living in the state of stuck: how technology impacts the lives of people with disabilities. Cambridge, MA: Brookline Books.
61. Sanders, M.S. and McCormick, E.L., 1987. Human Factors in Engineering and Design. McGraw-Hill, USA.
62. Smith, R.O., 1987. Models of service delivery in rehabilitation technology. In: Rehabilitation Technology Service Delivery: A Practical Guide. Washington DC: RESNA Press.
63. Smith, D.B.D., 1990. Human factors and aging: and overview of research needs and application opportunities. Human Factors, 32 (5), 509–527.
64. Safran, D.G. Graham, J.D. and Osberg, J.S., 1994. Social supports as a determinant of community based care utilisation among rehabilitation patients. Health Services Research, 28, 729–750.
65. Schneider, J., 1997. The use of an ergonomic tool in the implementation of successful workplace rehabilitation. In: Halimathun Mohd Khalid (ed.), Asian Ergonomics (5th SEAES Conference), International Ergonomics Association Press. pp. 298–302.
66. Torres-Davis, A. and Crowl, B., 1995. Assistive technology legislation applied to rural populations. Technology and Disability, 4, 29–34.
67. Torrens, G.E. and Kay, G.H., 1995. Design for physical disability: a discussion of research and development methods through a commercial conclusion. In: proceedings of the design interfaces, University College Salford. European Academy of Design, Vol. 1.
68. WeiBmantel, H., Biermann, H., Muller-Dietsche, A.L. and Schwenk-Schuster, B., 1994. Experiences with the usage of design-rules matching the needs of disabled people. The 2nd postgraduate course on Gerontechnology (7-8th November), University of Oulu.
69. Williams, I., 1992. Prevention and anticipatory care. In: J.C. Brochlehurst, R.C. Tallis, H.M. Fillit (eds.), Textbook of geriatric medicine and Gerontechnology. Churchill-Livingstone, pp. 1029–1037.
70. WHO, 1980. International Classification of Impairments, Disability and Handicaps: a manual classification relating to the consequences of disease. Geneva: World Health Organization.
71. WHO, 1981. Expert Committe on Disability Prevention and Rehabilitation. Geneva: World Health Organization, WHO Technical Reports Series 68B, pp. 7–37.
72. Wright, G.N., 1980. Total Rehabilitation. Boston: Little Brown.
73. Zinder M., 1994. Technique de soins en psychogeriatric; issue d'une approche cognitiviste. Psychologie Medicale, 26 (5), 479–482.

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Fatigue Effects in Computer Tasks

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Fatigue effects brought about by computer encoding were documented in this study using the classification of subjective feelings of fatigue proposed by the Industrial Fatigue Research Committee. The productivity of the workers was also correlated with the time of the day to determine the behavior of productivity and fatigue feelings. The study revealed that the workers experience different subjective feelings of fatigue and strongly feel them as time progresses.

1. BACKGROUND OF THE STUDY

Computers have already been an essential part of our everyday life. With a lot of possible uses from complicated computations to games, this equipment had found its way to modern offices. Most of the tasks that were previously done manually are now computerized and as such, computer workers abound in all offices.

Encoding data into the computer is one task that almost every computer worker does in the office. This requires entering operational data into the computer and typing documents that are needed inside the office. The job requires the worker to sit for long hours in front of the computer and rarely take rest breaks. With the nature of the computer-encoding job, it is a fact that the workers experience fatigue. This feeling of tiredness affects their job performance and well being. Hunting[1] found out that Visual Display Terminal (VDT) operators suffer a variety of muscular complaints, which includes sore shoulder, back pain and sore wrists. Data entry operators suffer the most while interactive operators and standard typists report lower levels of complaints. This study only affirms that computer operators are prone to fatigue because of the requirement of their job.

Unfortunately, however, the condition of computer workers have not yet been studied in the past to discover what are the manifestations of fatigue in them and how these manifestations affect their job performance. Without this knowledge, there is no idea how to improve the job of computer workers in order to maintain a level of productivity that is acceptable to an organization. A survey done by the National Statistics Office in 1998 indicated that an average of 4.42% of the total workforce in 1995 consist of clerical workers. Computer workers are classified under this but there is no data exactly about this. [2]

2. THE PROBLEM

The manifestations and effects of fatigue have not yet been studied among computer workers in the Philippines to determine how worker productivity can be sustained or improved.

2.1 Subproblems:

1. What fatigue symptoms do computer encoders experience?
2. What is the behavior of fatigue feelings throughout a working day?
3. How does fatigue affects the productivity of computer encoders?

3. SCOPE AND LIMITATION

This study will focus on the observation of computer encoders to determine what are the manifestations of fatigue they experience while doing their job. It will also identify the appropriate efficiency and well-being measures to assess the effects of fatigue. In relation to this, time was also correlated to the efficiency of the worker.

The study was limited to observing college students who were given encoding jobs in school due to the difficulty of controlling the experimental environment.

4. RESULTS AND ANALYSIS

The results of the experiment were summarized and analyzed in the succeeding sections of the report. In this part of the study, the mechanics of the study will be discussed as well as the detailed interpretation of results. Statistical analyses will be used to better understand and interpret the data obtained.

Workstation used

The workstation used in the experiment consists of an ergonomic type chair that is adjustable manually and an office table. The chair has a seat pan width of 18 inches and has a height of 22 inches. The table on the other hand has a height of 31 inches from the ground. The surface of the table has a dimension of 20 inches by 30 inches.

Performance measures

The experiment was conducted using 5 subjects, consisting of two females and three males. They were required to use typing software that records their typing accuracy and speed. The ***typing accuracy*** is defined as the percentage of characters correctly typed. An accuracy rate of 96% indicates an average of approximately three mistakes per line on an exercise. ***Typing speed***, on the other hand, is reported as words per minute typed. A word consists of five characters including spaces.

Aside from collecting data on the subjects typing accuracy and speed, ***subjective fatigue ratings*** for each time segment were also gathered. For each time segment covering 1 to 1.5 hours, the subjects were asked to fill out a questionnaire asking the degree of fatigue feeling they experience.

Time segments

A single day of observation is divided into six time segments. A time segment is defined as a length of time that may cover 1 to 1.5 hours when a subject's performance was measured. Each time segment is independent of another time segment. There are three time segments in the morning and three in the afternoon. The first two time segments in the morning consist of one hour each followed by a 15-minute break. The third time segment (also in the morning) is

1.5 hours before lunchtime. In the afternoon, there are also three time segments with the same time divisions as that in the morning.

Fatigue Ratings per Segment

The results of the observation can be seen in the table below. The detailed results include the subjective ratings of fatigue given by the subjects for each time segment and the average of the ratings per time segment.

Table 1
Average Fatigue Ratings Per Time Segment

FATIGUE SYMPTOMS\TIME SEGMENT	**AVERAGE FATIGUE RATING**						**GRAND**
	1	**2**	**3**	**4**	**5**	**6**	**AVE**
Category 1							
Heavy in the head	2.8	2.5	2.0	2.5	2.2	1.9	2.3
Tired	2.9	2.5	1.8	2.2	1.9	1.4	2.1
Yawn	2.9	2.4	1.8	2.2	2.2	1.9	2.2
Drowsy	2.7	2.3	1.8	2.3	2.2	1.7	2.2
Strained eyes	2.7	2.3	1.9	2.5	2.0	1.4	2.1
Clumsy in motion	2.9	2.6	2.3	2.9	2.6	2.2	2.6
want to lie down	2.7	2.4	1.8	2.5	2.1	1.5	2.2
Category 2							
difficulty in thinking	2.9	2.7	2.2	2.7	2.4	2.0	2.5
weary of talking	3.0	2.9	2.7	2.9	2.7	2.4	2.8
Irritable	3.0	3.0	2.7	2.9	2.7	2.5	2.8
unable to concentrate	3.0	2.7	2.3	2.6	2.3	2.1	2.5
forgets things	3.0	2.7	2.4	2.9	2.8	2.3	2.7
makes mistakes	2.6	2.3	1.9	2.2	2.1	1.5	2.1
distorted posture	2.8	2.5	2.2	2.6	2.3	1.7	2.3
no energy	2.9	2.8	2.4	2.6	2.7	1.9	2.5
Category 3							
Headache	2.9	2.9	2.7	2.9	2.8	2.3	2.7
stiff in shoulders	2.5	2.1	1.7	2.1	1.8	1.3	1.9
Lbp	2.8	2.1	1.4	2.0	1.6	1.3	1.9
Thirsty	2.7	2.5	2.0	2.3	2.1	1.9	2.2
husky voice	3.0	2.9	2.7	2.8	2.7	2.4	2.8
feel unwell	2.9	2.9	2.7	2.9	2.7	2.5	2.8
Category 4							
Neck	2.3	2.1	1.5	2.2	1.7	1.3	1.8
Hands	2.4	1.9	1.5	2.3	1.6	1.3	1.8
Buttocks	2.9	2.5	1.9	2.7	2.1	1.7	2.3
Thigh	2.9	2.3	1.8	2.5	1.8	1.4	2.1
Feet	2.9	2.7	2.5	2.7	2.5	2.1	2.6
Arms	2.5	2.1	1.7	2.3	1.8	1.5	2.0

The average fatigue ratings of each category were compared against each other. Category 1-fatigue symptoms refer to feelings of drowsiness and dullness while working. The strongest feeling of fatigue occurred at the end of the observation period. There had been a steady decrease in rating for the first three segments, which indicate that the fatigue feelings get more intense. The trend reversed after the fourth segment that can be attributed to the longer rest period after lunch. However, after that peak in the rating, there had been a steady decrease again up to the last segment of the observation.

Among the fatigue symptoms included in Category 1, the one felt most by the subjects is "strained eyes" and the least felt is clumsiness in motion. One explanation for intense feeling of strained eyes is the long duration of being in front of the computer which was proven by other researchers to cause dry eyes.

A linear trend line was fitted into the data and the computed correlation coefficients revealed that the most negative correlation of each time segment was with tiredness followed by strain in the eyes. This result only proves that as time progresses, the workers are more prone to drowsiness and dullness despite of the presence of breaks in working time.

Category 2 fatigue symptoms refer to difficulty in concentration experienced by the subject. The behavior of the results in this category is very similar to Category 1 results in the first three segments. The fatigue rating slowly decreased before lunchtime and increased afterwards. It can be noted, however, that the average ratings for the fourth and fifth segment increased and the only significant decrease was in segment six.

The most obvious sign that the subjects find it difficult to concentrate is by making mistakes, which can be later correlated with the accuracy of the subjects. The propensity of the person to commit mistakes can be tied up to the feeling of fatigue. As the subject become tired, the more mistakes he/she can commit.

Being irritable, on the other hand, seemed to be not felt by the subjects as can be seen from the graph. The high rating can be explained by the fact that the subjects do not interact with other people so the feeling of irritability did not become obvious.

A linear trend line was fitted into the data and the computed correlation coefficients indicate that seven of the eight fatigue symptoms have strong negative correlation. This indicates that as the time of work progresses, the workers are prone to experience fatigue. Forgetting things did not have a good correlation because the encoding process did not affect the memories of the subjects. This means that the capability to memorize does not diminish as time progresses. In the experiment, the subjects were not required to memorize anything so they were not able to experience forgetting things.

All of the fatigue symptoms had good negative correlation with time just like the other symptoms discussed earlier. This only means that fatigue intensifies as time progresses. Even though a fatigue symptom is not felt so much by the subject, the correlation is good. The data only proves that even the least felt symptom can intensify with time.

The last category of fatigue symptoms considered in this study pertains to body pains felt by the subjects while encoding. As can be seen from Table 1, pain occurs strongly in the hands, neck and arms. The pain in the hands and arms can be explained by the constant pounding on the keys by the subject and the absence of armrest. The neck pain on the other hand can be explained by the absence of headrest of the chair used in the experiment.

The behaviors of the fatigue ratings are almost the same with the results of categories 1 to 3. The fatigue ratings increase after lunchtime and slowly decrease until the lowest point is reached at the sixth segment.

Linear trend lines were fitted on the data and the correlation coefficients obtained revealed that all the fatigue symptoms indicate a good negative correlation with time just like the results for Categories 1 to 3. These results only validate further that fatigue symptoms were felt strongly as time progresses.

Productivity Measures

Aside from getting the behaviors of fatigue ratings over time, the productivity of the subjects were also analyzed. Productivity was defined in this study as accuracy and the speed of typing. The subject is considered productive if he/she types the words correctly and does it at a constant speed.

The data show that there had been a constant decrease in accuracy for the first three segments. After lunch, however, the accuracy increased but decreased during the last segment. The data obviously have no linear correlation with time. This only indicates that even if a person experiences fatigue, the accuracy does not necessarily decrease.

There is a negative relationship between time and speed. As a person experiences fatigue, the speed decreases. There had been a steady decrease in speed for the first four segments but a slight increase was experienced on the fifth and sixth segments. It is interesting to note that after the break of one hour, the speed had not improved unlike the results on fatigue ratings. This only means that fatigue significantly affects the productivity of a worker.

Correlation analysis was performed to determine the relationship of fatigue ratings and productivity, the results indicate that almost all fatigue symptoms are correlated with typing speed but not with accuracy. High correlation coefficients were obtained for category 2 fatigue symptoms, which indicate that, the decrease in typing speed was brought about by difficulty in concentration.

5. CONCLUSION AND RECOMMENDATIONS

This study focused on the issue of fatigue among computer encoders and how it affects their performance. Some of the conclusions that can be obtained from the experiment are the following:

- The fatigue symptoms that were strongly felt by the encoders are tiredness, strained eyes, committing mistakes, stiffness on the shoulders, low back pain, neck pain, hand pain and thigh pain.
- Fatigue is felt more intensely as working time progresses. After 3.5 hours of working, fatigue ratings decreased. However, after a long break for lunch, the intensity of fatigue feeling decrease.
- The accuracy of a worker is not affected by fatigue. The experiments showed that there had been no decrease in accuracy as working time progresses. However, the speed of typing decreases as fatigue sets in. There had been a decrease in typing speed at the latter part of the day.

This study had been an initial step to investigate the working conditions of computer encoders. The results, however, were confined to determining the effects of fatigue. Further study is recommended to establish ideal working conditions to improve worker productivity and well-being.

The fatigue ratings can be sought to improve by future researches by identifying the aspects of the computer workstation that can be redesigned.

[1] Hunting, W, Laubli, T. and Grandjean. 1980. Constrained postures and VDU operators. Ergonomic Aspects of VDT, Taylor and Francis Ltd. London.
[2] National Census and Statistics Office. 1998. Philippine Statistical Yearbook.

REFERENCES

1. Bloswick, D.,Gerber, A., Sebesta, D.,Johnson, S. and Mecham, W. 1994. Effect of mailbag design on musculoskeletal fatigue and metabolic load. *Human Factors*. 36 (2), 210-218.
2. Brown, I.D. 1964. The measurement of perceptual load and reserve capacity. *Transactions of the Association of Industrial Medical Officers*, 14, 444-449.
3. Broadbent, D.E. (1957). Effects of noise on behavior. In C.M. Harris (Ed.), Handbook of Noise Control (pp 1-33). New York: McGraw-Hill.
4. Fernstrom, E.,Ericson, M and Malker, H. 1994. Electromyographic activity during typewriter and keyboard use. *Ergonomics*, 37, 3, 477-484.
5. Finkelman, J. 1994. A Large Database Study of the Factors Associated with Work-Induced Fatigue, *Human Factors*, 36, 232-243
6. Hunting, W, Laubli, T. and Grandjean. 1980. Constrained postures and VDU operators. Ergonomic Aspects of VDT, Taylor and Francis Ltd. London.
7. Kogi, K., Saito, Y. and Mitsuhashi, T. 1970. Validity of three components of subjective fatigue feelings, *J. Science and Labour*, 46, 251-270.
8. Matsumoto, K and Harada, M. 1994. The effect of night-time naps on recovery from fatigue following night work. *Ergonomics*, 37, 899-907.
9. National Census and Statistics Office. 1998. Philippine Statistical Yearbook.
10. Oberg, T. 1994. Subjective and objective evaluation of shoulder muscle fatigue. *Ergonomics*, 37, 8, 1323-1333.

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Game Controller Design with Reduced RSI Risk Using Ergonomic Design Criteria

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The aim of this study was to design a new game controller with reduced RSI risk. To find out what causes RSI risk research has been performed with the use of existing game controllers. Excursions of the upper extremity during play with different controllers have been measured. The angles between the limbs observed in different controllers were compared. Furthermore a study about personal preferences with regard to RSI related items has been done using a questionnaire. Answers to the questions were used to create a list of design criteria. Example of an item in this list is that holding the device for a long period of playing should not cause pressure spots on the hands. Static positions prolonged are excluded by the use of flexible handles to change the grip. In the new design also the use of triggers for as well the index- as the middle fingers was introduced. Which spreads the actions over different fingers, which may reduce RSI risk.

1. INTRODUCTION

Since more than a decade the play of computer games is strikingly increasing. For PC use controllers are manufactured in different countries with many designs. In general these designs look similar, build up by two handles with positioned buttons for targeting, shooting, racing, jumping, kicking or related ways of simulated competing. In detail differences can be observed in especially the handgrip and triggers. The game controller is connected to the PC with a flexible electric wire, while during play the keyboard is not used.

During play the physical effort is not only restricted to the operation of the buttons. In some players the grip on the handles becomes forceful. Arm position and trunk posture in general are quite static, and sometimes asymmetric and extreme. Also because games can last several hours uninterrupted, it is plausible that the incidence of physical complaints is increasing. As also known from other computer interfaces like mouse and keyboard, complaints related to game controllers are called Repetitive Strain Injury. This is a collective name of different complaints, located in the hand-arm-shoulder complex. This indicates that the etiology of soft tissue lesions is connected to the mechanics of the major joints as well as the mechanics of the individual fingers. (Pascarelli & Quilter, 1994). In the market of game controllers an evolution is in progress, frequently new designs become commercially available. The question arises how far new devices anticipate on the RSI problem. We expect that this is limited because design criteria are still scarce. Therefore we decided to start a biomechanical study on the effect of the use of game controllers and to formulate design criteria. Aim of this study is to design a new game controller, which reduces RSI risk.

2. WRIST EXCURSIONS IN GAME CONTROLLER USE

2.1. Methods and materials

In this research joint excursions of the arm using different controllers were compared by measuring them with an instrument that measures the angle between the limbs.

To estimate risky postures of the upper extremity, a scale is defined of the different movements of each joint of the arm which contains zones (described in angles).

There are data for the comfort zone and discomfort zone. These zones are based on the maximum excursion of each joint, this resulted in the following division of zones:
the neutral/comfort zone contains 30% of the maximum, the intermediate zone contains 30-70% of the maximum, the discomfort zone contains 70-100%. (Steenbekkers & v. Beijsterveldt, 1998)

Graphs were used to present the percentage of excursions in the different zones. (See figures 1-3).

Using this zone division four game controllers were compared, the controllers used are:

- Microsoft® Sidewinder® Freestyle Pro
- Microsoft® Sidewinder® Game Pad
- Logitech™ Wingman Game pad Extreme
- Logitech™ Thunderpad

This research is done in an office with a table and a PC, the four game controllers, a chair for the subject, a video camera and measuring-instruments. One game was used to make a good comparison. The game used is A2-racer, a car-race game of Davilex.

During the research actions of fingers, wrists, forearms and elbows are registered by the video camera. The postures and the reach of buttons on the videotape are analyzed afterwards. The excursions where measured every 20 sec. during playing the game uninterrupted.

Because in the Microsoft Freestyle and the Logitech Wingman a motion sensor is implemented, these controllers are tested two times per subject; using the motion sensor and using the directional button. The motion sensor feels the angle at which the controller is being held and transfers that into an action. This leaves the fingers free. For this research four subjects were used.

2.2. Results

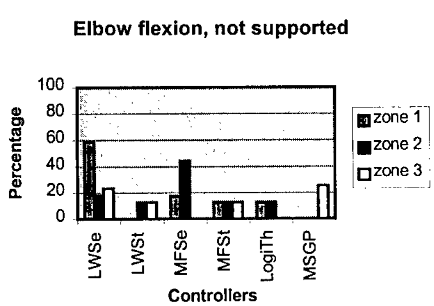


Figure 1

As expected using the motion sensor of the Logitech Wingman and the Microsoft Freestyle many movements in the intermediate and the discomfort zone appeared. Especially in wrist and elbow movements.

For this we can conclude that using a motion sensor has a negative effect on the RSI risk.

Looking at the excursions of the joints when not using the sensor mode, it appeared that the movements of the shoulders stay in the neutral zone.

A lot of movements are seen in the intermediate zone of extension of the wrist using the Logitech Thunderpad. This can be explained by the handles being short. It is possible to hold the lowest roundings of the device in the palm of the hand by which wrist extension occurs. Ulnar deviation at the Microsoft Freestyle can be ascribed to the weight in front of the device which causes forward tilt of the controller and bending down of the hands.

Ulnar deviation outside the comfort zone when using the Microsoft Game Pad appears because the device is straight and points up. Although it is not necessary, subjects try to reduce this by pointing down the device which causes ulnar deviation.

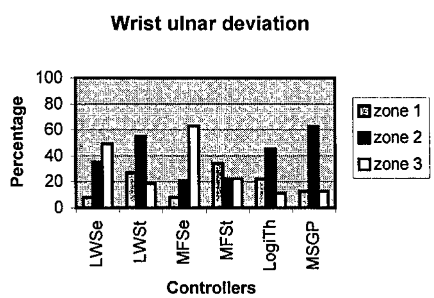


Figure 2

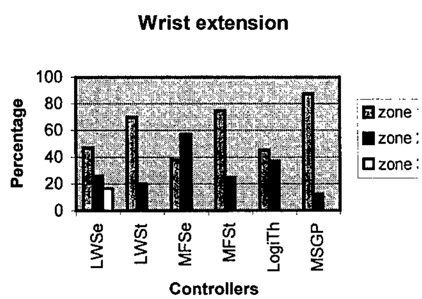


Figure 3

2.3. Figure 1-3

Recordings of joint positions during play. Percentage of time in zone 1 (neutral/ comfort zone), zone 2 (intermediate) and zone 3 (discomfort).

The graph for wrist extension is derived by eliminating flexion from the flexion/extension movements. The same for ulnar deviation, eliminating radial deviation.

LWSe= Logitech Wingman Sensor
LWSt= Logitech Wingman directional button
MFSe= Microsoft Freestyle Sensor
MFSt= Microsoft Freestyle directional button
LogiTh= Logitech Thunderpad
MSGP= Microsoft Game Pad

3. SURVEYING USERS OF GAME CONTROLLERS

3.1. Methods and materials

This study regards personal preferences with regard to RSI related items. The research has been done using a questionnaire of 19 questions. 16 test subjects were used, under the 16 test subjects there are different groups; they are divided into eight persons who are 14 to 18 years old and eight persons who are older than 18, the population also exists of eight males and eight females and eight persons with small hands and eight persons with large hands.

The division in small and large hands is based on the length of the hand, for small hands approximately P5 of the population, large hands approximately P95 of the population.

The subjects could hold the controllers during the whole test. The controllers were not connected to the PC, so the test subjects could only compare the different controllers by holding them in their hands.

The questionnaire was based on different literature sources on RSI.

Questionnaire:

1. Is the upper arm and shoulder relaxed while holding the device?
2. Are the wrists in a natural posture?
3. Is horizontal position of the forearm possible?
4. Is there restriction during support of the forearm?
5. Do hands and fingers have a good grip?
6. Can fingers and thumbs be held in a comfortable posture?
7. Is pressing the buttons heavy?
8. What do you think about the velocity of reflection of the buttons?
9. Is there a comfortable reach of the buttons?
10. What do you think about the size of the device?
11. How do you feel about the weight?
12. Does the device have an ergonomically shape?
13. Is there an equal distribution of the weight?
14. What do you think about the shape of the device?
15. What do you think about the shape of the directional button?
16. What do you think about the shape of the trigger buttons?
17. What do you think about the shape of the buttons on top?
18. How do you feel about the colors?
19. What do you think about the structure, texture of the material?

The answers to the questions had to be given on a VAS-scale of 10 cm. Using the answers at the questions, a Analysis of Variance has been done using SPSS 8.0, with a significance level of $\alpha=0.05$.

3.2. Results

No significant differences between the devices were found for the whole subject group. Therefore each question was examined as well as the different groups: men, women, subjects with small and big hands and different age groups.

Table with significance scores
(Whole population, for each question)

Question	Significance	Worst device	Best device
1. Upper arm and shoulder relaxed	NS	-	-
2. Wrists natural posture	NS	-	-
3. Forearm horizontal position	S (0.008)	1	2 en 3
4. Restriction during support	S (0.001)	1	2 en 3
5. Hands and fingers good grip	NS	-	-
6. Comfortable posture fingers	S (0.015)	1 en 3	2
7. Force pressing the buttons	S (0.040)	3	4
8. Velocity of reflection of the buttons	NS	-	-
9. Comfortable reach buttons	S (0.010)	1	2, 3 en 4
10. Size of the device	S (<0.0001)	1 en 3	2 en 4
11. Weight	NS	-	-
12. Ergonomically shape	NS	-	-
13. Distribution of the weight	S (<0.0001)	1	2, 3 en 4
14. Shape of the device	S (0.025)	1 en 3	2
15. Shape of the directional button	NS	-	-
16. Shape of the trigger buttons	S (0.018)	3	1, 2 en 4
17. Shape of the buttons on top	S (0.013)	3	1, 2 en 4
18. Colors	S (0.015)	3	1 en 2
19. Structure, texture of the material	S (0.010)	4	1, 2 en 3

Device 1 is the Microsoft Sidewinder Freestyle Pro
Device 2 is the Microsoft Sidewinder Game Pad
Device 3 is the Logitech Thunderpad Digital
Device 4 is the Logitech Wingman Game pad Extreme

In the second column S means that this question has a significant difference for the whole population. NS means Not Significant, no significant difference between the devices. Because the different age groups are not a significant factor, group matching for this aspect is not necessary.

Gender gives a significant difference. It seamed that women judge the controllers more positive than men. For gender there is found no difference between the devices.

It is important to divide subjects with small and big hands equally because a significant difference is found between the devices for the subjects with small hands. This group judges the Logitech Wingman Gamepad Extreme as the best device and the Logitech Thunderpad Digital as the worst. Between gender and age groups no significant differences were found.

4. SUMMARY

Groups	Best controller	Worst controller
14-18 year olds	Logitech Wingman Gamepad Extreme	Microsoft Sidewinder Freestyle Pro
18 year and older	Logitech Wingman Gamepad Extreme	Logitech Thunderpad Digital
Small hands	Logitech Wingman Gamepad Extreme	Logitech Thunderpad Digital
Large hands	Logitech Wingman Gamepad Extreme	Logitech Thunderpad Digital
Men	Logitech Wingman Gamepad Extreme	Logitech Thunderpad Digital
Women	Microsoft Sidewinder Game pad	Logitech Thunderpad Digital
All	Logitech Wingman Gamepad Extreme	Logitech Thunderpad Digital

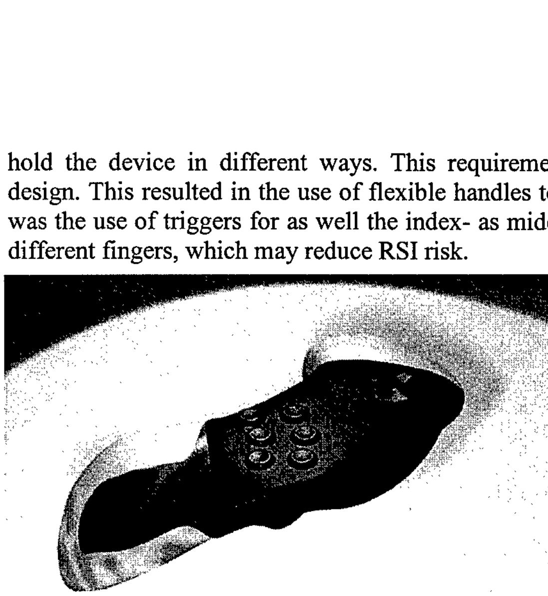
4.1. List of design criteria

In this report we restricted to ergonomical criteria:

- The controller should have handles which support the whole hand. The handles should not be too thick (< 4.5 cm) to obtain a natural posture of the hand and fingers. The length of the handles must not be too big to avoid restricting the support of the forearm on the table. The handles should not be too short for the hand and fingers to get a good grip. Finger flexor and extensor tendons are interconnected by collagenous fibres, therefore finger positions should not deviate too much.
- It must be possible to hold the device in more different ways. When the design forces the hands in a fixed position, the only solution would be the alternating use of different controllers. Users should be able to choose a comfortable grip.
- The top side of the controller with the buttons should not be straight with the handles, otherwise ulnar deviation will occur. The angle between the top plane and the handles should not be too small (> 130°) to cause a good vision and reach of the buttons.
- The triggers should have a long dimension (min. 3.5 cm), to avoid too much flexion of long index- and middle fingers and to make control of the buttons possible for small fingers. This can be realized by placing the buttons in the middle of the controller and they should be long enough.
- The device should have an ergonomically shape, no edges which can cause skin pressure peaks, stuck of fingers and impingement nerves and tendons.
- Excursions of the hand should stay in the neutral zone. This should be realized by the shape and position of the handles. The distance between the handles and the angle between them should position the hands as much as possible in a straight line with the arms. Therefore the angle between the hands should be at least 25°.
- The buttons should not be too near to the wrist to avoid extreme bending of the fingers. They should not be too far to reach for a natural posture of the wrist. The buttons should not be too much at the side of the controller to avoid extreme extension of the hand.
- Buttons should not require too much force, not too small as well in order to get a good feedback pushing the button.

4.2. Design proposal

The comment that holding the device for a long period of playing time with the hands in the same position causes pressure spots and the fact that holding joints in a static posture for a long time contributes to RSI risk, resulted in the design criterium that it must be possible to hold the device in different ways. This requirement was a starting-point for making the design. This resulted in the use of flexible handles to change the grip. Another starting-point was the use of triggers for as well the index- as middle fingers. This spreads the actions over different fingers, which may reduce RSI risk.

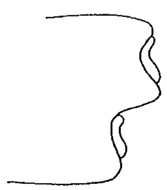
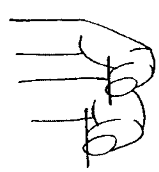


The handles of the controller have an oval shape which causes a comfortable grip for hand and fingers. The controller allows for an almost vertical position of the hands and therefore the hand and wrist approach the neutral position. This is important to reduce RSI risk. For the flexible handles a silicon gel is used, this is transparent which raised the idea to make the handles transparent which makes the inner form visible. A nice effect. The controller has a screen in front for the infrared control. The directional button is pointing straight ahead and contains a hole in the middle to make positioning of the thumb easier. The four trigger buttons on the bottom are formed ergonomically.

5. DISCUSSION

The result of this study is a design of a game controller which may reduce RSI risk. For this device we developed design criteria aiming at exclusion of extreme joint excursions and minimization of force and repetitions. When comparing this new design with existing game controllers we think that significant improvement is achieved in different parts.
Furthermore, with reference to RSI literature the new device meets the following basic requirements:

The device in the present stage could not be tested when playing games because it only presents the outer dimensions. The next step is the fabrication of a working prototype. However the model in its present form already gives the answer on how joint positions are in operation.

Item	Motivation
Changing grip by the use of the flexible material.	Change of posture is better than holding the same static posture.
Ergonomically shaped, handles enough grip by the use of the flexible material; no edges.	No compressing of nerves etc.
Use of triggers for index - and middle fingers.	Less actions of thumb, actions performed by other, strong fingers.
Right angle between handles.	Hands in a straight line with the arms.
Finger positions should not deviate too much, while finger flexor and extensor tendons are interconnected.	Fingers easy to position, smooth surface.
Angle between top plane and handles not too big, device not too straight.	Avoids ulnar deviation by reducing pointing up of the controller.
Angle top plane and handles not too small.	Provides good sight and reach of buttons.
Long triggers and placed in the middle of the device.	Usable by more lengths of fingers, not too much flexion of the fingers.
Possible to make a good difference between directions of directional button.	Avoids unnecessary mistakes, repeating of action and therefore it reduces actions.
Dimensions directional button.	Directional button not too big to avoid covering too much distance.
Distance between the buttons.	Too much distance between the buttons causes the fingers to move between too much distances.
Two triggers positioned in different planes. 	Easier positioning, not getting confused at which button the finger is located, approaches neutral position of the fingers. 
Buttons have holes on top in the middle.	Fingers do not slip off the buttons, less muscle force.
The buttons must return quickly to their original position.	Not necessary to lift up the fingers to get the buttons back in the original position. Less actions.
Buttons easy to reach.	Natural posture, no overstressing or too much bending.
Force on buttons	Not too high, 0.5N – 0.6N.
The weight should be divided equally to provide stability.	No need to reduce this in ulnar deviation.
The controller causes an almost vertical position of the hands.	Hand and wrist approach the neutral position, which reduces RSI risk.

6. CONCLUSIONS

From this study we conclude the following:

- In game controller use extreme joint excursions occur, in particular ulnar deviation and extension of the wrist.
- Users mention comfort as of primary importance
- Main features of the new design are exclusion of extreme wrist excursions, less finger flexion, optimal reach of buttons, minimization of the level and the number of repetitions of force exertion and elimination of areas of skin pressure peaks.

REFERENCES

1. J.N.A.L. Leijnse, C.J. Snijders, J.E. Bonte, J.M.F. Landsmeer, J.J. Kalker, J.C. van der Meulen, G.J. Sonneveld, S.E.R. Hovius, 1993. The hand of the musician: the kinematics of the bidigital finger system with anatomical restrictions. J. Biomechanics, Vol. 26, 1169-1179
2. Karwowski, W. & Marras, W.S. The occupational ergonomics handbook. CRC Press, 1999.
3. Marklin, R.W., Simoneau, G.G. & Monroe J.F. The effect of split and vertically-inclined computer keyboards on wrist and forearm posture. Proceedings of the human factors and ergonomics society, 41th annual meeting, 1997.
4. Steenbekkers, L.P.A. & v. Beijsterveldt, C.E.M. Design-relevant characteristics of ageing users. Subfaculty of industrial design engineering, Delft university of technology, 1998.
5. Pascarelli, E. & Quilter, D. Repetitive strain injury, a computer user's guide. John Wiley & Sons, Canada, 1994.

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Improving Manual Material Handling to Decrease Workload of Female Workers of a Canning Factory

H. Sudhana

Female workers in the packing section of canning factory in Denpasar have main duty cleaning corned beef cans and then packing them into carton box. Besides that they also have additional duty which is incidental in nature, that is, moving packing boxes which are going to be put onto the trucks. Subjective complaint as a result of this additional workload comes from all the female workers. They thought that the job was very tiring and evoked musculoscletal pains. Improvement of the ways of lifting, carrying, and lowering boxes had been done for 24 subjects of the research. Findings showed that there was a decrease of workload, in this case, the percentage of cardiovascular load from 70.98 % to 29.62%. The index of WBGT indicated that before the improvement the duty required 75 % work and 25 % rest every hour after the improvement, however, the work could be done for 8 hours (8 hours continuous work). Besides that there was a change of perception over the workload, as seen from SWI index from 3.72 to 1.72 after improvement of manual material handling was done.

1. INTRODUCTION

Female workers in the packing section of canning factory in Denpasar have main duty cleaning corned beef cans and then packing them into carton box. Besides that they also have additional duty when shipment of the goods is done, that is, moving packing of corned beef onto the trucks.

Working process is done in turn by a team work of eight persons. By standing in line on a truck, each box measuring 29.5 cm long x 20 cm wide x 24.5 cm high and weighing 13 kg is lifted, carried, an put onto the truck with more than 1000 boxes in number in each shipment.

Unnatural posture such as stooping when lifting and lowering the load, swinging her arms when handing over the load to her fellow worker is found. Subjective complaint as a result of this hard job is made by every worker, either a musculoscletal complaint or dissatisfaction towards their work, as this is thought of as being an extremely hard job by them.

Research results concerning the effect of workload in manufacturing industries, find high level of musculoscletal complaint such as low back pain as a result of manual material handling or as a result of unnatural posture (Chavalitnikul, cs, 1995. Vilki, cs, 1993, Wilfrid, 1993). Complaint of fatigue, stress, and dissatisfaction as a result of factory work that demands self adjustment is reported by Kogi (1997), and also Khaleque and Hossein (1993). This study aims to see the influence of the improvement of manual material handling over decreased of workload.

Based on the problem above, improvement is made on the ways of lifting, carrying, and lowering packing box. The ways adopted is by practicing lifting and lowering as well as making carrying equipment aid, trolley, to be used on a truck.

2. MATERIAL AND METHOD

The research was done in canning factory in Denpasar in 1999. Design used was Treatment by subject design.

2.1 Subject

The 24 subjects are female workers at the packing section. Subjects were chosen by means of simple random method with the following criteria. Age is maximally 40 years, healthy, minimally having 2 years' work experience

2.2 Procedure

The subjects are divided into three groups, each group consists of 8 persons.

2.2.1 Measuring Workload

To know the influence of work improvement on workload, heart rate and subjective complaint were measured, all of these were done before and after work improvement. Heart rate was measured by ten-pulse method over resting pulse, working pulse, difference between the resting and working pulse, and calculated based on % CVL. Subjective complaint was used as data by means of Subjective Workload Index (SWI), developed by Cergo International Belgium (1995). To know the allocation of work-rest period, WBGT index was measured before and after improvement.

2.2.2 Anthropometry of Subject

Anthropometry data of the subject in standard standing posture (Pheasant, 1988) was measured to make the size of trolley. The data needed were knuckle height to obtain the height of the trolley base and elbow height to obtain the height of the trolley handle.

2.2.3 Analysis

Characteristics of subject, anthropometry data, and the condition of work environment are analyzed descriptively. To uncover the influence of work improvement, the average of heart rate, and the average index of subjective complaint, before and after the improvement are compared by using *t* test with level of significance $p = 0.05$.

3. RESULT AND DISCUSSION

3.1 Subject Characteristics

Subject characteristics such as the average of age, height and body weight, blood pressure, work experience are presented in Table 1.

Table 1. Subject Characterictics

No	Variable	Mean	SD	Range
1	Age (year)	33,37	2,63	29 – 39
2	Height (cm)	154,02	5,11	145 – 164
3	Weight (kg)	54,04	7,71	46,5 – 70,5
4	Blood Pressure			
	Sistolic (mmHg)	112,08	11,2	90 – 135
	Diastolic (mmHg)	74,37	7,56	60 – 80
5	Experience (year)	12,04	2,80	3 – 22

From Table 1, it can be seen that the average of subject age is 33.7 years, status of health is within the normal limit. Commonly they have worked in the packing section for more than 12 years.

3.2 The Change of Heart Rate and Workload

The indicator of work load in this study is the change of heart rate and % CVL and subjective workload index between before and after the improvement. In Table 2, the change of heart rate, % CVL and WBGT index, as well as SWI index are presented.

Table 2. The Change of Heart Rate, % CVL, WBGT Index, SWI Index

No	Variable (n = 24)	Before Improvement		After Improvement		t	p
		Mean	SD	Mean	SD		
1	The Resting Pulse (beat/minute)	82,59	2,83	83,24	2,69	1,78	0,087
2	The Working Pulse (beat/minute)	121,99	2,00	100,00	1,79	-35,81	0,00
3	The Difference (beat/minute)	39,40	3,36	16,71	3,48	-30,00	0,00
4	% CVL	70,98	5,75	29,62	6,05	-30,03	0,00
5	WBGT Index (°C)	26,74	0,61	27,71	1,38	1,59	0,15
6	SWI Index	3,72	0,33	1,72	0,38	-19,31	0,00

From the table, it can be seen that the heart rate that rests between before and after work improvement is not significantly different. The improvement of manual material handling in this study is done by practicing the ways of lifting and lowering object ergonomically, that is, lifting and lowering the object with one leg stepping forward in order to achieve stability, bending the knee and hip as well as straightening the back, the object being carried must be near the body (Bridger, 1995. Dul and Weerdmeester, 1993). The way of transportation is improved by using trolley. After this improvement, the working pulse decreases significantly from 121.99 pulses per minute indicting the moderate category of work to 100.00 pulses per minute or the category of light work (Granjean, 1988). The difference between working pulse and resting pulse is also significant, that is, from 39.40 pulse per minute to 16.71 pulses per minute.

The indicator of workload in this study is % CVL. Before the improvement of % CVL 70.98% indicating cardiovascular load of heavy category, and if related to WBGT index, it needs 75 % work and 25% rest for every hour. After the improvement of % CVL to 29.62% indicating light cardiovascular load related to WBGT index, the work can be done for 8 working hours (Manuaba and Vanwonterghem, 1996).

The subjects' perception toward their workload can be seen from Subjective Workload Index. Before the improvement it is 3.72 while after the improvement it is 1.72. This means before the work improvement it is regarded as disturbing the comfort as it is not interesting, tiring, risky because they can slip as the plastic cover on the truck floor is very slippery or they can be struck down by boxes. After the improvement that kind of feeling disappeared, as tiredness reduced and the presence of equipment aid makes the work more interesting and they are more relaxed.

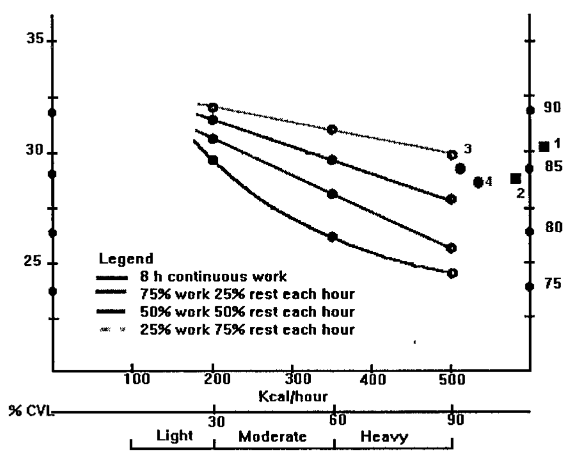
4. CONCLUSION

From the result and discussion, it proves that the improvement of manual material handling can decrease workload.

REFERENCES

1. Bridger, RS. 1995. *Introduction to Ergonomics*. New York: Mc Graw Hill, Inc.
2. Chavalitnitikul, C. Nopteepkangwan. Kanyanopas. 1995. Improvement of lifting heavy objects work. *Human Ergology 24*. Japan: Centre for Academic Publication.
3. Grandjean, E. 1988. *Fitting the task to the Man*. A Textbook of Occupational Ergonomics. 4th Edition. London: Taylor & Francis.
4. Kogi, K. 1997. Psychosocial Issue. *Environmental Management and Health*. Vol 8 No 5.
5. Manuaba, A and Kamiel Vanwonterghem. 1996. *Improvement of Quality of Life. Determination of Exposure Limits for Physical Strenous Tasks Under Tropical Conditions*. Final Report. Dept. of Physiology School of Medicine Udayana University – CERGO International Brussels, Belgium, The Commission of the European Communities Brussels, Belgium.
6. Pheasant, S. 1988. *Body Space, Anthropometry, Ergonomics and Design*. London: Taylor and Francis.
7. Subjective Workload Index, 1995.
8. Vilki, M. Matila. Siuko. 1993. *Improving Work Posture and Manual Material Handling Task in Manufacturing*. A Case Study. The Ergonomics of Manual Work. Taylor and Francis.
9. Wilfried , T. 1993. *From manual lifting to manipulator and organizational changes*. The Ergonomics of Manual Work. Taylor and Francis.

WBGT INDEX AND WORK-REST PERIOD



Note :

Po (before improvement) % CVL 70,98 ; WBGT index 26,74 °C

P1 (after improvement) % CVL 29,62 ; WBGT index 27,71 °C

PART FIVE

Military Ergonomics

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

An Investigation of Luminance Effects on Visual Performance in Military Cockpit Tasks

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As Operation Desert Storm demonstrated, there is an increasing dependence on night vision devices such as night vision goggles (NVGs) in military missions. One human factors concern related to this development, is the compatibility of luminance level between NVGs and cockpit displays such as the horizon display. Landmark work reported by US Air Force involved subjects looking through an NVG at an alphanumeric stimulus followed by naked eye viewing of an analogue ball horizon display. This paper reports a follow-up of previous work by the US Air Force and Rabin and Wiley (1994) and extends the scope of investigation in several directions; namely the introduction of ecologically valid visual stimuli for the NVG view, and a study of potential visual performance degradation when transiting between NVG and cathode ray tube (CRT) horizon display views.

1. BACKGROUND

In recent decades, military forces around the world began to realise the importance of round-the-clock operational capability. As demonstrated in Operation Desert Storm, night operations are critical in modern warfare. This motivation to overcome limitations arising from conditions such as bad weather, long hours of darkness, etc. led to the development of night vision devices (NVDs) to enhance the visual capability of pilots (Day, 1996).

With advancements in technology, the human component often becomes a critical link in the human-machine system. As such, it is vital to address human factors issues during the design, development and implementation of these sophisticated systems. In the case of NVGs, biocular, binocular and monocular models are available. It is thus important for commanders to understand both technical specifications and user requirements, as each type of NVG differs in advantages and shortcomings when operated under various conditions. This concern is critical in the case of aviation as pilots must be provided with the most appropriate NVG, for example to ensure visual compatibility when transiting between different luminance levels attributed to the NVG and aircraft controls, indicators and displays. The ability of a pilot to make split second decisions would depend on this visual compatibility over a wide range of operation conditions, e.g. during dawn and dusk.

In this respect, total dark adaptation does not occur during military operations, as visual performance is demanded within seconds, not within minutes of luminance transition. In particular, NVGs introduced into the cockpit may not be compatible with other displays (see Figure 1) which have been optimised for night operation by naked eye.

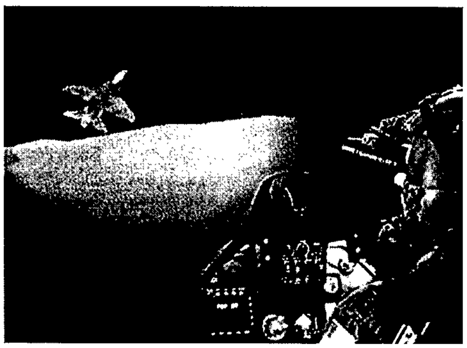


Figure 1. A simulation of an NVG and cockpit view
(Extracted from http://www.alhra.af.mil)

This situation raises a number of questions concerning compatibility in luminance levels and in the visibility of displays, when a pilot transits between looking at photo-amplified images in the NVG and at other cockpit displays with the naked eye. The study by US Air Force involved subjects looking at a static alphanumeric stimulus through an NVG followed by an analogue ball horizon display with the naked eye. Although the results of this work indicated that visual performance was affected, it suffers from a number of limitations with respect to the ecological validity of the stimulus and the narrow scope of investigation. However, it is clear from their results that visual performance can be affected by transitions between devices of widely varying luminance level. More specifically, the US Air Force believes that no measurable effect on visual acuity would arise unless the difference in luminance between the adapting and test fields is at least 2 log units.

Rabin and Wiley (1994) examined transient effects on visual resolution when switching from a forward-looking infrared (FLIR) device to an NVG. Their objective was to determine whether exposure to different display luminance when switching from a higher luminance display (i.e. FLIR) to a lower luminance display (i.e. NVG) would lead to adverse effects on visual resolution. Their results showed a significant reduction in letter recognition in the first second of switch from FLIR to NVG. With brighter luminance, visual loss lasted up to 4 seconds including a 2X reduction in visual acuity and a 3X reduction in contrast sensitivity. By varying size, contrast, lighting conditions and duration of exposure, they estimated the magnitude and duration of visual loss after switching from a very bright FLIR display. This transient reduction after switching from a FLIR display to an NVG could interfere with object recognition during critical periods of aircraft control, target acquisition, and firing. Rabin and Wiley (1994) recommended that large differences in luminance should be avoided to optimise visual performance and pilot safety. Since the study was conducted with simulated FLIR and NVG displays, caution should be taken to extrapolate the findings to cockpit devices. In addition, their study used a letter recognition task which did not take into account the dynamic imagery experienced during flight operations.

From the studies on the effect of transition viewing between devices of different luminance levels, it is evident that visual performance was affected. The studies may be distinguished as follows. The US Air Force investigated transitions between a brighter NVG and a duller analogue horizon display, while Rabin and Wiley (1994) compared a brighter FLIR and a duller NVG. With the emergence and implementation of CRT-based cockpit devices, a wider study of devices other than the FLIR may be pertinent; e.g. when pilots transit between the NVG and CRT horizon display.

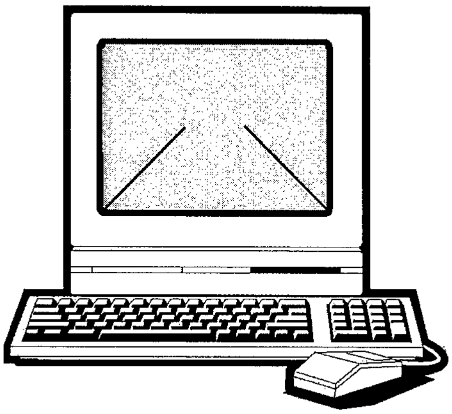
Based on informally reported NVG operation conditions, the luminance level of cockpit displays varies in such a way that the symbology projected onto the head-up display (HUD) when viewed through the NVG could be brighter at times and the targets brighter at other instances. This is dependent on time of the day, and other factors. As such, it is important to identify the maximum allowable difference in luminance level in the transition between devices to reduce visual degradation.

This paper reports a study on potential differences in effect on visual performance when an analogue (addressed by US Air Force) and CRT horizon display is operated with an NVG. It extends the scope of previous studies to include the use of more ecologically valid stimuli for the NVG view (as opposed to a letter recognition task). Various military targets such as tank and aircraft are shown at different locations and under different terrain masking. This consideration is important to better characterise the luminance level of an operationally realistic NVG view.

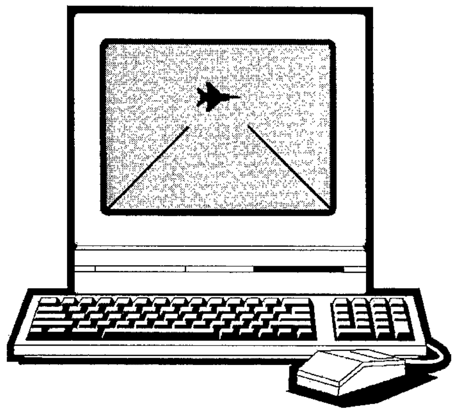
2. EXPERIMENTAL DESIGN AND SET-UP

The experiment involved an assessment of subject performance in three tests; namely trial, reference and transition viewing tests. The trial test is to familiarise subjects to the targets they are expected to identify in the NVG view (see Figure 2). The targets used will include a side profile of a tank, a fighter jet and a helicopter projected onto a screen, to simulate what the pilots might see in real operations. The targets are located centrally on the screen. The NVG view without target first for 4 seconds without targets to allow subjects to get accustomed to the background. This scene will be followed by target exposure for 4 seconds in the NVG view. This timing is consistent with the pilot response time for target identification and hostility assessment, set by the Republic of Singapore Air Force (RSAF). At any one time, only one target will appear and the NVG view with or without target will be presented alternately until all targets are presented. In the trial test, timing will not be recorded as the test is intended only to familiarise subjects.

In the reference test, the same targets are to be used except that their positions will be altered to ensure no target would appear at the same location. The duration of NVG view with or without target remains the same as the trial test. The subjects will be divided into three groups of the same number and exposed to the targets in randomised sequential blocks to account for any order of exposure effects. Time for target identification will be recorded manually. Only the timing for correct identification will be used in the analysis of speed of task performance. Accuracy of task performance relating to the number of errors will be analysed separately.



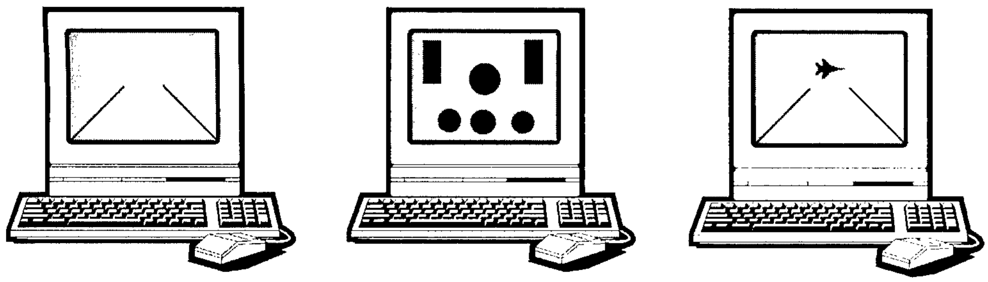
1. NVG view presented for 4 seconds



2. Presentation of various stimulus for 4 seconds.

Figure 2 Experiment Set-Up for Trial and Reference Tests

In the transition viewing test (see Figure 3), the NVG view with a target will be presented first for 4 seconds followed by a slide showing the cockpit display. Thereafter, the NVG view slide with a target will be displayed alternately with the cockpit display. This test is to simulate a pilot transiting between viewing the NVG and the cockpit display with the naked eye. In the cockpit display view, the subjects will be asked to identify the orientation of the horizon display to ensure that they focus their attention on the CRT display. Performance time and accuracy for target identification in the NVG view will be recorded. As for the horizon display, subject performance in terms of correct identification of its orientation will be monitored. If a subject were to identify the orientation incorrectly, the corresponding data obtained for the NVG view is rejected, as it would be unsafe to assume that the subject has focused his/her attention on the CRT horizon indicator prior to the display transition.



1. NVG view without target presented for 4 seconds.
2. Exposure to CRT horizon indicator.
3. Presentation of various targets for 4 seconds each.

Figure 3 Experiment Set-up for the Transition Viewing Test

30 participants without prior experience of NVGs will be invited to take part in the three tests. The experiment will be carried out in a dark room to ensure no other light source is visible. The participants will be given a briefing by the experimenter to orientate them to what they are expected to do.

Data collected from reference and transition viewing tests will be analysed to uncover the effect of luminance changes on visual performance arising from transitions between an NVG and a CRT cockpit display. It is anticipated that transition viewing between the CRT horizon display and NVG will result in degradation in visual performance due to their different luminance levels.

3. CONCLUSION

The introduction of CRT-based devices into the cockpit has raised concerns in terms of compatibility with the NVG. The US Air Force study addressed visual transitions between the NVG and an analogue horizon display. Rabin and Wiley (1994) reported that rapid transitions from a bright FLIR display to a dimmer NVG display may lead to a transient decrement in visual performance. The present study is concerned with visual performance effects arising from transitions between a brighter CRT horizon display and a dimmer NVG. The motivation of the study is to determine the effects on visual performance when users transit between the horizon display and the NVG. It is hoped that the data collected in the study will contribute to the development of human factors guidelines to ensure compatible design of user interfaces for CRT devices and NVGs. As the research project is ongoing, the results will be reported at the time of paper presentation.

REFERENCES

1. J. R. Day, Keynote Address, Night Vision Conference, (1996).
2. J. Rabin, R. Wiley, Switching from Forward-Looking Infrared to Night Vision Goggles Transitory Effects on Visual Resolution, Aviation and Space Environmental Medicine, 65:327-9, 1994.
3. S. H. Schwartz, Duplex Nature of the Retina, Visual Perception, 45-47, 1999.

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

A Mobile Information Support System for Combat Soldiers

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This paper describes the design and evaluation of a mobile computer system that supports the Army's dismounted infantry command and control functions. The work described in this paper represents the first step in identifying user and system requirements for this application. The objectives of the study were to identify requirements of the hand-held computer as well as to investigate the methodology for evaluation of such systems. A concept demonstrator of the hand-held computer, based on the Apple Newton 2000, was prepared for use during a field exercise in February 1998. User feedback from the exercise is discussed as well as the future directions of this work.

1. INTRODUCTION

Australia's program in soldier modernisation, Project WUNDURRA[1], was initiated in late 1993. At this time, an enabling program of research was instigated by the Land Operations Division of the Defence, Science & Technology Organisation (DSTO) in order to provide the necessary scientific support. Project WUNDURRA relates to the evolutionary process of soldier modernisation through the incorporation of appropriate technologies and the adoption of improved procedures. A major theme to this research is the principle of the Soldier Combat System (SCS), which is itself part of larger systems ranging from the section to the company.

The introduction of new technologies could have significant impact on dismounted soldier capabilities. Equally as important, however, are the changes in techniques and procedures that could be enabled through the application of a new concept. Hence, Project WUNDURRA is not restricted to a study of technologies, but has the broader task of understanding the fundamentals of infantry tasks in order to optimise their capability through the appropriate application of technologies or changes in tactics, techniques and procedures. The SCS had not been analysed previously in this manner and thus a first step was the establishment of an evaluation methodology.

[1] An aboriginal word meaning warrior

In October 1995, Australia initiated a series of evaluation studies with the primary aim of establishing such a robust methodology, referred to as the 'battlelab' methodology. The studies compared baseline and enhanced sections engaged in a variety of operational situations. An infantry section comprises nine soldiers and is commanded by a non-commissioned officer (NCO), usually a corporal. The infantry section has been identified as the smallest discrete unit for analysis. During the studies, the baseline sections were equipped with current equipment, while enhanced sections were provided with a variety of technological enhancements including thermal weapon sights, hand-held computers and intra-section communications.

During the field component of early studies, the large potential of hand-held computers on the capability of an infantry section was identified [2]. This potential would be realised not only through the computers enhancing the direct actions of the section, but also through them improving the degree of co-operation between the section and adjacent units. These improvements were not realised during these trials, however, due to the immature nature of the system employed. This was evident in several key features. First, the system was not intuitively related to the soldiers' previous experience and training. Second, the system could not operate at night without excessive illumination, this being a threat to section security. Third, soldiers using the system considered the weight and power requirements excessive, given that they are required to carry and operate such equipment in all weather conditions, day and night. Fourth, there was a lack of suitable mechanisms for recording user interactions with the system for evaluation purposes.

The current schedule for Project WUNDURRA has a planned acquisition phase post 2005. It has been assumed that within this time frame commercial portable computing systems will solve many of the hardware-related problems identified in early studies. Hence, the focus of the current research is in identifying the functional requirements and user interfaces for this system. The vehicle for this research is a concept demonstrator based on commercial hand-held computing devices and other components.

This paper outlines the design and implementation of this concept demonstrator. The paper then presents the results of an observational study carried out to evaluate the effectiveness of this system. The results are then discussed in terms of future enhancements to be made.

2. COMBAT SOLDIER SYSTEM

Initial work on Project WUNDURRA provided a framework for analysis of the system, based on the observation of a series of eleven generic infantry section and platoon activities and six core skills [2]. During field studies and other analytical work this framework has proved useful in analysing the impact of new technologies and procedures on small unit capabilities. The potential impact of a hand-held computer on infantry core skills and associated functionality are outlined in Table 1.

As described previously, the infantry section is the smallest tactical unit on the battlefield. An infantry Platoon comprises three sections plus a headquarters; a Company comprises of three platoons; and a Battalion has roughly four companies. While the structure in which the section operates may change, and in fact the composition of a section itself may change over time, the basic tasks of an infantry section are assumed to be relatively constant. Currently, a foot-mounted infantry Battalion has access to the following internal means of communication:

- Combat Net Radio (VHF and HF);
- Land Line (unit local telephone system);
- Text (written instructions passed by courier, e.g. dispatch rider); and
- Verbal orders (face-to-face contact, e.g. briefings/orders in-groups).

The method used for the passage of information will depend on the timeliness, relevance and accuracy of the information. Currently, several studies are under way to investigate the impact of Battlefield Digitisation at the higher command levels (Battalion and above). The WUNDURRA study fills an important gap in the knowledge at the lower level by examining the impact of Battlefield Digitisation below sub-unit (Company). At this level, information is passed by either Combat Net Radio (voice) or direct verbal communication. Information originating from a section would be interpreted and retransmitted several times before reaching the battalion intelligence officer.

Battlefield Digitisation in this context is the exploitation of technologies in the areas of sensors, data transfer, manipulation and visualisation to enhance the situational awareness of commanders and hence assist in the planning and execution of military tasks.

Table 1. Potential benefits of digitisation for combat soldier tasks and the respective function requirements for the proposed system

Core Skill Description	Impact of Digitisation	Required Functionality
Communication The exchange of information between soldiers at all levels.	Access to information in databases as well as automatic entry of information into the system including GPS position data	• Formatted text messages • Database access • Integrated computer and communications
Navigation The ability of soldiers to plan and execute navigation tasks.	Access to GPS as well as GIS and other terrain information.	• Integration of GPS with computer and digital map • Route planning tools
Surveillance The ability to observe and detect actions in a desired target location	Access to a suite of battlefield sensors such as UGS, UAV and sensors employed by other units.	• Transmission of surveillance sensor data • Real time access to surveillance sensors employed by other units.
Target Engagement The act of acquiring and engaging a target with a weapon system.	Improved situational awareness will enhance ability to engage targets and provide fire support.	• Real time access to GPS location of other units • Real time update of intelligence information
Protection The soldiers' ability to protect themselves from injury through camouflage or other means.	Improved situational awareness will prevent 'blue on blue' engagements. Health monitoring will also enhance survivability through improved planning.	• Real time GPS update of friendly positions. • Access to health status and other database information.
Movement Represents the soldier's ability to manoeuvre over flat ground as well as obstacles.	Improved route planning through access to terrain databases.	• Access to database and route planning tools.

The benefits of Battlefield Digitisation identified in Table 1 can all potentially be provided through the functionality of a hand-held computer. Such a system also has the potential to impact on all six of the core skills. This assumes that the computer has access to GPS or other navigational aids and wireless communications with other units.

As a result of the above analysis, we identified some critical functionality required by the hand-held computer employed in support of digitisation at the sub-unit level and below. In summary, these are:

Pre-formatted text based messages

The majority of messages as described by the Standard Operating Procedures follow a pre–defined format and for most instances can be pre-formatted and used with information available from the GPS. An example of a text-based message can be seen in Figure 1.

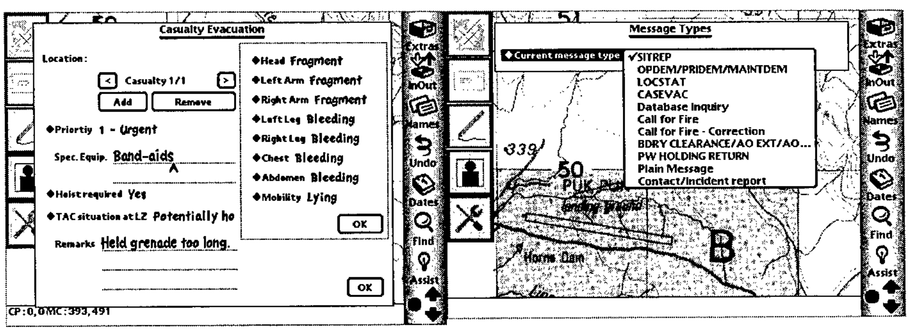

Figure 1 Pre-formatted text based messages

Digital Map with Integrated GPS and route planning tools

As the soldiers would have a GPS (Global Positioning System) unit as part of their communications jacket, critical information about where the soldier is positioned is made available on a digital map of the area, thus providing accurate information all the time without the soldier relying on using a magnetic compass and paper map. An example of this can be seen below in Figure 2.

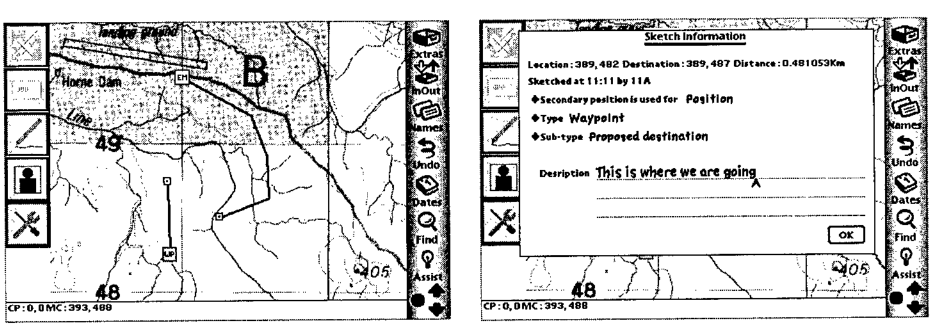

Figure 2 Digital Map with Integrated GPS and route planning tools

Access to database information (including Geographical Information System)

The ability for a soldier to plan and execute navigation tasks requires a vast amount of information, including overlay data about terrain characteristics. Such information would reside on a central server and be made available to the soldiers upon request. Some of this information can be seen in Figure 2.

Real time access to information from battlefield sensors

Real time access to battlefield sensors such as Unattended Ground Sensor (UGS) and Unmanned Aerial Vehicle (UAV) are paramount in the situational awareness of the soldier.

Orders, planning and execution tools

Manoeuvre warfare is essentially based on the theory that whichever side in a conflict is able to go through the 'OODA Loop' the fastest will gain a significant advantage over the other. 'OODA' stands for 'Observation-Orientation-Decision-Action'. It is further proposed that only a decentralised military force can have a fast OODA cycle [5]. This means that units at all levels must be informed and be able to act appropriately to situations as they arise.

This initial list of desired functions has been used as the basis for the design of a concept demonstrator for the hand-held computer. In the recent studies associated with Project WUNDURRA not all of these functions have been enabled; however, sufficient functionality was established to elicit user feedback on the merits or deficiencies of such a system.

3. DESIGN CONSIDERATIONS AND IMPLEMENTATION

The basic design philosophy has been an iterative design-test-design process. This process used feedback from user trials to guide requirements after an initial design was implemented based on subject matter expert input and on standard operating procedures documentation. Due to the need to maintain a redundant capability and obtain initial user acceptance, it was important for the initial system to replicate current procedures. In this way, training time could be significantly reduced. If the technology is accepted into service, re-engineering of processes to make best use of the system would then be possible.

The system described in this report was constructed for initial investigation during the Soldier Combat System Enhancement Study (SCSES) conducted in February 1998 in Townsville, Queensland. The system was based on the Apple Newton 2000, as it provided the desired functionality in relation to size and weight, with a screen size and other features (i.e. Pen-based computing and PCMCIA slots) to enable investigation of the desired functionality. The Newton provided a cost-effective solution that enabled the required degree of control over software development. The equipment consisted of the following components:

- Apple Newton 2000;
- Sony GPS unit;
- Maxon Data radio and modem; and
- 12 V dry cell battery.

Message Templates

During Army field exercises the use of a pen and paper system for preparing messages was observed. At the heart of this process is a folder containing information on message templates referred to as a 'vuee tuee[2]'. Eleven message templates were available in the initial demonstrator, including:

- Situation Reports (SITREP);
- Casualty Evacuation (CASEVAC);
- Location Status (LOCSTAT); and
- Contact Report.

The replication of these templates system into the Newton created a 'digital vuee tuee' capability. This functionality provided an intuitive system that replicated current capabilities while:

- increasing efficiency of message transfer;
- decreasing error rates associated with the compilation of text;
- being acceptable to the customer because of its familiarity; and
- mimicking current mechanism, thus maintaining redundant capability.

Navigation

Current navigation is accomplished by section commanders using map and compass. While some hand-held GPS units are used, these are not yet standard issue. The elements of the navigation skill are:

- identifying position (relating map to ground);
- determining distance (on a map as well as on the ground);
- determining direction (grid and magnetic bearings); and
- interpreting terrain features (relating map to ground).

Access to the GPS and digital maps enables the display of current locations of friendly units and other intelligence information. A stand-alone GPS will enhance navigation capability to some degree; however, the true benefits of digitisation are realised only when this information is used to contribute to the commander's situational awareness by providing real-time movement tracking to assist in planning, target identification and engagement.

The digital map employed on the Newton demonstrator (4 colour grey scale 953 x 811 pixels, scanned at 100dpi resolution) resulted in the loss of some map features such as contour lines. An example of one of the maps used during the study is shown in Figure 2. The primary objective of the mapping system on the demonstrator was the display of icons representing location of friendly units and special features (such as unattended ground sensors). As the wireless link was not functional during the study only that unit's position was indicated, greatly restricting the functionality of the system.

4. AN OBSERVATIONAL STUDY

The primary objective of the 1998 SCSES was the refinement of the methodology for the evaluation of enhancements to the SCS [4]. Hence, while activities involving the hand-held computer were limited by the lack of a reliable wireless link, they did provide an opportunity

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[2] A soldier's standard field notebook

to observe the technology being used by soldiers and to assess the way in which the equipment should be evaluated in future.

The demonstrator was used in three experimental situations during the Townsville study. These are listed in Table 2, along with the functionality used. In order to remove the issue of the weight and bulk of the equipment, it was carried by the Subject Matter Expert accompanying the section until required. In this way, feedback could be obtained from the soldiers on the application of the technology without comments associated with an immature system. The 'fragile' nature of the equipment also necessitated its portage by someone outside of the section so that this did not interfere with other aspects of the trial.

Experiment	Functionality	Data Collection
Vehicle Check Point and Observation Post	Access to database of suspicious vehicles and persons.	Interviews
Fighting Patrol	Use of pre-formatted text messages.	Time to compile and transmit messages recorded
Building Clearance	Access to the floor plans of the buildings used during the planning phase.	Interviews

Table 2 Details of the three experimental situations selected

Training on the demonstrator was conducted with all section commanders (corporals) and section 2ICs (experienced privates or lance corporals) involved in the study as well as with the platoon commander. This training involved a total of 7 subjects. Each subject was provided with a unit for the training session, which involved approximately one hour of formal instruction followed by a further 30 minutes of informal question and answer. One of the most satisfying aspects of the demonstrator was the ability of the soldiers to master the full functionality of the system in this limited time. This was attributed to the fact that the design was based on their current unit SOPs.

The experiments detailed in Table 2 were conducted only once by each of the baseline and enhanced sections. During each experiment, however, several opportunities arose in which the hand-held computer was used. A summary of the results of these experiments as well as the after-action reviews and post-training interviews are given in Table 3.

Table 3. A summary of the results collected

Functionality	**Comment**
Text Messaging	Standard reports from the baseline section required 10-15 minutes to compile and transmit. The same messages required less than 2 minutes for the enhanced section.
Database access	During the vehicle checkpoint, the computer was used to access information on recent suspect vehicles and persons. No conclusive result was obtained on the performance of this system compared to pen and paper based information.
Access to floor plans	The availability of floor plans was identified as a useful tool during the study. However, the lack of familiarity with MOUT (Military Operations in Urban Terrain) operations distracted from identifying any quantitative benefits.

In regards to the database search, it is probable that the impact of the computer will increase in proportion to the size of the database. During previous field exercises, where larger numbers of civilian vehicles were involved, the tracking of suspects was not achieved.

In general, the feedback on the demonstrator was very positive. Most of the discussion during interviews focused on how the message template functions could be enhanced. This included:

- placing some templates critical to a task on the 'desktop', where they would require only a single pen touch to activate; and
- automatic filling of some data fields based on available digital information.

Many of the issues identified were related to hardware. While some of these issues, such as weight and power, will be solved by future commercial systems, issues such as a suitable viewing device are worthy of further examination. During the trial, the Thermal Weapon Sight was linked to a head-mounted display worn on the user's helmet. The head-mounted display could also be used as a means for viewing the computer system; however, the system used did present several problems [3]. The use of a touch screen with a head-mounted display could also present problems requiring a reassessment of the input device. This requires further investigation. Amongst the hardware related issues identified were:

- use of a higher resolution colour map;
- low visibility viewing options;
- establishment of links with other battlefield systems;
- weight and power requirements;
- larger screen size; and
- smaller overall footprint for easy stowage in belt pouches.

5. DISCUSSION

With regards to the development of a hand-held computer for section and platoon use the demonstrator and field trial provided two key outcomes. First, it emphasised the need to conduct a controlled Command Post Exercise (CPX) experiment to investigate the functionality of the device under controlled conditions. Second, it provided an extensive list of software modifications and issues that need to be solved before such an activity should be undertaken. One of these issues is the need for the automatic recording of user interactions for evaluation purposes.

The CPX experiment would focus on the activities of an entire company rather than the actions of a single section. The trial highlighted that the system would provide major benefits if its functions were integrated within the company (i.e. a common situational awareness picture and immediate access to intelligence information). Using a CPX environment in which to conduct the experiment would give the investigators sufficient control to conduct a detailed study.

Phase 2 of Project WUNDURRA is due to begin next financial year and will run for four years. The objective of this phase of the project is to identify the system requirements for the next generation of Australian Combat Soldiers. The demonstrator program outlined in this report is one of a number of programs that will contribute to this system definition. The research conducted to date highlights the non-trivial nature of finding the correct solution to fulfil the requirements of soldiers at section and platoon level. It is likely that without the current program, 'off-the-shelf' software and hardware will be unable to satisfy the specific user requirements.

The recent dropping of support for Newton products by Apple has necessitated a move to the more popular Microsoft Windows CE platform as a basis for the demonstrator. The current work schedule is focused on:

- transferring acquired knowledge from the Newton to the CE platform (i.e. message templates);
- updating the message template software based on user feedback from the trial;
- upgrading the wireless communications capabilities;
- investigating navigation planning and execution tools;
- investigating an 'automated' orders process for studying issues of intra-company communications;
- linking of hand-held computers to current war games for use as CPX drivers; and
- investigating the user interface.

6. CONCLUSION

The demonstrator prepared in response to the requirements of the 1998 SCSES has proved a valuable tool in identifying the user and system requirements for hand-held computing below the company level. The use of non-military commercial hardware has been shown to be a cost-effective mechanism for obtaining user feedback on potential future components of the Soldier Combat Systems.

As a result of these studies the next generation of demonstrator is now being investigated. This system, in addition to the improvements suggested from user feedback, will also be optimised for the conduct of a Company-level CPX and will include in-built data collection tools.

REFERENCES

1. Baldonado, M., Chang, C.-C.K., Gravano, L. and Paepcke, A. (1997): The Stanford Digital Library Metadata Architecture, *Int. J. Digit. Libr.* 1 108–121
2. Hobbs W.S.R. and Curtis N.J. (1998) An Analysis of Infantry Activities and Technologies based on Results from the Infantry Technology Study: Singleton 1995, DSTO-TR-0637.
3. Tactical Displays for Soldiers: Human Factors Considerations, National Research Council (US) Panel on Human Factors in the Design of Tactical Display Systems for the Individual Soldier.
4. Hobbs W.S.R. and Fowler G. (1998) Non-Intrusive Techniques for Monitoring Soldier Combat System Activities During Field Studies, Proceedings in the ITEA Test Instrumentation Workshop, 23-26 March 1998, Lancaster, California.
5. H.T. Hayden (1995) Warfighting: Manoeuvre Warfare in the U.S. Marine Corps, Greenhill Books, London.

User Acceptance and Psychological Reactions to Respiratory and Body Protective Devices for a Cold Environment

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The aim of the present study was to evaluate two different respiratory protective devices (RPD) and two body protective devices (BPD) in respect of acceptance and psychological reactions. The protective devices were designed to be used by rescue personnel in NBC-contaminated environments. The evaluation was carried out under three environmental conditions; from room temperature to –20°C, 30 minutes in –20°C and from –20°C to room temperature. During the 30 minutes in –20°C the participants were to the following four activities; no activity (7 minutes), carry sandbags (7 minutes), walk in stairs (7 minutes), and read text (9 minutes). 10 persons between 32 and 54 years of age participated in this study. There were 3 men and 7 women and none of them had any prior experience of wearing RPD or BPD. All participants tested the two RPDs (Full face mask 90 and TST) as well as the two BPDs (SRV and TST). The following main results were found; The use of RPD and BPD in general always creates discomfort and disturbance for the users but not severe enough to prevent using the protective devices for as long as it is considered necessary. Though there are some significant differences between the two RPDs. The sound level was judged higher for TST than for Full face mask 90 ($p < .07$). TST was experienced more open and with more space compared to Full face mask 90 ($p < .01$). In the cold environment TST was colder then Full face mask 90 ($p < .04$) and when changing from the cold environment to room temperature the visibility in TST was significantly worse than in Full face mask 90 ($p < .10$). The BPDs were judged as equal in discomfort and constraint except for the cold environment condition where TST was experienced as colder than SRV ($p < .08$) and when changing from the cold environment to room temperature where SRV was experienced as warmer than TST ($p < .06$)

1. INTRODUCTION

In case of N-, B-, and/or C-accidents whether these occur during war- or peacetime, people must go into these situations to take care of injured or contaminated persons and also do decontamination work in the environment. In Sweden it is the health and medical staff that has the responsibility to care for people injured or otherwise exposed to N-, B-, and C-substances (military or civil products). The conditions under which the work must be carried out can vary from indoor to outdoor and from summer to cold winter with temperature way below –20°C. It is a justifiable demand for the medical staff to have access to protective devices that will function under these conditions. This puts special demands on the design and function of the equipment. It has to be designed to shelter from both heat and cold and also from vapor and moisture. As for function it is a certain demand that work is restricted as little as possible by the equipment. Many different problems can be identified while weighting the need for protection against the need of performance. The most obvious problem concerns comfort. It is very likely people that wear protective devices of different sort experience discomfort (Letts, 1962; Douglas, Hack, Held, & Revoir, 1976; Morgan, 1983; Mauritzson-Sandberg & Sandberg, 1986). Comfort might be viewed as a personal sensation that doesn't necessarily have to reflect physical characteristics of the equipment. Ergonomics/shape on the other hand has to do with the equipment's actual design. Adjustment problems and the concrete shape of the devices constitute important aspects in research, development and in the use of protective devices (Shepard, 1962; Safety Maintenance 132, 1966; Mauritzson-Sandberg & Sandberg, 1986). The fit of the respiratory protective devices (RPD) depends on the size of the face and due to great variations this is regarded as one of the biggest problems concerning RPD (Cotes, 1962; Letts, 1962). Morgan (1983) ascertains that an ill-fitted device may cause distinct pain spots that can be experienced as almost unbearable.

An important condition for efficiency in rescue work is the ability to communicate with the rescue team (Ernsting & Gabb, 1962; Shirling, 1962; Douglas et al, 1976). Mauritzson-Sandberg & Sandberg (1986) found in their research that 63% of the test group found it difficult to talk while using RPD. Further, 64% thought that longer conversations were not possible without great difficulty. Similar results were found by Mauritzson-Sandberg & Sandberg (1988) where 58% of the test group were unable to maintain normal communication. In critical situations it is also important to monitor the environment to identify obstacles and potential risks. RPD's that covers the whole face always restricts the sight (Shepard, 1962). The visual restriction can depend on two different causes: the shape and size of the visor and vapor and moisture in the RPD. It has been documented by Douglas et al (1976) and Mauritzson-Sandberg & Sandberg (1983) that restriction in eyesight, for example the inability to retrieve peripheral information,, may lead to unwanted reactions of both physiological and psychological nature.

When it comes to the body protection devices (BPD) it may be assumed that the discomfort is more tolerable than for RPD, at least this should be true if the BPD is not either too small or way to big. However one should not neglect the potential problems associated with a ill-fitted BPD. Tasks for example that demands accuracy in hand and finger movement may not be possible to perform with gloves that does not fit.

The aim of the present study was to evaluate two different RPDs and two BPDs in respect of acceptance and psychological reactions. The protective devices were designed to be used by rescue personnel in NBC-contaminated environments. The evaluation was carried out in three different environmental conditions.

2. METHOD

2.1. Subjects

10 persons aged between 32 and 54 years participated. There were 3 men and 7 women. None of the participants had any prior experience of wearing RPD or BPD.

2.2. Apparatus

Two different kind of RPDs were used: Full face mask 90 and TST with TST's fan unit. The two BPDs were SRV and TST. Both BPDs consists of jacket and pants. Full face mask 90 and SRV as one protective suite and the TST as the other protective suite.

2.3. Procedure

Before the test phase the participants were informed of the purpose and the procedure of this investigation. All 10 subjects were to test both protective suites i.e. every subject did two tests. To control for order the subjects were divided into two subgroups and used RPD and BPD according to table 1.

Table 1. Presentation order of RPD and BPD to each group.

Group	Test1	Test2
Subgroup1	Full face mask 90 and SRV	TST
Subgroup2	TST	Full face mask 90 and SRV

The test contained three environmental conditions:

1. **Condition 1: from warm environment to cold**

Dressing (RPD and BPD). Walk from the dressing room to cold store

2. **Condition 2: Cold environment**

Stay in cold store for 30 minutes at a temperature of –20°C. During the stay the following activities were to be done:

a. Rest (7 minutes)
b. Carry sandbags (7 minutes)
c. Walk in stairs (7 minutes)
d. Read text (9minutes)

3. **Condition 3: from cold environment to warm**

Walk from cold store to dressing room. Undress RPD and BPD

After the test the subjects had to answer a questionnaire about their experiences of the protective devices.

3. RESULTS

3.1. Acceptance and comfort

To completely inexperienced users, dressing, general comfort and fitness are three important initial components effecting the prolonged use of the protective devices. The question; "How hard was it to put on the RPD" showed no significant difference. Both RPD were judged to be equally easy to put on. As for the general comfort there was a significant difference ($p<0.025$) between RPD. The TST was experienced more comfortable than Full face mask 90. Despite the fact that both RPD were judged as comfortable rather than uncomfortable there were problems with the fitness. Both RPD were significantly worse ($p<0.01$) than the reference point (good fitness/no problems). The localization of the problems for both of the RPD are forehead, nose, chick, and chin and additional problems for Full face mask 90 were neck, straps around the head, and not enough room for glasses. The sound level was judged on a scale from 0 (not annoying at all) to 6 (most annoying). Despite the high general sound level in the cold store there was a significant differences ($p<0.07$) between the two RPD. The sound level in TST was more annoying than in Full face mask 90. Both RPD were judged to be equally airy.

3.2. Attention, monitoring, communication, and mobility

All subjects experienced more or less constrain according to attention, monitoring the environment, communicate with other, and mobility.

Table 2. Effects on attention, monitoring, communication, and mobility
(0=normal condition/no disturbance; 6=severe constrain or disturbance)

Issues	RPD	Mean	Std
Effects my Attention	Full face mask 90	2.5	2.17
	TST	1.9	0.74
Monitoring the Environment	Full face mask 90	2.8	2.25
	TST	2.4	0.70
Allow me to Talk	Full face mask 90	2.6	1.65
	TST	2.6	1.71
Catch what other Says	Full face mask 90	3.9	1.60
	TST	4.6	0.97
Allow me to Move	Full face mask 90	1.6	1.35
	TST	1.4	0.52

There were no significant differences between the RPD but if the comparison between the normal condition and the responses is calculated all means in table 2 are significant ($p < .01$).

3.3. Temperature and sight

The only condition where there was a significant difference in temperature ($p < .04$) between the RPD was the cold environment. TST was experienced as colder than Full face mask 90. There was also a significant difference ($p < .10$) between RPD concerning sight. Full face mask 90 was experienced to have a more restricted sight than TST. When changing from cold environment to warm the difference was reversed ($p < .10$). Common limitations were vapor and moisture and visor not completely transparent but for Full face mask 90 additional limitations were to narrow/small visor and distorted visual field.

3.4. Body protection

There were no significant differences between BPD. The subjects experienced the BPD in the same way and not particular uncomfortable though there were some minor constrain concerning motor activities and body movements.

4. CONCLUSIONS

It is important to point out that the focus in this study is not on the technical or protective performances. From a technical and protective point of view the RPD and the BPD are equal.

This study has its focus on the psychological and subjective experience related to the protective devices respectively. A protective device, which is technically perfect but creates major negative psychological reactions has a limited use in hazardous environments and therefore it is important to describe and measure the reactions individual experiences when wearing the protective.

The results confirms the general hypothesis that comfort and fitness is more crucial attributes to RPD than to BPD. The results shows no significant differences between the two BPD and actually none of them differs significantly from what is judged as acceptable comfort. An alternative explanation, but hardly likely, is that the BPDs are as ordinary clothing referring to comfort and mobility. The BPDs are made of a material that is supposed to give a first-rate protection in environments where N-, B-, and C-agents are present. Furthermore the BPDs are designed to be worn over the clothing. When it comes to respiratory protection the results shows that the different RPD creates different reactions both psychological as well as physiological. One general finding is that both devices creates discomfort but in different degrees. The lack of comfort is for example linked to dressing procedure, the wearing, the fitness and if the device is viewed as tight or airy. An important aspect has to do with the possibility to maintain attention, monitor the situation and communicate with others with a minimum of disturbance. Also in those matter the RPD produces disturbances for example moisture and distorted sight. The speech flow was also influenced particularly when it comes to apprehend what other people were saying.

REFERENCES

1. Cotes, J.E. (1962). Psychological aspects of respiratory design In Davies, C.N. (Ed) *Design and use of respirators* London: Pergamon Press.
2. Douglas, D.D., Hack, A.L., Held, B.J. & Revoir, W.H. (1976*). Energy Research and Development Administration Division of Safety, Standards and Compliance Respirator Manual* LA-6370-M, Los Alamos Scientific Laboratory, Los Alamos.
3. Ernsting, J. & Gabb, J.E. (1962). Problems of communication in breathing equipment In Davies, C.N. (Ed) *Design and use of respirators* London: Pergamon Press.
4. Letts, H.J.R. (1962). The limitations of gas-masks and dust-masks as mean of protection against hazards. In Davies, C.N. (Ed) *Design and use of respirators* London: Pergamon Press.
5. Mauritzson-Sandberg, E. & Sandberg, L. (1983). Bestämning av nedre åldersgräns för användning av folkskyddsmask för barn *FOA rapport C40l82-C2 Sept.*
6. Mauritzson-Sandberg, E. & Sandberg, L. (1986). Adaptation och tillvänjning till folkskyddsmask vid långtidsanvändning *Civilförsvarsstyrelsen Cfs nr 1.04-98F.*
7. Mauritzson-Sandberg, E. & Sandberg, L. (1988). Skyddssökning och *evakuering Statens Räddningsverk P21-006/88.*
8. Safety Maintenance 132, (1966). Keeping up with development. Respiratory protection *Safety Maintenance 132* July, 25 – 28
9. Shephard, R.J. (1962). Ergonomics of respirators In Davies. C.N. (Ed*) Design and use of respirators* London: Pergamon Press.
10. Sherling, F.C.A. (1962). Breathing apparatus in the British fire service In Davies, C.N. (Ed) *Design and use of respirators* London: Pergamon Press.

PART SIX

Human Computer Interaction

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Conceptual Graphical User Interface Design for an Electronic Technical Manual With a Small Screen Display

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Although studies on cognitive load theory suggest that materials can be actively structured to eliminate extraneous load and enhance learning, many present day technical manuals still disregard the cognitive processes of the reader. We propose a structure and method of presenting technical instructions that takes into consideration the cognitive processes of the user. Furthermore, the method was shown to have potential to be used for presenting the information in a small display. A software prototype was created to demonstrate the concept.

1. INTRODUCTION

Traditional technical manuals are written for large visual displays such as paper manuals, and recently in notebook, subnote and tablet computers. The complexity, technicality and quantity of the information demand a large visual real estate to present the exhaustive content page, large static graphics and long verbal description. A recent evaluation study [9] on wearable computer, paper manual, and notebook computer highlighted some usability problems for such information systems for users out in the field. The size of such systems proved to be less than ideal to serve as mobile aids and the information presentation may not be necessarily friendly.

A small handheld computer will be able to solve the mobility problems of maintenance aids. But such devices will lack the advantages of large display systems such as the hard copy manuals. Navigation and usage of such devices might be more difficult since the presentation of information will be constrained by the small display size. Hence the challenge is to design the graphical user interface to present complex technical information effectively and yet allow the user to easily locate the information required, within a small visual display.

2. OBJECTIVE

This project proposed and developed a prototype electronic technical manual to present technical information based on the human cognitive process, on a small visual display similar to a palm-sized computer.

3. THEORY

Application of the cognitive load theory in instructional design

According to the cognitive load theory, in the process of information acquisition, information elements are assimilated and organized cognitively by the reader according to the manner that they will be dealt with [2] [10]. These information elements are organized into cognitive constructs known as schemas. Each schema is then treated as a single element. Sweller et al. [10] claimed that schemas reduce the burden on working memory by allowing multiple elements of information to be treated as a single element.

In the military context, if instructional material in technical manuals is to be presented in an effective manner (especially in a small display), it must be structured to facilitate schema acquisition [3]. However, a review on conventional presentation formats of technical material showed that they were seldom presented with regard to the cognitive processes of the reader. For instance, verbal instructions and graphics are often grouped as separate sources of information (see *Figure 1*). The instructions were usually presented in a continuous series of steps side by side with a complicated diagram with numerous part labels.

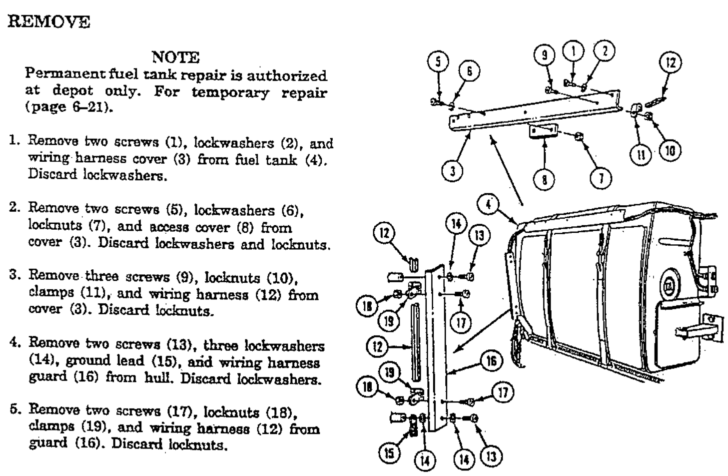

Figure 1 Split attention effect: verbal instructions and graphics are grouped as separate information sources. From Organization Unit Maintenance Technical Manual for Carrier Personnel, Full Tracked Armoured, M113A2 & M113A2MK1 FOVs. TM SM-9-250-261-20-1 [7]

Chandler et al. [2] termed this as the split attention effect. The user would have to mentally integrate the verbal instructions with the graphics to render the information intelligible. This imposes a heavy cognitive load on the user. Sweller and Tarmizi [11] recognized that devoting cognitive resources to integrating two or more sources of information is likely to interfere with schema acquisition. Such display format not only demanded more cognitive load on the reader, but also demanded a large display area per page.

Instructional designs can be based on an understanding of the cognitive load theory to eliminate any avoidable load on working memory in learning. Chandler *et al.*[2] demonstrated a method of achieving this through physical integration of text and graphics. In implementing the method, a single diagram needs to be broken down into a series of smaller diagrams with contextual instruction integrated into the diagrams. This would however mean more pages of instruction if they were published in a paper manual. For example in Figure 1, five steps were presented in one page including the diagram. Using the integrated text and graphics approach, the instructions could be broken down into 5 pages of instruction, each with its own small diagram. Although not economical for a paper manual, it would fit well for an electronic media, especially on a small display. Applying the principles in this project, information of a technical manual [7] was broken down into series of simpler instructions with the textual and graphical information integrated to support schema acquisition and small display presentation.

4. THE PROTOTYPE TECHNICAL MANUAL

The prototype was developed for a screen size of 6 by 8 cm. The resolution (240 by 320 pixels) was set to match an equivalent display typical of the palm or handheld device e.g. Cassiopeia. The prototype was written using HTML (Hypertext Mark-up Language), identical to web pages, and utilises Microsoft Internet Explorer as the graphical user interface. The contents of the manual were taken from a technical manual for servicing and maintenance of the M113 Armoured Personnel Carrier vehicle [7].

4.1 Navigation architecture of the prototype

The prototype consists of a huge database of technical information, which can be accessed using three navigation tabs or menus, namely, Contents, Troubleshooting, and Maintenance. This was modelled with the likely activities engaged by the technicians when they used maintenance aids. By allowing direct access to troubleshooting and maintenance specific information, the user can more effectively access the information they required most.

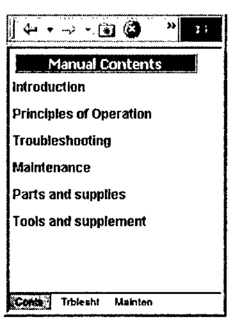

Figure 2 Contents page

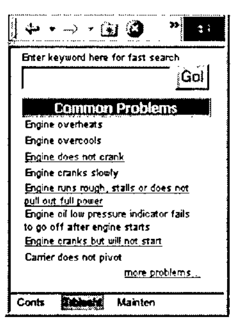

Figure 3 Troubleshooting page

4.1.1 The *Conts* page

The *Conts* page is the content page (Figure 2) of the manual where all manual content can be accessed. It has the same function as the traditional content page for searching information but the display is simplified to fit in the small display. Each main heading can be expanded down the hierarchical ladder and the elemental headings are hyper linked to the respective information pages. Such method of presentation, called the cascading styled menu interface, was found to be effective for browsing large hierarchical table of contents as reported by Chimera and Shneiderman [1].

4.1.2 The *Trblesht* page

The *Trblesht* page (Figure 3) assists the user in troubleshooting the vehicle when there is a symptom or failure in the system. This is a very common task expected of a technician. The Trblesht page consisted of three navigation sections: (a) Keyword search, (b) "Hotlist", and cascading style menus.

4.1.2.1 Keyword Search

Nielson [11] regarded that menu-driven navigation is best used for information systems that are small enough to be covered exhaustively and familiar enough to the users to find their way around. For information systems that are large and unfamiliar to first time users, a query search function to find information may be the fastest way. Along this line, a keyword search function is built in to allow the user to search for troubleshooting-related information within the database. First time users of the prototype manual will find this feature useful.

4.1.2.2 Hotlist

The hotlist of common problems serves as shortcuts to the database. The hotlist is to be assembled from the experience of veteran technicians and combat personnel who knows the most common problems associated with the vehicle system. If the problem the user is searching for is within the list, he can click on the problem to go directly to the problem without having to go through a search process. Otherwise, he can click on the "*more problems...*" link provided to access the entire list of troubleshooting problems presented in a cascading style menu format.

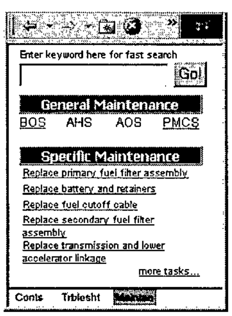

Figure 4 Maintenance page

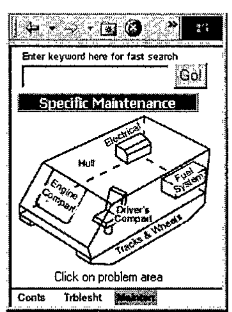

Figure 5 Pictorial menu

4.1.3 The *Mainten* page

The opening page (*Figure 4*) for the *Mainten* tab follows a layout almost identical to that of the *Trblesht* tab. The keyword search function here works in the same way as that under the *Trblesht* tab except that the churned results are limited to maintenance information. However, the lower frame consists of two sections, *General Maintenance* and *Specific Maintenance*.

4.1.3.1 General Maintenance

General Maintenance covers all maintenance tasks that are to be done on a regular basis, with or without any fault with the system. Examples are *Before Operations Servicing (BOS)*, *Ad-Hoc Servicing (AHS)*, etc.

4.1.3.2 Specific Maintenance

The *Specific Maintenance* section provides links to the repair and maintenance tasks. When the user knows the repair task he needs to perform but does not know or remember the steps in carrying it out, he will be able to find the instructional steps here. A hotlist of common specific maintenance tasks serves as shortcuts for instant access as in troubleshooting section. A "*more tasks...*" link at the bottom links the user to a pictorial menu.

4.1.3.3 Pictorial Menu

The pictorial menu (*Figure 5*) is a simplified diagram of the M113 carrier, with 6 respective areas made into hotspots and linked to cascading styled text menus of the same category. Users can thus intuitively search for the specific task. The pictorial menu is used as a more intuitive interface. Graphics is employed here because the options for *Specific Maintenance* can have spatial meanings. And it has been demonstrated that it takes 25% to 30% longer to read typewritten text than graphics on a screen display [6], [8].

4.2 Presentation of Technical Information

The technical information for troubleshooting and maintenance were usually presented as in Figure 1 in most traditional manuals. In the prototype, diagrams were reduced in size to fit the display and presented in several stages instead of all at once. These series of diagrams were presented with the instructions according to the logic of the tasks on hand. As the user will only perform one task per page, the design not only save the space for presenting the information, but also reduce the cognitive workload of the user as he will not be distracted by unnecessary information.

4.2.1 Troubleshooting

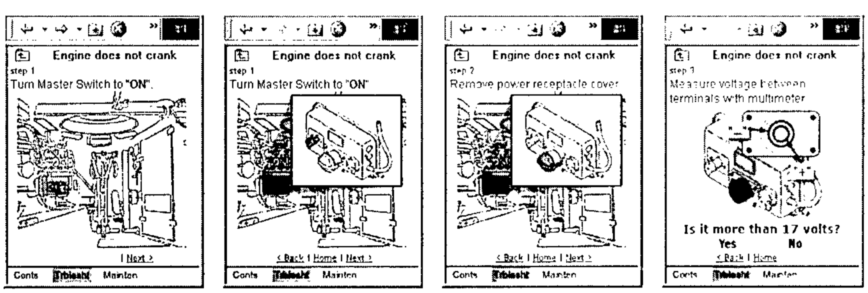

Figure 6 A troubleshooting task

Figure 6 show a series of troubleshooting "steps" or pages that gave the instruction for troubleshooting "Engine runs rough, stalls or does not pull out full power".

The instructions for troubleshooting were simplified and illustrated with diagrams. Note that despite the smallness in size, the pictures were still able to illustrate the contextual meaning required for diagnosis. The navigation tools, Next>, <Back, Home, and the diagnostic questions allow the user to navigate and interact with the system easily. The concept of only showing what was required allows the user to easily follow the steps and perform the task without any distraction. Repair tasks were directly hyper linked to the specific tasks at the end of the diagnosis.

4.2.2 Specific maintenance

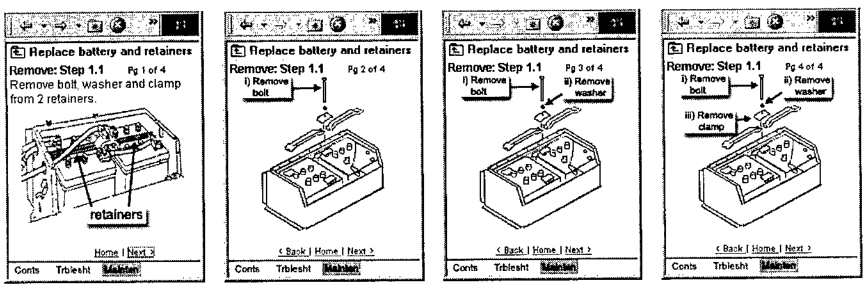

Figure 7 A specific maintenance task

For the repair task, a similar format was used as in a troubleshooting task. To describe the task of removing a battery retainer (Figure 7), the manual would need to locate the retainer and describe the removal action. By first presenting an overview of the battery compartment, then focusing on the location of the parts that held the retainer, and subsequently an additive step-by-step ordered removal instructions expressed in graphical form, the task of battery retainer removal was described. Note that the graphics are vivid and representative of the parts of the vehicle. The diagrams could be further enhanced if the CAD (Computer Aided Design) drawings of the vehicle were available. The integration of the text and diagram also reduced the cognitive load of the user in comprehending the process.

It should be noted that the instructions were rewritten to enhance readability. Positive phrasing and simple language were used to cut down information processing. For example, the original statement for checking shutoff valve was "Ensure manual shutoff valve is not closed" was changed to "Ensure manual shutoff valve is open."

4.3 Others

There were other aspects of the prototype that were presented differently compared to traditional manuals. These are not described in details but are listed below:

- Warnings and cautions were presented when needed or before the required steps.
- Wordings of the warnings were also carefully chosen to concisely and yet accurate depict the meaning.
- Flashing symbols and headings were used to give special highlights on necessary items.
- Troubleshooting task consisted of a complete loop where after a series of troubleshooting steps, the user will arrive at the maintenance task and after the maintenance steps, the system will go back to the original troubleshooting task to ensure that the original fault was eradicated.

5. CONCLUSION

The prototype was demonstrated to vehicle technicians and was favourably commented. The integration of graphical and textual information provided an attractive way of presenting information in a small display and yet giving a less cognitively demanding information system. Further work will complete a fully functional prototype to conduct a usability evaluation of the software integrated with a handheld computer. This will be evaluated as software cum hardware system instead of the current software prototype.

REFERENCES

1. Chimera, R., and Shneiderman, B. (1994). An exploratory evaluation of three interfaces for browsing large hierarchical tables of contents. ACM Trans. Information Systems, 12, 4 (October), pp. 383-406.
2. Chandler, P., Kalyuga, S., and Sweller, J. (1998). Levels of Expertise and Instructional Design. The Journal of Human Factors and Ergonomics Society, 40, 1 (March), pp. 1-17.
3. Chandler, P., Cooper, M., Sweller, J., and Tierney, P., (1990). Cognitive Load as a Factor in the Structuring of Technical Material. Journal of Experimental Psychology: General, 119, 2, pp. 176-192.
4. Gick, M. L., and Holyoak, K. J. (1980). Analogical problem solving. Cognitive Psychology, 12, pp. 306-355.
5. Hewish, M. (1996). Wearable Information Tailored To Battlefield. Jane's IDR Extra, 1, 11, pp. 1-7.
6. Nielsen, J. (2000). Designing Web Usability: The Practice of Simplicity. New Riders Publishing, U.S.A.
7. Organization Unit Maintenance Technical Manual for Carrier Personnel, Full Tracked Armoured, M113A2 & M113A2MK1 FOVs. TM SM-9-250-261-20-1
8. Smith, P. A., Newman, I., A., and Parks, L. M. (1997). Virtual hierarchies and virtual networks: some lessons from hypermedia usability research applied to the World Wide Web. International Journal of Human-Computer Studies, 47, pp. 67-95.
9. Soh, B.K. Chui, Y.P., Ashokan, R., Ong, V. (1999). A field usability evaluation of a wearable computer for vehicle maintenance. DMRI Technical Report.
10. Sweller, J. (1994). Cognitive Load Theory, Learning Difficulty, and Instructional Design. Learning and Instruction, 4, pp. 295-312.
11. Sweller, J., and Tarmizi, R. (1988). Guidance during mathematical problem solving. Journal of Experimental Psychology; General, 112, pp. 634-656.

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Development of an Interactive Tutor for Designers of Internet Enabled Public Information Kiosks

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This paper investigates the quality of the user interface design of applications targeted at the SingaporeOne (S-One) initiative. These interactive applications are accessed via the internet or specially designed internet enabled kiosks. To this end, an expert walkthrough of the systems was conducted. The walkthrough revealed that the user interface design of many of these applications were rather poor in usability and inadequate in task support functionality. This may be due to the low level of human factors awareness among programmers. As a result of their poor understanding of human factors design guidelines and concepts, the programmers were misled to believe simply that a graphical user interface was all that was needed to ensure usability. To raise the awareness of human factors concerns, an interactive design tutor may be developed to provide programmers with explicit real examples extracted from the expert walkthrough conducted earlier. Examples of good user interface design and common inadequacies will be provided as illustrations. In this way, programmers may then be able to understand and apply human factors design principles better. It is hoped that the increased uptake of human factors would translate into the design and development of more effective and usable S-One applications.

1. BACKGROUND

In the wired (or soon to be unwired) world, nothing evokes feelings of unbridled freedom like the internet. It has over the years, evolved into a lifestyle rather than a tool. Many businesses and individuals have already taken advantage of the awesome capabilities of the internet. Things are no different in Singapore. In 1991, the Singapore Government announced plans to wire up the entire island with a high speed network to provide Singaporeans with broadband internet access to sites both inside and outside Singapore.

This initiative, known as IT2000, comprises two phases. The first phase involves implementing a network of information kiosks, placed at strategic locations all around Singapore. The second phase comprises a series of broadband network services (known as SingaporeOne or S-One) that may be accessed by users from their homes or work places. In particular, users will be able to obtain real time information wherever they are and whenever they need it. Applications and information will include up-to-date weather information, stocks, bus routes and schedules, e-commerce, on-line education and so on. Some of the applications are already onstream. More advanced applications are imminent, for example, Wireless Application Protocol (WAP) based applications for mobile telephones, applications for future hand-held computers and Personal Digital Assistants (PDAs), interactive and internet television, etc. These applications can improve the lives of Singaporeans tremendously in the near future. The objective of the Government is to transform Singapore into an 'intelligent island' (NCB, 1991).

However, for the initiative to be a success and its applications used effectively, they must first be accepted by the users. Unfortunately, an expert walkthrough of a number of the applications offered by S-One revealed that they are generally poor in usability and also inappropriate in task support functionality. As a result, the applications can be cumbersome and difficult to use. This poor appreciation of user requirements and human factors, could slow down the public uptake of S-One applications.

One reason underlying poor user interface design is that programmers and webpage designers are generally unaware of human factors design concerns. Another reason for the poor state of affairs, is that existing user interface design guidelines can be vague and difficult to interpret and understand, let alone apply. In particular, human factors concepts tend to be poorly illustrated and exemplified by real examples relevant to the context of application. If human factors is considered, they tend to be addressed only at the end of the design cycle, after all the functions have been finalised. This situation does not usually support effective uptake of human factors contributions, leading to the 'too-little-too-late' problem of poor human factors input (Lim and Long, 1994). Furthermore, webpage designers are often driven by aesthetics without giving due consideration to adverse usability implications. Unfortunately, an aesthetic design does not imply good usability. For example, many designers use the popular MacroMedia Flash movies to make their webpages stand out. Although these movies can be made attractive, they can take a long time to load and so might try the patience of users. Other webpages are packed full of colour, images and icons, that the task support functions are totally buried and lost to users.

To address these problems, an interactive design tutor is being developed to convey basic human factors concerns and knowledge to S-One designers and programmers of internet-based public information systems (PIS). To this end, good design examples and common mistakes are first identified via a review of existing S-One applications. These examples are then used as illustrations, to augment a selected set of established user interface design guidelines extracted from existing sources such as Smith & Mosier (1986) and internet Apple Human Factors Guidelines (*www.apple.com*). In this way, an interactive design tutor may be developed to provide programmers with explicit real examples. Programmers may then be able to understand and apply human factors design principles better. With an increase in uptake of human factors contributions, the design and development of more effective and usable S-One applications may be realised.

2. A SAMPLE REVIEW OF AN EXISTING SINGAPORE-ONE APPLICATION

In general, many of the mistakes made by programmers are very basic. These mistakes can be avoided by making them aware of basic human factors design principles. Some common mistakes include poor color combination, layout design, task structures, use of text, etc. Some examples of these mistakes follow.

The Picture Archive of Singapore (PICAS) website (*http://nhb.picas.gov.sg*), allows users to purchase rare and historic pictures of Singapore. Users are required to complete a number of steps before they can purchase the pictures. Figure 1 is a page showing the result of a search. The screen shows the description as links on the left side of the screen and a few "thumbnails" on the right side of the screen. At first glance, there are several things wrong with the screen design. First, the letters are all in upper case and underlined. It has been established that users will take longer to read uppercase and underlined characters. Although it is common practice to underline links in internet applications, it is unnecessary to underline the entire sentence. Some of the text encountered here might also be smaller than the recommended 15 arc minutes (BSI, 1993). More critically, the user interface failed to support the user's task adequately. For example, when the user clicks on a link, he/she is taken to a page with a lot of irrelevant information (see Figure 2). Alternatively, clicking on the thumbnail will take a user to an enlarged image. Users might find it confusing to see two similar links taking them to different pages.

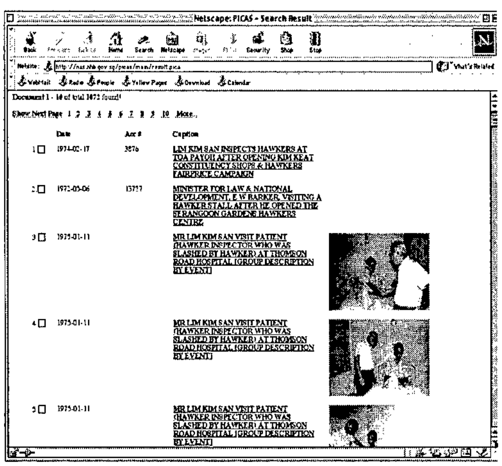
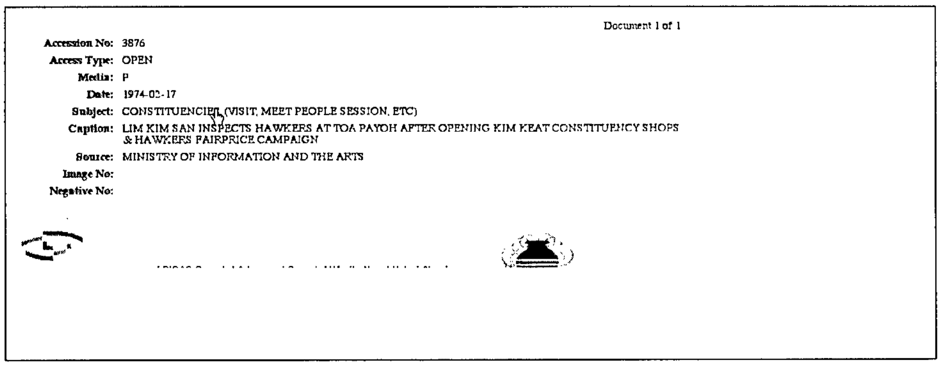


Figure 1. A Result Page for PICAS Search

Figure 2 shows the picture information page. Among the information available here is archive number, source, date, event, etc. Normally, such information would only be interesting for would be historians or users doing research on Singapore's past. However, in this case, the application requires the user to input the information to order pictures.


Document 1 of 1

Accession No: 3876
Access Type: OPEN
Media: P
Date: 1974-02-17
Subject: CONSTITUENCIES (VISIT, MEET PEOPLE SESSION, ETC)
Caption: LIM KIM SAN INSPECTS HAWKERS AT TOA PAYOH AFTER OPENING KIM KEAT CONSTITUENCY SHOPS & HAWKERS FAIRPRICE CAMPAIGN
Source: MINISTRY OF INFORMATION AND THE ARTS
Image No:
Negative No:

Figure 2. PICAS Information Listing of the Attributes of a Picture

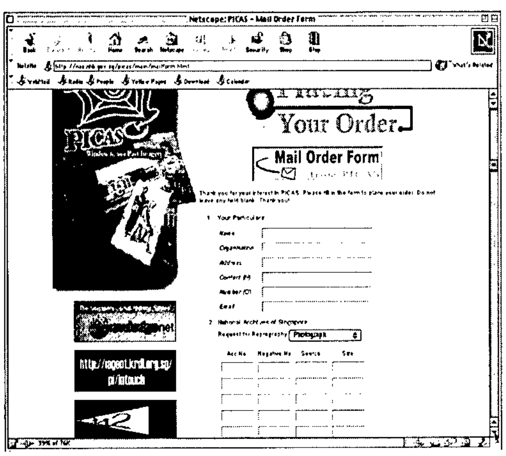


Figure 3. PICAS Picture Mail Order Form

Specifically, the user has to transfer some of the information presented in Figure 2 (such as Acc No. (Accession No.), Negative No., Source and Size) to the Mail Order Form shown in Figure 3. The user is thus required to do a lot of typing, e.g. the string "Ministry of Information and the Arts" into the "Source" field (Figure 3). The user is also left guessing whether he/she has to type the entire name of the ministry or its acronym (MITA). Furthermore, users are not prompted on the same screen, the size options for the pictures available (3R, 5R, custom size) and their cost. This oversight shows that programmers do not understand user task requirements. The above examples are only two of the many problems encountered at this site.

Programmers must understand that the information shown in Figure 2 is irrelevant to a user who wishes to purchase some archive pictures. Even if the information were to be presented for completeness, users should not be required to input the information as part of the picture purchasing task. A link such as "Buy" or "Order" could be added to take users to the Mail Order Page, and the information on the picture can be extracted from the site database and presented to the user. All the user has to do then, is to confirm the purchase. This design makes it much easier for a user to purchase a picture from this site.

3. DEVELOPMENT OF AN INTERACTIVE DESIGN TUTOR

The main aim of the interactive tutor is to make programmers and designers understand the concepts of good user interface design. At the time of writing, the interactive design tutor is under development.

Unlike paper based guides, an interactive design guide can actively involve designers and programmers in learning about human factors concepts. Where traditional paper-based guides are vague, the interactive tutor can use real examples of existing web pages or applications to illustrate a point or design concept to the designer. In this way, designers will be able to read a textual account of human factors concepts, as well as see for themselves how they may be applied appropriately.

It is envisaged that the interactive design tutor will include the following functions and key features:

- Human factors design concepts and guidelines pertinent to S-One/IT2000 applications. The concepts will span task analysis to interaction level design. Designers and programmers may then be exposed to both usability and functionality concerns of human factors design.
- Use of interactive multimedia (sound clips, movies, animation) to support illustrations, examples and quizzes. Digital video will also be used to show designers user reactions to an existing application. These can be extracted from basic footage recorded during a usability test. By using animated examples and sound as opposed to lines of text found in paper-based guides, human factors design concepts can be made more graphic and interesting for assimilation by designers and programmers.

- Real examples of good and bad user interface designs extracted from existing S-One/IT2000 applications. The effects of poor design may thus be conveyed to designers and programmers in this way. How the design could be improved will also be illustrated explicitly.
- The level of human factors knowledge of a designer/programmer will also be taken into account by the interactive tutor. Different modules of human factors content and topics may be configured and introduced progressively to designers and programmers as they learn more about human factors.

The interactive tutor will be programmed using MacroMedia Director, the industry standard for designing multimedia applications. Using Director, the interactive tutor may be ported to both the Macintosh and Windows platforms with little modification. Further, Director movies can be "shocked" using an application called MacroMedia Shockwave. "Shocked" Director movies can be integrated with any web page and can thus be viewed over the internet. These design considerations will make the interactive tutor widely accessible to designers and programmers of SingaporeOne applications.

4. CONCLUSION

The IT2000/SingaporeOne initiative holds great promise and potential for Singapore. However, the public must first accept and embrace the technology. They must not only be willing to use it on their own free will, but in many cases, to also change their conventional way of doing things (for example, internet shopping as opposed to visiting a store). To ensure user acceptance of such a high impact technology, the applications must be very usable. This is particularly so for SingaporeOne applications as they are targeted at the widest possible user base, i.e. the young and old of the general public. A good understanding of human factors design requirements is therefore vital for success. It is hoped that the interactive tutor will be able to contribute towards advancing this national initiative, by helping programmers and designers better assimilate and implement human factors design considerations.

REFERENCES

1. British Standards Institution (1993). Ergonomics Requirements for Office Work with Visual Display Terminals. London, BSI.
2. Lim, Kee Yong & Long, John (1994). The MUSE Method for Usability Engineering. Cambridge University Press.
3. National Computer Board, Singapore, (1992). A Vision of an Intelligent Island : IT2000 Report. SNP Publishers.
4. Smith, Sidney L. & Mosier, Jane N. (1986). Guidelines for Designing User Interface Software. Mitre Publishing.

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Characterizing and Representing Virtual Human Neck Posture for HCI

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With wide spread use of online transactions, e-commerce or even standalone computer applications, the demand for virtual humans such as a vitual attendant, a virtual cashier, a virtual sales person, etc., has increased. Users feel tired looking at a human photograph as an interface to the computer application. A major challenge in designing virtual humans for deployment in the user interface is the gaze control and neck posture. This paper reports a new algorithm for a simple neck posture computation for virtual humans. We believe this will have wide use in the deployment of virtual humans at the User Interface.

1. INTRODUCTION

A diversity of eye, head and neck postures may be generated in the view surface by gaze intersection, which ensures that the neck posture and gaze are interrelated. Observation indicates that there are five major gaze postures, illustrated in idealized form in Figure 1. Top gaze, typically generated by the stretching of the neck, tilting of the head and looking above the head at a characteristic angle to the horizontal plane. Straight gaze on the other hand is linear on a horizontal line from the eye. Bottom gaze is the tilt when facing downward. Left gaze is when the neck is stretched and rotated to the extreme left, when the head still remains in the upright position. Right gaze is same as left gaze, but the eye is pointing to the rightmost direction.

The primary purpose of our research is to develop an efficient algorithm for gaze animation of humans, for a given gaze trajectory. The understanding of a particular gaze system may be gauged by considering all aspects of the behavior, viz., analysis of vestibulo-ocular (VOR), positional, saccadic, optokinetic, and smooth pursuit eye movements. The eye, head and neck movement in relation to the torso can be effected by the fact that eye follows the target during a reach operation. The surface in which the eye moves can be: when looking at an object that is above the head to the object lying at your feet, or to the extremes on the left and right. This helps to define the mid-eye position of the gaze trajectory to be defined on a surface. A person's gaze is a powerful input in animation of the eyes, head and neck. By defining a surface that contains the intersection of the mid-eye point with the gaze direction vector provides the required information for orientation of the head, eyes and neck. The five major gaze postures have been used to define the bounding surface, which is the pyramid in the simplified form. Any other gaze direction vector will intersect this pyramid at only one point, which uniquely helps to solve for the posture of eye, head and neck postures. The pyramid is easy to implement, computationally inexpensive and we show that the pyramid approximation produces convincing results. Figure 1. shows the five major gaze intersection with the pyramid. The pyramid helps to define the trajectory of the eye. This is used in the head IK algorithm to solve for the neck position in 3D space. Figure 1 shows the orientation of the head and neck at extreme positions of the head.

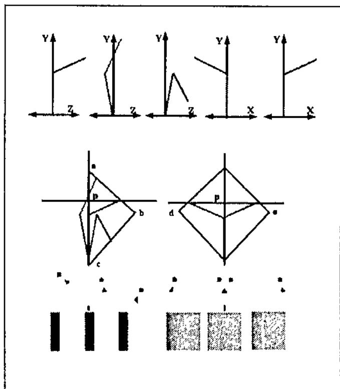

Figure 1. Gaze Limits

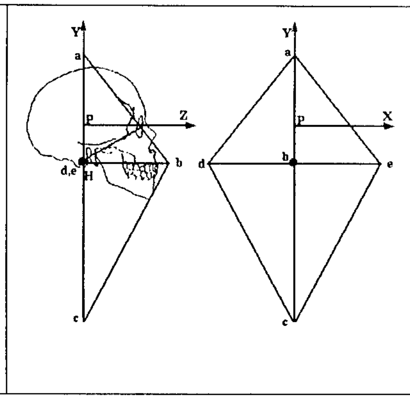

Figure 2. Pyramid: Front and Side Views

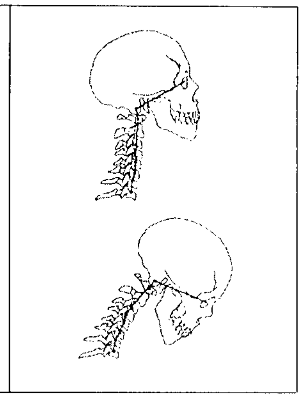

Figure 3. Neck Position during Gaze

The two link four DOF human neck and head used in our work is an approximation of the biological head as indicated in the artistic representation of the head. The goals of this research work are to develop:

- a mathematical model based on biomechanical properties of the human head and eye movements.
- successful algorithms for coordinating the head and eye movements for gaze animation.
- solutions for adapting the existing algorithms for a variety of human gaze behavior.

1.1 Definitions

Some of the terms that define the behavior of eye movement are defined below:

- Fovea is the small shallowly depressed region in the centre of the retina where the vast majority of photoreceptors in the eye are located.
- Saccade is the method by which an oculomotor reaction moves the eyeball such that the image of interest is fovealized. This eye movement is necessary so that the image of an object that requires detailed perceptual analysis projects onto this high-resolution area.
- Vestibulo-ocular reflex(VOR), helps to hold the retinal images stable by counter-rotating the eyes during head movements.
- Gaze direction is the line of sight from the eye to the target.
- Gaze trajectory is the path followed by the line of sight from the initial gaze direction to the final position.
- Gaze pyramid is the surface that contains the mid-eye position during neck, head, and eye movements.

1.2 Contributions

The main contributions of our work are:

- We propose a pyramid approach for the gaze trajectory during reach.
- We show that an IK algorithm is used to solve the head and neck posture during gaze animation.

2. EXPERIMENTAL DETAILS

Gaze angle and neck posture are interrelated. In this section we describe techniques to compute the neck posture for animation of the neck, head and eyes.

2.1 Algorithm for Gaze Animation

The following is a schematic overview of the algorithm used to obtain neck orientations and associated head positions while varying the gaze directions along the gaze trajectory. The algorithm was designed and implemented using C++ on a SGI Octane workstation. Gaze trajectories were specified and for each gaze direction in the trajectory, the mid-eye intersection was obtained on the pyramid. This in turn was used by the IK routine for computing the neck posture. The new neck postures and head orientations were computed and displayed.

Gaze_Animation_Algorithm()

```
{
Input initial Gaze Direction
Input EYE MOVES WITH HAND
Input the Gaze Trajectory
For each gaze orientation
    {
    Compute Eye trajectory On Pantograph
    Compute the neck orientation using Head IK
    Compute head and eye orientation
    }
}
```

2.2 The Human Model

Essentially, this requires two components, a human model capable of moving like a real human, and an animation model that naturally simulates human motion. The model is a simple human skeleton built with low resolution blocks and a sphere for the head, all modeled hierarchically for proper limb movement. Each of the joints is limited to be capable of rotating only within a realistic human range. For example, the neck will only tilt forwards and backwards in a 90 degree range, from -30 degrees to 60 degrees. The neck joint keeps the head continuously pointed at the cursor. Numerous studies demonstrate a strong link between eye and head movements.

2.3 Head and Neck Inverse Kinematics

The kinematics of the head and neck have been studied by researchers from a biomechanical research point of view. We approximate the head and neck by a two link mechanism. We find that this is similar to the arm movement with a different set of constraints. Figure 4 illustrates the head and neck coordinate system. Several solutions exist for IK of arm that can be used.

We extend the simple geometric IK arm algorithm [7] for our head model. The neck has three degrees of freedom and the head has one degree of freedom about the neck.

2.4 Testing Procedure

The animation tests the behavior and dynamic interaction of gaze angle and the neck posture. Several tests can be used to validate the model. Figure 5 shows the sequence of head movement of a human eye tracking in normal pursuit, using the pyramid trajectory and IK algorithm. These are test images used in testing the behavior of eye movements. However in a real subject, the axis of movement also changes dynamically and hence simple trignometric rules don't give the desired neck postures. In our experiments, we try to simulate a sequence for the vertical movement of the head. The next experiment is to obtain the lateral flexion of the gaze direction.

The five vertices for the bounding pyramid for our experiments are as *a*, *b*, *c*, *d* and *e* for the five vertices of the pyramid and *p* the center of projection for gaze directions. The pyramid has a four sided base and four triangular faces. So given a target the mid-eye position on the pyramid is computed by a simple intersection of the gaze line with the triangular faces of the pyramid.

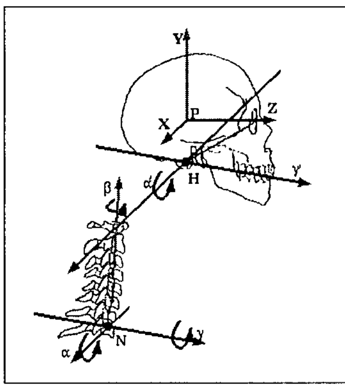

Figure 4: Head and Neck Coordinates

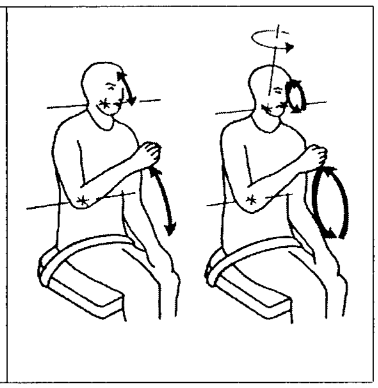

Figure 5: Examples of Gaze Trajectory

2.5 Head and Eye Orientation

Where should the eye be moved next? Eye behavior can be characterized under three groups [3]. Reading a text, can be thought of as an exploratory behavior characterized by direct saccade-fixation sequences. How the eye moves to the Line of Sight can be done in several ways cf. Fick, Listing and Helmholtz. Our method described in the paper follows the notation described by Helmholtz. If the line joining, two eyes are horizontal, the eye can rotate about this axis to turn up or down. Similarly to turn left or right, a rotation about the vertical axis is required. However it is noted that this is independent of the neck posture. For simplicity, for our test cases we assume the eye along with the head is oriented along the gaze direction. The head orientation can however be derived based on the human behavior described in[3].

3. RESULTS

3.1 Vertical Gaze Trajectory

An animated sequence of vertical gaze trajectory of normal smooth pursuit has been generated when the gaze is pointing upward and when the gaze is directed towards the floor. The trajectory for the gaze direction is on a vertical straight line. As the gaze is directed along the trajectory, for each new position, the new mid-eye position will be computed. This in turn is used by the IK algorithm to compute the neck posture and head posture. The hand position is moved in the opposite direction to that of the head.

3.2. Lateral Gaze Trajectory-Right

Another sequence of head movement of a human eye tracking in normal pursuit, using the pyramid trajectory and IK algorithm for the neck posture can be computed for the trajectory which moves the gaze direction to the right from a center position. However, the rate at which the gaze shift is done can be controlled by the human behavior.

3.3. Lateral Gaze Trajectory-Left

Figure 7. shows the sequence of head movement of a human eye tracking in normal pursuit, using the pyramid trajectory and IK algorithm. In this example, the gaze trajectory is selected so that the head is turned to the left and the corresponding neck postures are computed.

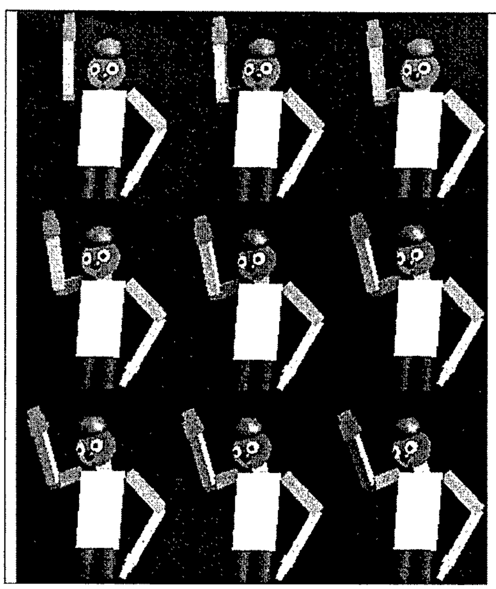

Figure 6: Eye Right Trajectory

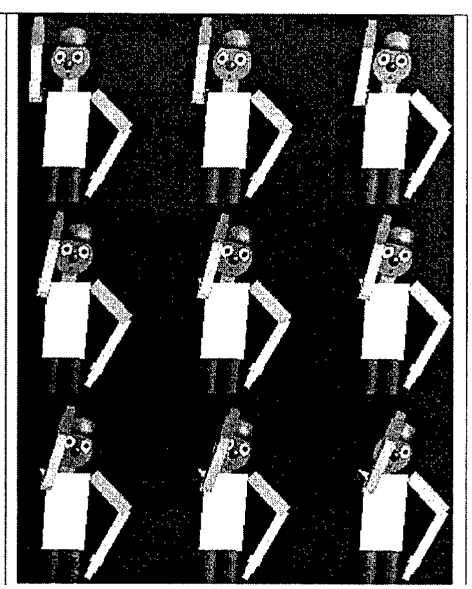

Figure 7: Eye Left Trajectory

4. DISCUSSION

4.1. Observations

Even though several research efforts have been made in human animation [5, 6, 1, 8], very little has been done in gaze posture animation. Most of the efforts have been targeted towards modeling human motor control and human behavior[2]. However not much has been reported for neck posture modeling and animation.

4.2. Comparison with Badler's Method

Badler uses the eye fixation as a reference point between the eyes[1]. This reference point helps to fix the head using the neck. Behavioral parameters are used to control the eye movements after the head is fixed. Also options exist for the user to specify a fixate eye position.

4.3. Comparison with Chopra's Method

Chopra's work[3, 4] on the other hand captures behavior of human eyes while performing simple tasks. Target object coordinates are converted into joint angles that manipulate the human model's head, neck and eyes. The mechanism which controls the model's head and eye movement is based on a study of eye-head coordination. Small gaze shifts produce only eye movement while larger shifts (between 20 to 90 degrees) generate combined head and eye movement. Chopra translates the behavior into trajectories that are given as input to the head-eye coordination system. Chopra's results have been applied for eye position and orientation during human locomotion and human gaze at distant objects, which has little effect on the head and neck orientation and eye shifts. It is not clear, how the orientation of the neck takes palce to obtain the head orientation. The main problems of the above work is that it does behavior animation but not gaze posture animation. Another problem with Chopra's work is that there can be more than one neck posture for a given gaze. Our approach does not face this multiple posture problem, as there can be only one mid-eye position on the pyramid for a given posture. A clever integration of Chopra's gaze behavior with our gaze posture will be the ideal system for human gaze animation.

5. CONCLUSION

Perhaps the most important finding of this work is the experimental confirmation of the validity of the IK algorithm for determining the neck posture. It could be argued that the pyramid scheme even though it doesn't represent the actual gaze surface, is acceptable approximation given the nature of the disparity in the human head size and shapes. Our next step in the research is to generate a corpus of gestures that involve gaze and neck posture. This will enable us to build an interface that can deploy virtual humans to mimick real human behavior.

REFERENCES

1. N. Badler, C. Phillips, and B. Webber. *Simulating Humans: Computer Graphics, Animation, and Control.* Oxford University Press, New York, 1993.
2. Eva Cerezo, Alfredo Pina, and Fransisco J. Seron. Motion and behavior modeling: state of art and new trends. *The Visual Computer*, 15:124-146, 1999.
3. S. Chopra-Khullar. Where to look? automating certain visual attending behaviors of virtual human characters. *PhD Thesis, Computer and Information Science, University of Pennsylvania, USA*, 1999.
4. S. Chopra-Khullar and N. Badler. Where to look? automating visual attending behaviors of virtual human characters. *Autonomous Agents Conf., Seattle, WA, USA*, May 1999.
5. Jessica K. Hodgins. Animating human motion. *Scientific American*, 278(3):46-51, Mar 1998.
6. M.Cavazza, R.Earnshaw, N.Magnenat Thalmann, and D.Thalmann. Motion control of virtual humans. *IEEE Computer Graphics and Applications*, 18(5):24-31, 1998.
7. Xuguang Wang and Jean Pierre Verriest. A geometric algorithm to predict the arm reach posture for computer-aided ergonomic evaluation. *The Journal of Visualization and Computer Animation*, 9:33-47, 1998.
8. Wu Zhongke and Edmond C. Prakash. *Chapter 14: Voxel Human Animation.* in Volume Graphics, ISBN 1-85233-192-5, Min Chen(Ed), Springer, NY, 1999.

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A Method for Uncovering the Dialogue Patterns of a Speech Driven Automatic Teller Machine for Bilingual Users

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A method for uncovering the dialogue patterns of a speech driven Automatic Teller Machine (ATM) is proposed in this paper. The dialogue is required for developing a hybrid prototype that simulates real world speech-driven ATM. The prototype is expected to accommodate bilingual users of Bahasa Melayu (Malay Language) and English. The method is based on word spotting and multiple mapping techniques. To simulate the technology, we use the Wizard of Oz approach. We present the interface design of the prototype, which will be evaluated in a separate usability study.

1. INTRODUCTION

The introduction of Automatic Teller Machine (ATM) as an alternative to banking transaction has enabled the public to perform a broad range of computer-based functions. Present day ATM systems provide a number of facilities, such as withdrawal, balance enquiry, cash transfer, and depository functions. Therefore, it is important that users are able to interact effectively with the system. However, the usability of ATM is still a concern, in particular the optimal use of ATM in supporting customer needs [1].

Rogers, et al. [2] claimed that there are still weaknesses in the current 'cash-in-a-hole' ATM. They asked if the ATM is so easy to use, why is everyone not using it? Clearly, the nature of human-computer interaction with the ATM is still very complex. Ooi [3] found that the first generation of ATM systems require users to perform a series of interactions to achieve the desired goals.

One possible solution to present-day ATM is to integrate speech recognition as part of the user interface. Although a developing technology, Automatic Speech Recognition (ASR) is relatively mature compared to emerging communication technologies such as the Internet [4]. Its advantage is because it enables a more natural interaction between the user and the computer [5], [6], [7]. In order to achieve a more efficient interaction, human factors issues encompassing cognitive, environment, task, dialogue design and user expectations have to be considered. Some studies have shown that it is more efficient to use ASR in an application that manages numbers, alphabets and words such as telebanking [8], [9], [10].

Hone, et al. [6] investigated people's responses to speech driven ATM. About one third of the respondents were skeptical of ASR potential. But there were users who would use it if the machine can offer faster interaction. Most of them refused to use ASR because it is not natural enough. Manzke, et al. [7], however, focused on physically and visually impaired users who find speech driven ATM beneficial as it enables them to perform their own transactions.

Using speech recognition as an input device raises various problems because speech tends to vary between speakers of different gender, age, experience, language, preferences and expectations. An acoustic voice from a different gender or cultural background will produce a different voice, tone, echo when pronouncing a word. Other factors, such as stress and sickness, can affect the speaker's voice. Also, memory failures due to large vocabulary size can induce stress. This may be alleviated by understanding the dialogue pattern of the user [4]. Allowing spontaneous natural speech can also help to reduce the memory load. The ASR technology when applied to an ATM enables users to perform the transaction without having to remember a particular word. However, ASR's accuracy depends on the software's features, including the vocabulary size, speaker independence or dependence, and training.

Using word spotting and multiple mapping techniques, the 'naturalness' of user-ATM interaction may be enhanced. Multiple mapping, in particular, is said to support bilingual interaction because the ability of speaking in a language to code an idea varies across cultures and gender. A speaker may have the same concept in different words, and code them in different ways, but they all shade the same meaning that is normally associated with the same word cluster [11]. The Sapir-Whorf hypothesis of linguistic relativity states that the structure of a culture's language shapes what people think and do. Whorf claimed that having a rich variety of terms could cause the speaker of a language to perceive the world differently from a person who had only a single word for a particular category [11].

2. DIALOGUE DESIGN FOR SPEECH DRIVEN ATM

Many users are reluctant to use a speech system because they perceive the interaction as not natural enough [12]. Previous ASR systems embed spoken commands within more complex utterances. A natural language interface is better as it encourages an informal and direct way of speaking, and users may use the language and style that are familiar to them to communicate their ideas [13]. An example of a natural language approach in Brems, et al. report study:

> *Natural Language Approach*
> "Sorry please repeat. Say collect, calling card, third number, person to person, or operator now."
> *Language Comprehension Approach*
> "Your request was not understood. Please say collect, calling card, third number, person to person, or operator now."

Natural language, as used here, means a person speaks naturally or instinctively using the most desirable and memorable word that comes across his/her mind.

2.1. Word spotting

New approaches in designing ASR user interfaces may improve the intelligibility and quality of natural interaction. Brems, et al. [13] used *word spotting* and *barge in* (intercept) to reengineer the traditional approach of ASR design. Word spotting refers to the capability of ASR to recognize key words in a user's response. Word spotting permits an ASR system to recognize the key word 'collect' even when it is embedded in extraneous speech, such as in "collect call please" (abridged syntax) or "I would like to make a collect call, please" (correct syntax). Barge in refers to the capability of an ASR system to recognize spoken commands while it simultaneously plays a prompt.

For example, in English and Bahasa Melayu (Malay language), respectively:

Correct syntax consists of eight words:

I	want	to	withdraw	money	from	savings	account
Saya	*nak*		*keluar*	*wang*	*dari*	*akaun*	*simpanan*

Abridged syntax consists of four words:

Withdraw	from	savings	account
Keluar	*dari*	*akaun*	*simpanan*

Language dualism is a typical characteristic of the Malaysian culture due to its colonial influence. As a result, Malaysian English is a growing phenomenon among Malaysians who are able to shift from one 'lect' to another (e.g. acrolect to mesolect, mesolect to basilect) instinctively [14]. Therefore, a dialogue of mixed syntax can be anticipated in a speech driven ATM, such as: 'Withdraw *dari* savings *akaun*'

In the example above, the words 'withdraw' and 'savings' are in English, while '*dari*' and '*akaun*' are in Bahasa Melayu. A hybrid ATM system is expected to be able to recognize the mixed syntax using word spotting technique, that is, words with the same meaning from both languages will be grouped to mean the same.

2.2. Multiple mapping

Another way to make it more intelligent and memorable for the users is to have a flexible vocabulary. McCauley [15] termed this approach "multiple mapping", that is using several alternative command words that give the same interpretation, thereby, a user is free to utter any of the command synonyms (presumably the one that is the most natural and memorable to the user) than having to learn a specific command. For example, an ATM user may say "withdraw" (in English) or "*keluar*" (in Bahasa Melayu), which has the same meaning, when making a withdrawal transaction from the ATM. Figure 1 illustrates this process.

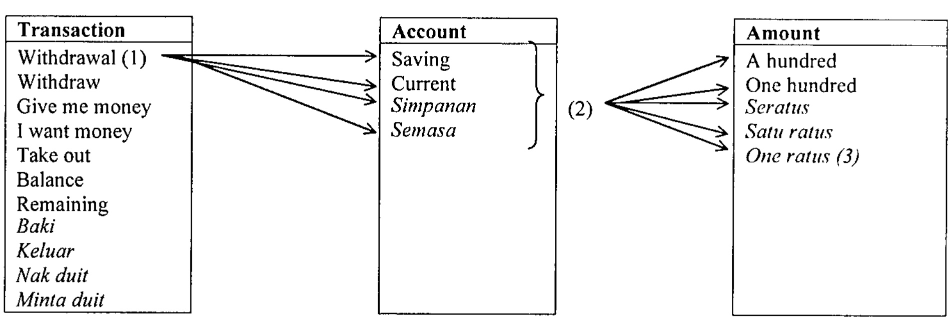

Figure 1. A multiple mapping approach that groups semantically similar words and matches them with other group of words across languages.

3. PROTOTYPE DEVELOPMENT

3.1. Wizard of Oz technique

The speech driven ATM may be simulated using the Wizard of Oz methodology (WOZ). WOZ is a prototyping technique that imitates the functionality of a system, and the operations are performed by a human person behind a screen. This method is used to collect data for designing systems dialogue, such as to determine user requirements and adapting the user's needs to match a predefined specification for a system. Understanding the user requirements is likely to produce a better application, and often it is less expensive to simulate. This technique helps the designer to get a more concrete description of the future system [16], [17].

In our study, real ATM users will be used to evaluate the simulated speech driven ATM system (also referred to as ATM hybrid). The user will initiate commands and the system subject will react or provide feedback. The system subject will be in an adjacent room, partitioned by a wall, so that the identity of the system subject will not be easily disclosed. Often, this is a weakness in the WOZ implementation. Both subjects will have their own communication interface as shown in Figure 2. The user subject will use speech and keyboard as command input devices. The system subject will listen directly to the command and key-in the response or feedback via a keyboard. A video camera will be set up to record the interaction and capture the dialogue said by the user.

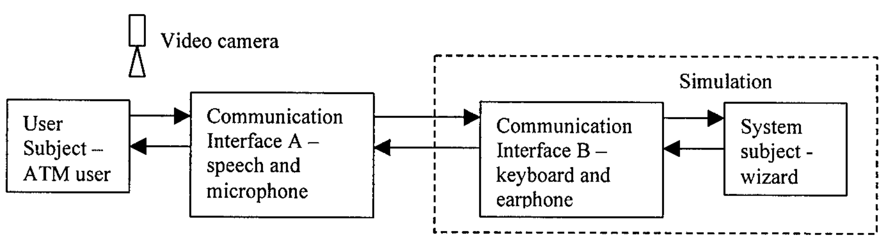

Figure 2. A generic model of human simulation (after Life and Long, 1985).

3.2. Tasks and dialogue capture

User subjects will perform their respective transaction task by speaking to the simulated system. Every user has to perform the withdrawal and balance inquiry tasks. However, no prior training will be given. The user subject will speak to the prototype system using a headset microphone. In Figure 2, the communication interface A consists of a display feedback from the system subject. The wizard will introduce some error feedback, intentionally, in order to motivate the user to speak in different ways when repeating the commands. In this way, several dialogue patterns may be uncovered. The user subjects will be told that they can speak in Bahasa Melayu or English when interacting with the system. It would be interesting to uncover if Malaysian English is a feature of the dialogue.

3.3. ATM hybrid configuration

The experimental set up comprises:

- a personal computer (PC) to simulate the interface and for conducting the experiment,
- two monitors to connect to the PC. This enables both the user subject and system subject to view the same interface during the user-system interaction,

- two input devices, the microphone and keyboard – for speech and manual input, respectively, by the user subject,
- a keyboard and headset earphone for the system subject to respond and listen, respectively, to commands made by the user subject.

The program for simulating the command and responses of user-system in the ATM hybrid was written in Microsoft Visual Basic 6.0. Figure 3 shows the interface design of the system. The feedback response will be quickly displayed on the screen to avoid suspicion on the user. The wizard's keyboard will be labelled with the specific command keys to accelerate the interaction. Also, some error feedback screens will be provided.

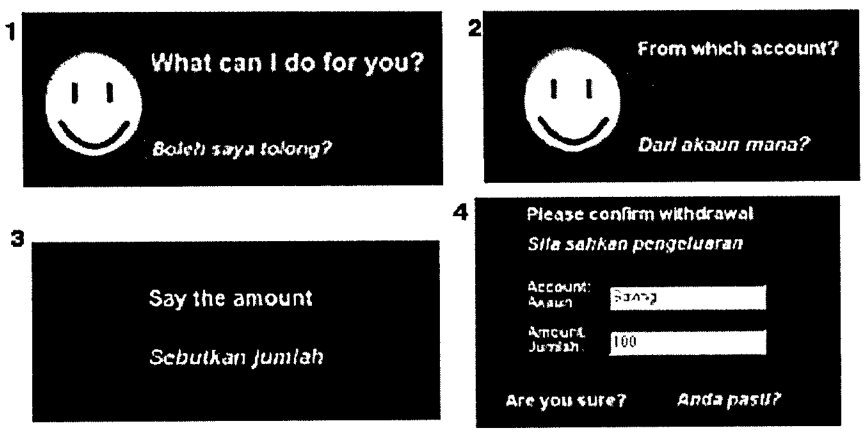

Figure 3. The user interface for the withdrawal task

4. FUTURE RESEARCH

The prototype will be evaluated in an experiment which aims to document the most frequently used words in a typical speech driven ATM transaction. This will enable the development of a generic dialogue for the hybrid ATM system. The latter system will be evaluated for usability in a follow-up experiment.

REFERENCES

1. C. Baber, N. A.Stanton, and G. I. Johnson, Editorial. From Public Technology to Ubiquitous Computing Implications for Ergonomics, Ergonomics, 41, 7 (1998) 921-926.
2. W. A. Rogers, E. F. Cabrera, N. Walker, D. K. Gilbert, and A. D. Fisk, A Survey of Automatic Teller Machine Usage Across the Adult Lifespan, Human Factors, 38,1 (1996) 156-166.
3. B. S. Ooi , Kebolehgunaan Arahan Mesin Teler Automatik: Satu Kajian Eksperimen ke atas Pakar dan Novis, Unpublished Bachelors Thesis, Department of Psychology, Universiti Kebangsaan Malaysia, Bangi, Selangor, 1991.
4. H. M. Khalid, and M. Helander, Human Factors of Speech Recognition, In W. Karwowki (ed.) International Encyclopedia of Ergonomics and Human Factors, Taylor & Francis, London, 2000 (in press).
5. W. A. Roger, and A. D. Fisk, ATM Design and Training Issues, Ergonomics in Design (1997) 4-9.

6. K. S. Honet, R. Graham, M. C. Maguire, C. Baber, and G. I. Johnson , Speech Technology for Automatic Teller Machines: An Investigation of User Attitude and Performance, Ergonomics, 41, 7 (1998) 962-981.
7. J. M. Manzke, D. H. Egan, D. Felix, and H. Krueger, What Makes an Automated Teller Machine Usable by Blind Users? Ergonomics, 41, 7 (1998) 982-999.
8. D. Karis and K. M. Dobroth, Psychological and Human Factors Issues in the Design of Speech Recognition System, In Sydral, Bennett and Greenspan. (eds.) Applied Speech Technology, CRC Press, Boca Raton (1995) 359-388.
9. C. Kamm, and M. Helander, Design Issues for Interfaces using Voice Input, **In** M. Helander, T.K. Landauer, and P.V. Prabhu (eds.), Handbook of Human-Computer Interaction (Second Edition), Elsevier Science, Amsterdam, 1997.
10. M.T. Hartman, T. Barlow, T., and T.E. Powell, Talking To Your Television, Proceedings of the Human Factors and Ergonomics Society, 42nd Annual Meeting (1998) 532-535.
11. J. R. Anderson, Cognitive Psychology and Its Implication, W.H. Freeman and Co., New York, 1985.
12. E. C. Schwab, H. C. Nusbaum, and D. B. Pisoni, Some Effects of Training on the Perception of Synthetic Speech, Human Factors, 27, 4 (1985) 395-408.
13. D. J. Brems, M. D. Rabin, and J. L. Waggett, Using Natural Language Conventions in the User Interface Design of Automatic Speech Recognition Systems, Human Factors, 37, 2 (1995) 265-282.
14. The Star, the people's paper, 12 May 2000, 18.
15. M. E. McCauley, Human Factors in Voice Technology, Human Factors Review, Santa Monica, Human Factors Society (1984) 131-166.
16. M. A. Life, and J. Long, The Use of People to Simulate Machines: An Ergonomic Approach, **In** E.D. Megaw (ed.), Contemporary Ergonomics, London, Taylor & Francis (1987) 117-122.
17. T. Klausen, Talking to a Wizard: Report From the Design of a Natural Speech Understanding System, AMODUES Project, ESPRIT Basic Research Action 7040, 1993.

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Confirmation and Error Recovery Strategies in Dialogue Design for Telephony Speech User Interfaces

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In speech interfaces, confirmation and error recovery strategies of the dialogue play an important role because misrecognition is unavoidable with speech recognition. While these strategies are necessary to ensure the reliability of the system, they may also make user interaction more time-consuming. For a telephony application, those strategies may also cause a higher call cost. If the target of recognition consists of several items (e.g., addresses), the speech system may recognize and confirm it in smaller chunks. While this may increase the completion rate, it may also increase the completion time. This paper discusses advantages and disadvantages of some confirmation and error recovery strategies. It then reports a simulation experiment to evaluate the strategies. Based on the simulation data, we discuss how these strategies should be chosen depending on the system and the task characteristics.

1. INTRODUCTION

Speech user interfaces are gaining popularity in recent years. More speech-enabled telephony applications, for example, are being deployed and replacing touch tone-based applications. Speech seems to be an obvious choice for telephony user interface since it is a natural means of interaction for humans and people have been talking into the phone for more about a hundred years. However, there are many challenges for this new technology. One such challenge is the occurrence of recognition errors. Recognition errors are inevitable for a number of reasons; for example, the user may cough while speaking, he/she may say something that is not in the system's vocabulary, the background noise may be too high, etc. While there are some recognition errors due to limitations of the current technology, which may be resolved in the future, those errors due to idiosyncratic characteristics of speech signals never go away. Since commercial telephony systems require a high level of reliability, reducing recognition errors and recovering from them when they occur are crucial aspects of speech interface design.

A speech dialogue system normally confirms the result of recognition by repeating to the user what has been recognized. The problem with confirmation is that it causes a call time to be longer than it should ideally be. The user may not only feel frustrated but also often get confused about the system's behavior. That harms usability of the system. As a consequence, it may increase the hang-up rate and/or decrease the likelihood of users coming back to the system. In addition, the long call duration results in a higher call cost and causes the system to fail to receive other incoming calls. Therefore, it is important for the speech system to minimize the call duration while maximizing the task completion rate.

In the literature, there are a few design recommendations [1, 2] and quantitative studies [3, 4] that compare different confirmation strategies. Niimi and Kobayashi [3] analyzed three strategies mathematically and compared them by the number of turn taking and task completion rate. Litman and Pan [4] examined subjective evaluation of a dialogue system and found some relationship with objective measures (e.g. task success rate, recognition rate, elapsed time, etc.) There are, however, no studies that address design criteria for a dialogue system based on a quantitative analysis.

This paper examines the effects of confirmation and error recovery dialogue designs on the performance of a telephony-based speech system with address recognition. First, we will discuss several dialogue strategies for confirmation and error recovery. Then, we will report a simulation experiment that evaluated these strategies.

2. DIALOGUE FLOW DESIGN

2.1 Confirmation strategies

Many recognition targets consist of multiple items. Addresses, for example, consist of four or five items (e.g., state or province / city / street / street number). To confirm such input, there are two basic strategies: *1. Whole confirmation*, which is to recognize and confirm, for example, the entire address (Figure 1 (a) and Figure 2, A), and *2. Partial confirmation*, which is to break up the recognized item into chunks and confirm them one by one (Figure 1 (b) and Figure 2, B).

Generally speaking, it takes more time to achieve the task in the partial strategy because there are more turn-taking between the system and the user due to confirmation for each query. The partial confirmation is, on the other hand, advantageous for multiple-item recognition. A common recognition error is that one part of the target, say the city, is recognized incorrectly. The whole confirmation cannot identify which part has been misrecognized. In contrast, the partial confirmation can avoid this situation as it confirms the target in smaller chunks.

The task completion rate, on the other hand, may seem to be higher with the partial strategy than the whole strategy, but in reality this is not always the case. The relative effectiveness of these strategies depends on the recognition rate, the vocabulary size, and the language model.

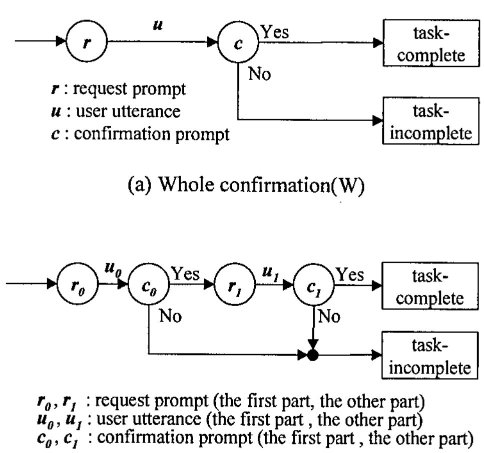


Figure 1. Confirmation strategies

A. Whole recognition and confirmation
System: Please say your name.(*r*)
Caller: John Smith. (*u*)
System: John Smith. Is this correct? (*c*)
Caller: Yes.

B. Partial recognition and confirmation
System: Please say your last name. (r_0)
Caller: Smith. (u_0)
System: Smith. Is this correct? (c_0)
Caller: Yes.
System: Please say your first name. (r_1)
Caller: John. (u_1)
System: John. Is this correct? (c_1)
Caller: Yes.

Figure 2. Example of confirmation

2.2 Error recovery

If a recognition error occurs, the system must resolve it. To do that, a dialogue flow must include *error paths*. We will introduce two types of error recovery confirmation here.

(1) Error recovery by alternative confirmation (AC)

Many ASR engines are capable of generating alternative results as a list of candidates (called n-bests). When an error occurs and the first item is found to be incorrect, the speech system with the n-best capability can present to the caller the second item as an alternative in the confirmation phase. Figure 3 (a) shows the dialogue flow that makes the whole confirmation (c) initially and if wrong, takes a path to the alternative confirmation (c'). The dialogue flow in Figure 3 (b) is the partial confirmation strategy with the path to the alternative confirmation after each partial confirmation.

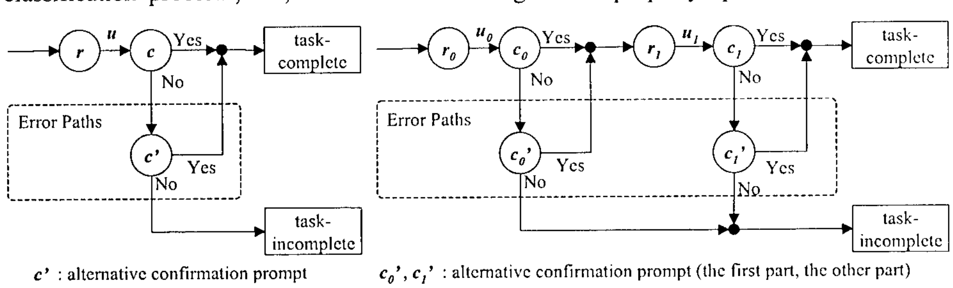
An advantage of the alternative confirmation approach is that the system does not have to ask the user to speak again. This can avoid a possibility of further misrecognition. It can also minimize the additional turn taking, hence the task completion time, for error recovery.

One issue about this strategy is that there is no guarantee that the second best is the correct choice. If the second choice is incorrect, there are a few choices that the system can take: 1) to present the next best match, 2) to ask the user to speak again, or 3) to terminate the error recovery. Which choice is optimal is not an easy question because there are trade-offs in each option.

Generally speaking, as the vocabulary size becomes larger, it becomes less likely that the second best match is the correct one. If there are only two possible words, the second best is guaranteed to be the correct one given the first choice is wrong whereas if there are more than two possible words, there is no such guarantee.

(2) Error recovery by retrying recognition and confirmation

The alternative confirmation strategy can only resolve errors caused by ASR's classification problem; i.e., the misunderstanding of the properly spoken utterance. If the



(a) WA (b) PA

Figure 3. Error recovery by alternative confirmation

cause of the recognition is accidental (e.g. failure to speak, accidental background noise, coughing, etc.), it is effective to ask the caller to speak again and retry recognition and confirmation. There are two choices for error recovery: 1) to retry in the same strategy as previous try (Figure 4 (a)) or 2) to change the error recovery strategy in the dialogue (Figure 4 (b)). The former option has a possibility of repeating the same recognition error as it repeats the same process of prompting and recognition. In that respect, the second option may be more desirable. With a slightly different prompt, the user may often change his/her speech behavior. On the other hand, a different prompting may confuse the user about what to say or how to say it and may end up with inviting more recognition difficulty.

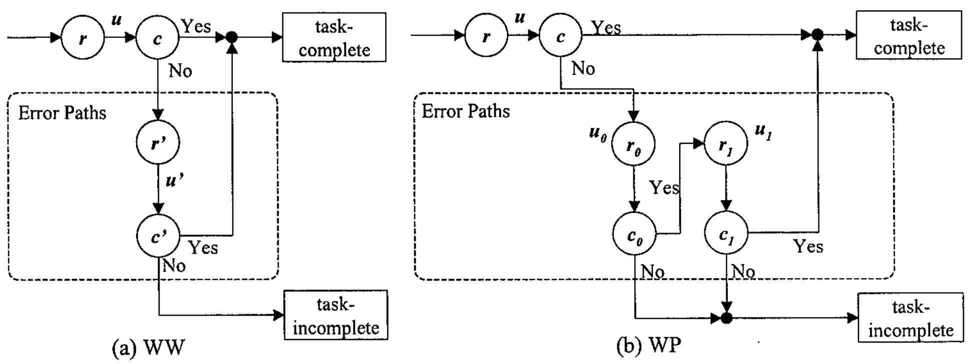


Figure 4. Error recovery by retrying recognition and confirmation

3. SIMULATION EXPERIMENT

In the previous section, we presented some basic confirmation and error recovery dialogue schemes. As discussed above, each strategy has its strengths and weaknesses. Therefore it is important to know what characteristics these dialogue models have and what the trade-off are in employing them. To evaluate the dialogue strategies, we conducted a simulation experiment of these models to obtain some data on performance.

3.1. Method

A total of eight dialogue simulations were constructed with different confirmation styles (whole / partial) and error recovery strategies (none / alternative / whole / partial) as follows:

(1) Whole confirmation and no error recovery (W)
(2) Whole confirmation and alternative confirmation error recovery (WA)
(3) Whole confirmation and whole confirmation error recovery (WW)
(4) Whole confirmation and partial confirmation error recovery (WP)
(5) Partial confirmation and no error recovery (P)
(6) Partial confirmation and alternative error recovery (PA)
(7) Partial confirmation and partial confirmation error recovery (PP)
(8) Partial confirmation and whole confirmation error recovery (PW)

In the simulation, we made the following assumptions:

1) It would take the system the same amount of time to play a confirmation prompt as that of the corresponding user utterance (i.e., $t(c) = t(u) + constant[=2sec]$).
2) An utterance for the initial recognition (u, u_0 and u_1) and the retry recognition (u', u_0', and u_1') would be the same.

The speech recognition software for Japanese developed by Nuance was used with a grammar that contained approximately 350,000 Japanese addresses developed by Omron. A total of 2,000 audio tokens of one person saying different addresses were prepared. They were submitted as user utterance input to each of the eight dialogue models in the experiment. For the partial confirmation, the addresses were broken into two parts.

In each simulation run, whether the task was achieved or not was recorded. In addition, the duration of each utterance was measured and the elapsed time to accomplish the recognition task was calculated for each address.

3.2. Results

The results for the dialogue models were plotted on the two-dimensional space with the mean elapsed time (MET) on the x axis and the task completion rate (TCR) on the y axis as shown in Figure 5.

The whole and no error recovery model (1) showed the shortest mean elapsed time (MET) whereas *the partial and whole model* (8) had the longest MET. This is expected because Model 1 required the smallest number of turns while Model 8 the largest. The other models are also, generally speaking, ordered as a function of the number of turns needed to complete the task.

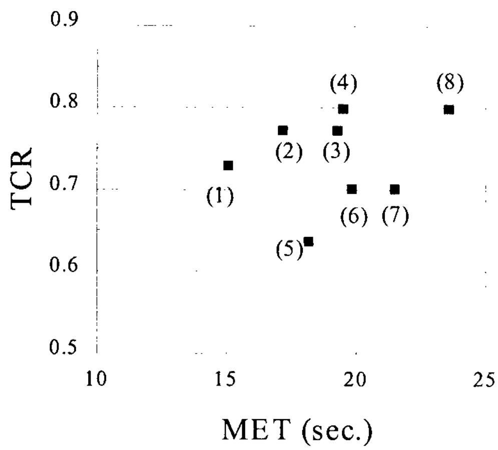


Figure 5. Result of simulation experiment

In terms of the task completion rate, *the partial and no error recovery model* (5) was the lowest while *the whole and partial model* (4) and *the partial and whole* (8) marked the highest. Model 5 showed the worst performance because this strategy did not have error recovery. Overall, *the whole and alternative strategy* (2), *the whole and whole strategy* (3), and *the whole and partial strategy* (4) showed relatively better performance in the experiment.

3.3. Discussion

In this section, we will discuss the issue on criteria for selecting a dialogue strategy, especially focusing on *the whole and alternative confirmation (WA) strategy* and *the whole and partial confirmation (WP) strategy*, which showed better performance in the experiment.

It is often said that the results from a lab test are not applicable because there are several differences between the research environment and the real world. Therefore, there is a concern that the experimental results are not useful to a real-world system. We argue that the simulation results we obtained *are* applicable to real-world systems.

First, we will consider the effect of the recognition rate on the dialogue system performance. We will show that the relationship between the two strategies will remain unchanged even if the recognition rate changes. The task completion rates (TCR) for these strategies are expressed by the following equations:

$$TCR_{WA} = P + (1 - P)P' \quad (1)$$
$$TCR_{WP} = P + (1 - P)P_0P_1 \quad (2)$$

where P denotes the recognition rate, P' denotes the probability of correct recognition given the first item in the n-best being incorrect, and P_0, and P_1 denote the recognition rates for the first part and the second part respectively.

The equations show that the task completion rates for both strategies increase as the recognition rate P increases. The difference in task completion rate between them decreases as P increases, but they never cross until the P becomes 1. In our system, P_0P_1 (= 0.64) was higher than P' (= 0.16), therefore, TCR_{WP} is always higher than TCR_{WA}. Likewise, the mean elapsed time of the WP strategy is longer than that of the WA dialogue. For both strategies, the performance of the dialogue system increases as the recognition rate increases. It is not necessary to consider another strategy depending on the recognition rate change unless the values of P' and P_0P_1 are swapped.

Second, how would the probability of the alternative choice being correct (i.e., P') affect the performance of the WA dialogue? If P' is very small, the task completion rate of WA (TCR_{WA}) comes close to that of no confirmation strategy ($TCR_W = P$). This means that if the likelihood of the second choice being correct is low, the WA strategy is not effective on error recovery. This is usually the case if the ASR has a large vocabulary, or the majority of errors are caused by accident (e.g. cough, etc.).

Finally, the design of prompt is important to guide the user effectively and to prevent repetition of the same user errors. Often prompts have to be modified as a result of the analysis on the live data from the deployed system. Would changes in prompts, especially prompt lengths have any effect on the results for these strategies?

The prompt duration has an effect only on the mean elapsed time. Basically, it linearly affects both strategies. The difference in duration between WA and WP would be approximately the length of the error recovery path. If long prompts are needed for the error recovery path to resolve user error, the difference between these strategies becomes large and the WA becomes more suitable. Though when most errors are accidental, as described in Section 2.2 (2), the WA strategy would be less effective in resolving the errors.

4. CONCLUSION

In this paper, we presented the confirmation and error recovery strategies that make speech dialogue systems more reliable. We discussed the strengths and weaknesses of these strategies. The simulation experiment with the dialogue models incorporating these strategies for address recognition showed that an inappropriate choice of strategy resulted in a longer task completion time and lower completion rate, suggesting that it would put a more burden on the user. We also discussed the issue of relevance of these simulation results for real systems in relation to the ASR's recognition rate and the system prompts.

In this study, we did not examine the effects of these strategies on the user's behavior and subjective judgment on the system's performance. To have a more thorough assessment to the system performance, it is important to see if the differences found in the simulation would have any psychological effects on usability. Investigating these areas would of course be a possible future work.

REFERENCES

1. Dafydd Gibbon, Roger Moore and Richard Winski (eds.), *Handbook of Standards and Resources for Spoken Language Systems*, Mouton de Gruyter (1997)
2. Bruce Balentine and David P. Morgan, *How to Build a Speech Recognition Application*, Enterprise Integration Group (1999)
3. Y. Niimi and Y. Kobayashi: Modeling Dialogue Control Strategies to Relieve Speech Recognition Errors, *Proceedings of Eurospeech '95*, pp.1177-1180 (1995)
4. Diane J. Litman and Shimei Pan: "Empirically Evaluating an Adaptive Spoken Dialogue System", *Proceedings of the 7th International Conference on User Modeling*, pp. 55-64 (1999)

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The Role of Cognitive Ergonomics in Educational Multimedia Applications

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This paper discusses some important, if not crucial, aspects of Cognitive Ergonomics that should be taken into account when authoring any educational multimedia product. This paper begins by discussing why educational multimedia is becoming more fashionable in the teaching and learning process. Thereafter, by placing the human-computer-interaction model side by side with the nature and function of the educational multimedia product, some important cognitive ergonomic factors will be highlighted.

1. INTRODUCTION

The real challenge for an educator has always been finding ways to maximise learning and the transfer of learning. This is due to the fact that what worked before may not work in the future. Learning is much more than just gathering information in a well-designed, teacher-centred environment. It is promoted when students pursue individual interests, when they build on prior knowledge, and when they engage in hands-on and authentic activities [1]. An important concept that has returned to instructional theory is the concept of learning through construction. However, such knowledge construction is usually mired in the classroom context due to some rigid structure embraced by the educators. As Lehrer [2] rightly put it:

> At the turn of the century, Dewey advocated learning centred but teacher-guided education built around efforts to link purpose and structure... He advocated and placed students in the role of developing rather than receiving knowledge. Unfortunately, schools rarely embrace this philosophy, in part because the metaphor of learning in schools is often one of knowledge transmission rather than of knowledge construction (p. 197).

The rapid development in the area of information technology and educational reform has contributed to the paradigm shift in instructional design: from a teacher-centred to self-regulated learning. With such reform, teachers hold the role of a facilitator – facilitating students' knowledge construction. When developing an educational multimedia package, therefore, the 'facilitating' roles need to be embedded into the system; and this is a real challenge for the multimedia developer.

There is a tendency for the multimedia developer, especially in the field of education, to overlook the ergonomics aspect of the product; especially on cognitive front. If this is not carefully looked into, we may just end up creating more books, in electronic form, in which facts and information are presented through various media without facilitating authentic learning. In other words, books (especially in the future) will be in the form of CD-ROMs and with a hi-tech way of turning its pages, such as clicking a certain button instead of actually turning the real pages. Since the conventional way of 'turning' pages is not popular anymore, users may face difficulty in figuring out how to actually turn those sophisticated pages. For the user, learning the interface will be another cognitive load, apart from learning the facts and information in the 'book' itself.

On the part of the educational multimedia developer, they may be lured into making their product more aesthetically appealing, since the competition in the area of such product design is ever so steep. Although such competition is healthy for the economy, such an unconventional design will potentially lead to the failure in addressing the issue of usability. Altering a common operation (e.g., turning the pages) may cause us to overlook the fact that not all users are computer savvy. Therefore, it is crucial to take into account the aspect of cognitive ergonomics (that is seemingly invisible), when designing these hi-tech educational multimedia application products.

2. EDUCATIONAL MULTIMEDIA APPLICATION

The traditional 'chalk and board' paradigm has long been outdated in the arena of educational technology. In fact, even the use of overhead transparency and PowerPoint presentation is becoming a bit too common. Students in the classroom are getting wearier whenever their teachers are starting up the computer. It is no more an item of educational technology that could motivate, least impress, the students anymore. Those technological savvy students, and those students with affluent parents have come across even more exciting learning materials – multimedia educational packages. Since such products have become so popular, many developers are emerging, so as to meet various demands from the end user.

Multimedia can be simply defined as a multiple means by which information is stored, transmitted, presented, or perceived [3]. It is any combination of text, graphic art, sound, animation, and video delivered through computer or any other electronic means. Through the utilisation of various media as such, multimedia greatly enhances the learning experience by involving more of the learner's senses. Learners are presented with a wide range of navigation routes in a non-linear fashion. For example, leaving an exercise half done to explore another topic before returning to complete the initial exercise. These navigational opportunities enhance the learners' own learning styles.

The main goal of having such multimedia educational systems is to create an opportunity for self-regulated learning. By self-regulated learning, students are expected to learn something at their own pace. Learners can set the pace of instruction and work through the content at a rate commensurate with their ability and motivation. In other words, each learner's learning style is being individualised. Learners have the option to repeat certain portions when necessary or desired, and change the speed at which they progress through each specific content area. In other words, such non-linear approach to knowledge and information encourages students for independent study according to their needs at a pace appropriate to their capabilities.

Another push factor for utilising such multimedia systems is because through 'ONE' platform, one can view a document through various media. Traditionally teachers have brought various books, videos, slides, sound recordings, and other media into the classroom, along with accompanying projection and playback equipment. With the advancement in information technology, multimedia creators have integrated these individual instructional resources into a cohesive meaningful way. Instructional elements and materials are stored so that it may be retrieved in a non-linear fashion, depending on the needs or interests of learners. Besides that, teachers can also use multimedia to respond spontaneously to students' questions by referring quickly to relevant portions.

Ever since Wundt (1912) claimed at the turn of the twentieth century that all thought processes were accompanied by images, numerous studies have been conducted to understand visual thought processes and to investigate instructional strategies facilitating those processes in learning. The instructional effectiveness of animation as a device for facilitating the visual learning process has been a primary issue in many recent computer-based instructional (CBI) studies because of animation's perceptually attractive, realistic and engaging attributes. The use of animation - artificially generated movements of pictures or graphics in computer displays - will continuously increase as the capacity of computers to develop and present such displays improves. However, research elsewhere found that images, whether animated or static, facilitate learning only when their attributes are congruent with the specific learning requirement (e.g., [4], [5]). For example, visualising an object's movement using animation is helpful for the understanding of dynamic concepts such as velocity because direct observation of those concepts in the movement of actual objects is practically impossible.

If people do not necessarily learn better through images per se, what it means is that multimedia creators have more responsibilities. They must think of what is to be animated and what not to, in order that the multimedia users can maximise their learning. This is really much more than a technical interface issue. It goes deeper into the knowledge construction level, of which is called a pedagogy issue by educators.

In the process of developing educational multimedia products, one must bear in mind that the main functional objective of such products is to achieve learning as well as transfer of learning. Educational multimedia products are also meant to be encouraging some degree of self-regulation in learning on the part of the learners. Since the process of its development involves complicated technical procedures, it is easy for one to pay much more attention to its technical effectiveness rather than the functional effectiveness.

Putting it simply, there are at least *two* main challenges that any instructional multimedia creators have to address: (1) Issues related to *pedagogy* (Is the product functionally appropriate in instructing its content knowledge to the users?); and (2) Issues related to *interface design* (user-friendliness, aesthetic etc.).

3. A MODEL OF HUMAN-COMPUTER-INTERACTION

What happens (cognitively) when a user sits in front of a computer, learning from the multimedia system? Figure 1 illustrates the elements and processes that are involved in the human-computer interaction. Information from the multimedia package will be displayed on the computer screen. The person perceives the information through his sensory system (audio or visual). The information then will be processed in his information processing system. Upon making sense and understanding the information displayed, he will then respond by generating command through the control system of the computer. The input command will go through an internal processing mode in the computer system. This process will continue in cycles until the person has achieved his goal.

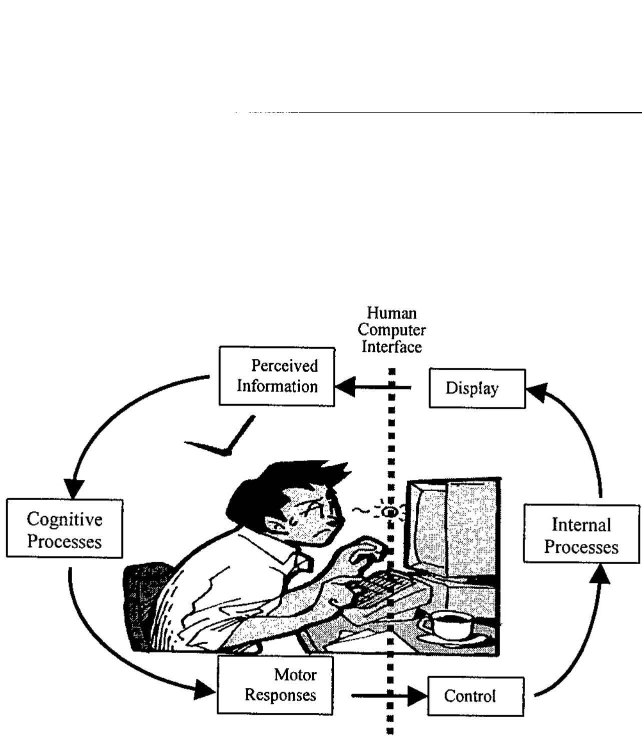

Figure1. Human-Computer Interaction Model (Adapted from Helander 1995)

As clearly shown in this model, the ability to learn from the multimedia package depends on two elements that have been mentioned earlier; i.e., the internal design of the lesson instruction (which boils down to its pedagogic issues) and the interface design.

4. COGNITIVE ERGONOMICS IN EDUCATIONAL MULTIMEDIA SYSTEM

A crucial question at this point is 'how can we make the educational multimedia system most effective in instructing learners?' As shown in Figure 1, the learner (or computer user) is at his autonomous state whereby he is in control of the whole learning environment. Whatever happens in his 'cognitive processes' stage will be what he has made sense of from the instructional package. Therefore, the multimedia product must include in it both pedagogically and technically sound elements so that the whole system is user-friendly and knowledge constructive.

4.1 Cognitive Ergonomics and Pedagogy Issues

As far as pedagogy is concerned, an approach that is most widely used in creating multimedia educational application is the constructivism approach. The roots of this approach lie in Deweyan progressivism, which argues that everyday learning always takes place within a social context [7], or at least a wider context other than the narrowly school-focused environment. Research elsewhere has shown that when students interpret an activity as unrealistic and non-meaningful, learning is likely to remain a classroom example and transfer will not occur. The way pieces of information are connected in the real world can be conveniently reflected by hypertext and hypermedia in the multimedia products. This is clearly reflected in Jonassen's [8] arguments:

> "...learners need instructional conditions that stress the interconnections between knowledge within cases as well as different perspectives of viewpoints on those cases that reflect the perceptions of different entities. Learners need flexible representations of the knowledge domains that they are studying, representations that reflect the uncertainties and inconsistencies of the real world" (p.386).

Petraglia [7] proposed that in order for authentic learning to occur, two things must be included: (1) learners should be introduced to informationally rich contexts for learning, and (2) learners should be active participants in their own learning. As educational technologists are busy both framing the issue of authenticity and designing environments that address it, they are not as transparent and unproblematic as they may seem (see [7] for details). Modelling the complexity of the real world in a structured computerised environment is certainly not an easy endeavour. We might need a super-human to think of the most effective way to model it because he will have to take into account of all the possible experiences of all the end users. Therefore, the best that we can do is probably to assume the lowest possible level of knowledge and, progressively extending it to higher level of complexity. In this case, the lowest level may be the commonest example of one's experience in everyday life. Thus, one important cognitive ergonomic principle to be highlighted here is a design principle that strives to construct multimedia environment that fosters constructivist learning.

4.2 Cognitive Ergonomics and User Interface

Studies have shown that educational multimedia packages with excellent hypermedia system may not necessarily enhance learning as students may be disorientated in the large information-space. For example, Hedberg and colleagues [9] found that most students did not know how to interact with and learn from the multimedia packages that they are using. We must not take for granted the fact that some computer users may not be familiar with the complex navigational procedures. Generally speaking, computer users can be categorised in three broad categories: (i) naïve, (ii) somewhat knowledgeable, and (iii) knowledgeable [10]. Both naïve and knowledgeable users face challenges as they work in hypermedia information systems; the size of the challenge varies depending on the type of user [10, 11]. Learner control (hot words, buttons, etc) provided may not necessarily enhance learning as students may lose task-orientation.

For example, when users are reactive (as in the case of typical naïve users), and with limited knowledge about the system, subject, and metacognitive, they are unable to move to higher levels of problem solving and understanding. Unable to call on a strong resource base of system or subject knowledge, the reactive naïve user focuses on responding to what is displayed on the screen, trying to make sense from what is seen [10]. Naïve users have difficulty interpreting the system response; the lack of understanding can lead to confusion and frustration. This, in turn can adversely affect user confidence and self-efficacy, further strengthening the reactive, rather than the planning, orientation of the naïve user.

Knowledgeable users may experience occasional disorientation, but in most instances, readily overcome it. Utilising a rich knowledge base in relation to the system, the subject, and their metacognitive abilities, knowledgeable users are able to plan for, interpret, and prioritise tasks based on the response of the system [11]. The skills of planning, interpreting and prioritising make knowledgeable users more proactive in their information seeking. The knowledgeable user moves readily into problem solving and higher-level understanding. Knowledgeable users plan, evaluate, generate, and construct, using the system as a resource to support their understanding [11,12].

From the example given above, it is clear that having the most comprehensive content in educational multimedia package is not sufficient. Learners may lose task-orientation in the complex navigation system. Taylor and colleagues distinguish between 'task semantics' and 'task syntax' when exploring multimedia environment [13]. Task semantics refers to the implicit knowledge learners use to understand the task, and task syntax refers to the aspects of the interface which learners operate in order to address task semantic. They argue that loss of task-orientation in the multimedia environment is due to too much attention being focused on the task syntax such as the navigation aspects of the interface, thus lose sight of the task semantics. This is expected because of our limited working memory capacity.

Therefore, another important cognitive ergonomics principle to bear in mind is minimising learners cognitive load, especially one that is related to the navigation aspect of the user interface. If learners' effort involved in navigating and interacting with the interface is minimised, mental resources available for comprehension and achievement of learning goal may be increased.

4.3 Learning from A Real Life Experience

In this session, a simple but yet eye-opening account of 'cognitive ergonomics in action' will be reviewed. This account contains an important principle that needs to be taken into consideration when designing educational multimedia product; something that might well be overlooked if developers are not careful. This happens when students were asked to author a multimedia application project in a learning environment. All the students were considered as novice with almost zero knowledge in multimedia product development. When designing for buttons to be used to move around in the environment, it was based on the 'minimalist' principle; which was to include as few buttons as possible on each frame. To do so however, it means that each frame will have an inconsistent buttons layout structure. This resulted in a situation whereby, on the second frame the "next" button is at the second position, but on third frame, the same function button (i.e., "next") is at a third position - so as to include the "previous" button onto its second position (see Figure 2) [NB: the first frame is the 'home' frame, which also serve as the 'directory' for the application].

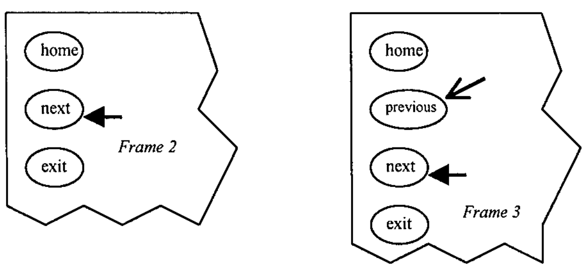

Figure 2. Interface design

Although logical thinking agrees that it is the most sensible thing to do because there is no need for a "previous" button on the second frame, as it will direct back to the "home" frame. However, when the whole design is completed and was evaluated, it was found that such a design could be quite confusing. User might continue to click the second button for moving to the next frame thinking that the "next" button will always be at the second position. Such unnecessary cognitive load is unproductive for the user; and worse still it might distract them from the main tasks – which is the *content knowledge construction.* With such an incident, it is all the more obvious that cognitive ergonomics is indeed a very important element to be taken cared of. One point to be learnt here is that, being 'minimalist' is not always the best policy.

5. CONCLUSION

The above discussion hopefully has raised some issues and information that are useful for awareness in designing educational multimedia products. If promoting self-regulated learner through educational multimedia application is our instructional goal, we must make sure that the end products incorporate in them, the facilitating role that has conventionally been played by real-teachers. Of course in order to maximise the benefit of educational multimedia product, cognitive ergonomics is not everything. For any user to be able to successfully navigate and process information from it, divergent thinking - the ability to view information from a multiple of perspectives, problem solving and independent thinking skills are critical. Users must actively attend the search task, be self-directed, and adapt to their interactions with the system if they are to find the information they seek. Hill pointed out that one of the most significant challenges facing designers, teachers and users who work with open-ended learning environments such as the hypermedia system is linear thinking [10]. It is up to the learners to adapt their way of thinking to the non-linear structure of the information-space.

REFERENCES

1. M. Nicaise and M. Crane, Knowledge constructing through hypermedia authoring, Educational Technology Research and Development, Vol. 47(1) (1999) 29-50.
2. R. Lehrer, Authors of knowledge: patterns of hypermedia design. In S.P. Lajoie & S.J. Derry (Eds.), Computers as cognitive tools, pp. 197-227, Hillsdale, N.J.: Erbaum (1993).
3. T. Vaughan, Multimedia Making It Work (4th Ed.), USA: Osborne (1998).
4. R. Meyer and J. Gallini, When is an illustration worth ten thousand words? Journal of Educational Psychology, 82, (1990) 715-726.
5. L.P. Reiber, Animation in computer-based instruction, Educational Technology Research and Development, 38, (1990) 77-86.
6. M. Helander, A Guide to the Ergonomics of Manufacturing, UK., Taylor & Francis Ltd. (1995).
7. J. Petraglia, The real world on a short leash: The (Mis)Application of Constructivism to the design of educational technology, Educational Technology Research and Development, Vol. 46(3), (1998), 53-65.
8. D.H. Jonassen, Cognitive flexibility theory and its implications for designing CBI. In S. Dijkstra, H.P.M. Krammer & J.J.G. van Merrienboer (Eds.), Instructional Models in Computer-Based Learning Environment, (pp.385-403), Berlin: Springer-Verlag (1992).
9. J.G. Hedberg, B. Harper and C. Brown, Reducing cognitive load in multimedia navigation, Australia Journal of Educational Technology, 9(2) (1993), 157-181.
10. J.R Hill, A conceptual framework for understanding information seeking in open-ended information system, Educational Technology Research and Development, Vol. 47(1), (1999) 5-27.
11. K. Khan and C. Locatis, Searching through cyberspace: The effects of link display and link density on information retrieval from hypertext on the World Wide Web, Journal of the American Society for Information Science, 49(2), (1998) 176-182.
12. P. Eggen and D. Kauchak, Educational Psychology: Classroom connections (2nd ed.), New York: Merrill (1994).
13. J. Taylor, T. Sumner, and A. Law, Talking about multimedia: A layered design framework, Journal of Educational Media, 23(2/3) (1997), 215-241.

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Effect of Cultural Background when Searching Chinese Menus

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With the rapid globalization of Information Technology, it is important to understand the performance of users with different cultural and linguistic backgrounds when using computer interfaces. In this study, the search performance of three different groups of users (Mainland Chinese, Hong Kong Chinese and non-native Chinese readers) was assessed. A full screen Chinese menu was used to evaluate the effect of (i) layout and (ii) word complexity. The analysis showed that there are significant differences in search performance among the different population groups. *Post-hoc* analysis showed that Hong Kong Chinese had significantly better search performance on the top horizontal area of the full screen menu, while Mainland Chinese had better search performance on the left vertical area of the menu. The results did not show any "preferred" areas for the non-native Chinese speakers. Thus, it may be concluded that designers ought to pay special attention to customize the graphical user interfaces for optimum performance even when the same information is being searched/read by different populations.

1. INTRODUCTION

The widespread availability of computers, fueled by the globalization of the Internet, brings users with very diverse cultural and linguistic background to interact with graphical user interfaces (GUI) on a regular basis. With the increasing complexity of these interfaces, visual search becomes an important user sub-task (Scott & Findlay, 1993). The rapid growth of B2B and B2C commerce and the recent trend in designing for global markets (Prabhu and del Galdo, 1999; del Galdo and Nielsen, 1996) has triggered the necessity for understanding the visual search patterns of users from diverse cultures. Differing language background of users can affect the search pattern and thus influence visual search performance (Nielsen, 1990). As a result, we attempted to evaluate the search strategies and overall performance when using Chinese menus of three groups of users having a diverse background in the Chinese language.

Due to the differences among differing languages, the general guidelines for interface design (Mayhew, 1992) based on the English language may not be applicable to interfaces using Chinese. For example, contrary to existing guidelines, Shih and Goonetilleke (1998) found that Hong Kong Chinese users had significantly better performance when using horizontal menus. They attributed their finding to the common writing style difference and suggested a "matrix transposition" to break the flow when displaying menu items written in Chinese. Their study was limited to a tool-bar type of menu and the validity of their results to a full-screen menu has great importance in an age where web-based screens are ubiquitous.

With the exception of the Korean and Japanese languages, written Chinese is very different from most other languages. Unlike English, Chinese text is commonly written and read in two orientations: horizontal ('Z' type orientation, starting in the top left corner of the paper) or vertical (inverted 'N' type of orientation, with text starting in the top right corner of the page). Since both of these orientations appear in various publications, it is hypothesized that item arrangement (layout) can affect the visual search performance of Chinese users. Even though Chinese readers are familiar with both orientations, their exposure level to these two formats could be very different. For example, in Mainland China common publications like newspapers, textbooks use predominantly horizontal "Z" orientation, while in Hong Kong vertical "N" orientation predominates.

Every Chinese character is formed by a sequence of "strokes", which varies from 1 to 3 strokes for very simple words up to 26 strokes for very complex words. In addition, each Chinese word in a text is written within a fixed square area, thereby contributing to the perceptual complexity of the words. Complexity of the targets and display noise has been found to affect the detectability of a target (Scharroo *et al.,* 1994). Hence, it may also be hypothesized that word complexity (or the number of strokes of each character) can also affect visual search performance.

The objective of this study was to assess visual search performance of three population groups (Mainland Chinese, Hong Kong Chinese, and Non-native Chinese speakers) with two word complexities and three layouts.

2. HYPOTHESES

The hypotheses investigated were as follows:

1. There is significant interaction between Population groups and Layout on search performance
2. Word complexity has a significant effect on search performance

3. METHODOLOGY

3.1 Experimental Task

The experimental task was to find a given Chinese word in a full screen search field. The participant was first presented with a target screen having the same layout as the search screen. In the target screen, all the words were the same: the target word. Figure 1 shows a target screen with the character (琱) as the target word. The reason for filling the screen with the target word was to prevent any bias in the starting position of the search.

Once the participant understood/memorized the target word, the search screen (Figure 2) was shown and the participant had to then search the target word in a "noisy" display of words. The font size of the Chinese words was 0.9cm*0.9cm, equivalent to a visual angle of 1°.

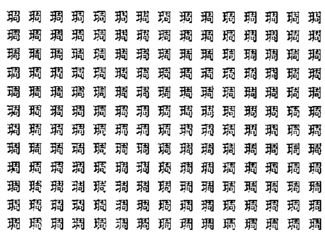

Figure 1. Example of Target screen

Figure 2. Example of Search screen

3.2 Experimental design

The experiment was a 3-population (Hong Kong Chinese, Mainland Chinese, and Non-native Chinese) × 3 - Layout (Row, Column and Uniform) × 2-Word-complexity (High and Low) × 10-trial design. The two independent variables of Layout (Row, Column and Uniform) and Word complexity (High and Low) formed 6 experimental conditions. The trials were blocked by these 6 experimental conditions. Each block had 10 trials. The six conditions formed a Latin square like design and the sequences were balanced among participants.

The three layouts of Rows, Columns and Uniform were created by varying the separations between the columns and rows of words. In the Uniform condition, the distance between rows and columns was the same and hence there was no dominant direction. The search screen in each of the layouts had nearly the same dimension, but with different number of rows and columns. The number of words in the three layouts was also very similar. The Row layout was similar to a horizontal writing orientation ("Z" type) while the Column layout resembled a vertical writing orientation ("N" type). The numbers of rows and columns in all three layouts were a multiple of three, allowing each of the layouts to be divided into 9 equal areas (Target position areas). The target location was balanced among these 9 target positions.

The Chinese words used in the experiment were categorized as low complexity or high complexity depending on the number of strokes. '*Low complexity*' words were those that comprised 10 to 12 strokes. Words with 16-18 strokes were categorized as *'High complexity'* words. The words were selected from the word index of 漢語大字典 Chinese dictionary (Hu-pei tzu shu chu pan she, 1989). Low Complexity words were within the15-34 percentile, while High complexity words were chosen from the 60-81 percentile of the word complexity distribution. All selected words were in a left-right format (example, 講 for "Talk"). Words with a top-down format (example, 葉 for "leaf") were not used as Chinese words with a left-right format can be depicted much clearer on a computer display. Furthermore, by using only one word format, the screen was "consistent" and any secondary cues of search with peripheral vision were eliminated.

3.3 Participants

A total of 18 participants were tested. All participants were paid for their time. The age range of the participants was 13-36 years. Three groups of six participants were chosen based on their "cultural" background: Hong Kong Chinese, Mainland Chinese who had lived in Hong Kong for less than 1 year and Non-native Chinese speakers. All 18 participants were able to recognize the Chinese words used as stimulus material in the experiment. Average time for experiment completion was 1 hour.

3.4 Materials and apparatus

The experimental program was coded in Visual Basic 6.0. The program was run on a Pentium 200MHz computer in the Microsoft Chinese Windows98 environment. A touch screen monitor and two external push buttons (Continue and Give-up) were used to obtain participant response. The ASL 5000 eye tracking system from Applied Science Laboratories was used to record the eye movement of participants during the search task. The eye tracking data are reported elsewhere.

3.5. Procedure

Each participant was given three practice trials before the actual experiment. In each experimental trial, the target screen (Figure 1) was first shown. After the participant understood/memorized the target word, he/she would press the "continue" button to signal that he/she was ready to proceed with the search task. The search screen (Figure 2) was then shown and the participant had 90 seconds to find the target word. When the participant found the word, the participant was required to touch the word on the touch-sensitive screen. Some search screens did not have the required target. If the participant thought that the target word was not present in the search screen, he/she was required to press the external "give-up" button to terminate the trial.

4. RESULTS

The dependent variables were *Percentage Correct* and *Search Time*. Percentage correct represents the percentage of trials having "Hits" or "Correct Rejections" within each experimental condition. These represent the trials in which the target word was found or where the participant correctly gave up a search when the target was not present in the search field.

The three-way (Population x Layout x Word complexity) ANOVA on percentage correct showed a significant effect for Population ($F (2, 90)=10.49$, $p<0.0014$). The *post-hoc* Student Newman Keuls (SNK) analysis showed that Non-native Chinese had a significantly lower percentage correct than both Mainland Chinese and Hong Kong Chinese. There was no significant difference between Mainland Chinese and Hong Kong Chinese. In addition, Layout ($F (2,90)=0.21$, $p<0.81$), Word Complexity ($F (1, 90)=0$, $p<0.94$) and all interactions were not significant at the $p < 0.05$ level.

Search time was the time taken to locate the target. A square root (SR) transformation was used to normalize the search time (ST) data. The Population * Layout * Word complexity * Target position ANOVA for square root transformed Search time (SRST) showed that Population ($F (2, 709)=24.6$, $p<0.0001$), Target position ($F (8, 709)=5.5$, $p<0.0001$), and the Target position * Population group interaction ($F (16, 709)=5.5$, $p<0.0001$) were all statistically significant (Figure 3). Word complexity ($F (1, 709)=3.35$, $p<0.0676$), Layout ($F (2, 709)=0.91$, $p<0.402$), and the other interactions were not significant at the $p < 0.05$ level.

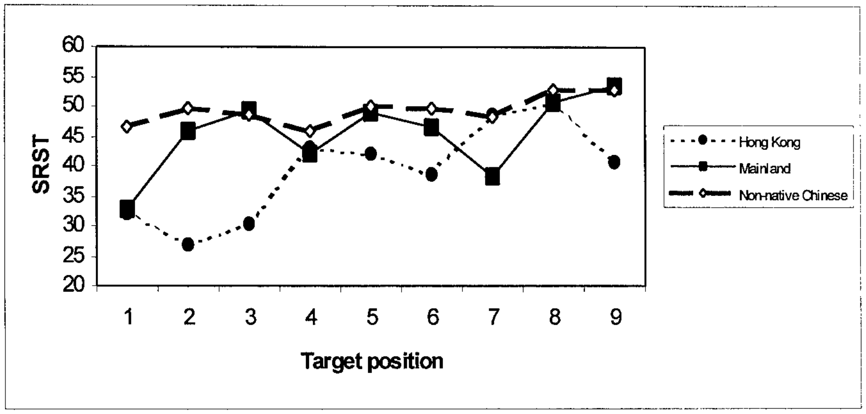

Figure 3. POPULATION * TARGET POSITION interaction on SRST.

A simple effects ANOVA on the interaction effect showed some interesting results (Table 1).

Table 1 Simple effects ANOVA for each population group using SRST

Population group	F- value (df) (Probability)	SNK grouping for Target Position* *SRST increases from left to right (→)*
HK Chinese	F (8, 257) = 10.89 (0.0001)	2 3 1 6 9 5 4 7 8
Mainland Chinese	F (8, 243) = 4.44 (0.0001)	1 7 4 2 6 5 3 8 9
Non-native Chinese speaker	F (8, 209) = 0.29 (0.9704)	4 1 7 3 2 6 5 8 9

* Levels sharing the same underline indicate no significant difference.

5. DISCUSSION

Word complexity did not have any significant effect on accuracy or search time. This shows that word complexity has no effect when searching full screen Chinese menus. That is, reading a complex Chinese word, with a high number of strokes is unlike reading an English word composed of many characters. Once a Chinese word is learnt, the time to recognize the word may not depend on the word complexity.

Layout and the Population * Layout interaction were also not significant at the $p < 0.05$ level. This result shows that the search performance as measured by percent correct and search time isn't different among the three layouts. A possible explanation follows. For the trials with 'Hits' on target, the total eye movement is the distance that the eye travels from the starting point to the end point (or target point) and is an indirect measure of search time. The distance traveled is determined by several factors, including the subject's starting position of the search process, target position, the layout, the subject's search pattern. Different combinations among these factors will result in large variations. In addition, if the search strategy changes during the experiment, it can also result in large variations in search time. If such variations are not "balanced", the differences in search time might be so large as to mask any small effect due to Layout related search factors such as fixation duration, saccadic distance, and so forth.

The significant interaction between Target position and Population group for search time reflects potential differences in search strategies among the three population groups. The SNK grouping for the Hong Kong Chinese group (Table 1) showed that target areas 2, 3, 1 (i.e., the top rows) were grouped together with the lowest search time. Besides, areas 2, 3, 1 were significantly different from areas 4, 5, 7, 8, 9. This shows that Hong Kong Chinese tend to search the top horizontal area first, regardless of the layout of the menu. For Mainland Chinese, areas 1, 7, 4 (i.e., the leftmost columns) were grouped together and had the lowest search time. The search time of Area 1 was significantly lower than areas 2, 3, 5, 6, 8, 9. This shows that Mainland Chinese start their search at the left top area of the menu. The search time results of Non-native Chinese speakers did not show any difference between the nine target positions. These results are in good agreement with the Shih and Goonetilleke (1998) study for 1-row and 1-column menus where Hong Kong Chinese subjects showed a faster search when using a horizontal menu. The present study also indicates that the "natural" search pattern for Hong Kong Chinese is horizontal. In Mainland China, most published information follow the "Z" pattern and the matrix transposition rule proposed by Shih and Goonetilleke suggests that the Mainland Chinese would have a better search performance with a vertical menu. The results of this study agree with this theory, as the Mainland Chinese favored a vertical search.

From an application standpoint, the results can be used when designing full screen menus. If the search time for an item is to be reduced (such as frequently used items), they should be positioned closer to the starting point of the search path. To minimize search time, items should be placed at the top horizontal area for Hong Kong Chinese. The ideal location for Mainland Chinese is somewhat more difficult to predict even though the results indicate that they have a bias towards a vertical search strategy.

6. CONCLUSION

By evaluating the search performance of Hong Kong Chinese, Mainland Chinese and Non-native Chinese speakers with Row, Column, and Uniform layouts, the differences in search behavior among the three groups were demonstrated. Hong Kong Chinese had better search performance on the top horizontal area of the menu. Mainland Chinese generally had better performance on the left top area of the menu. Non-native Chinese speakers did not show any significant preference on search area. In addition, word complexity and layout showed no difference in user performance. The results of this study may be used in the design of screens to optimize user performance.

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REFERENCES

1. Del Galdo, E. M. and Nielsen, J. (1996). *International user interfaces*. New York: Wiley.
2. Mayhew, D. (1992). *Principles and guidelines in software user interface design*. Englewood Cliffs, NJ: Prentice-Hall.
3. Nielsen, J. (1990). Usability testing for international interfaces. In J. Nielsen (Ed.), *Designing user interfaces for international use* (pp39-44) Amsterdam: Elsevier.
4. Prabhu, G. V. and delGaldo, E. M. (1999). *Designing for Global Markets*. Rochester, NY, USA Backhouse Press
5. Scharroo, J., Stalmeier, P. F. M. and Boselie, F. (1994). Visual search and segregation as a function of display complexity. *Journal of General Psychology*, 121(1), 5-17.
6. Scott, D. and Findlay, J. M. (1993). Visual Search and VDUs. In: Brogan D., Gale, A., Carr, K.(Ed.) *Visual Search 2* (pp. 301-307) London: Taylor and Francis.
7. Shih, H. M. and Goonetilleke, R. S. (1998). Effectiveness of menu orientation in Chinese. *Human Factors*, 40 (4), 593-576.

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Experimental Evaluation of Pen-based Chinese Word Processing Usability*

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An evaluation experiment was conducted to compare four interface styles: Hanwang Fixed Window, Translucent Mobile Single Window, Translucent Mobile Double Window, and No Window. Subjects tested the four styles for typical word process task, including input, insert, exchange on a free style text edit system. The results show that the TMDW was the most efficient and the most accurate mode, in terms of total editing time and accuracy rate. Also experimental data exhibited that NW is the most nature style, in terms of the subjects' preferences. This experiment confirmed that a proper employment of interface style could improve the interactive efficiency of text editing systems. Our tests for the first time give statistical support to the view that the nature gesture is useful for editing interface for word process systems.

1. INTRODUCTION

After computer is used more and more widely, text and papers are appeared on the screen. Writing down the text and papers directly on the electric form by using computer becoming the main mode of work in the office and school. The type of writing tools varies from the very beginning of Notepad, WordPad, to the well-organised Microsoft Word. All of these products are facing the growing requirement of word input and text organisation. However, almost all of the text editing applications are developed based on the traditional input devices, keyboard, and mouse. The elements, which composed the layout of the system, are element of WIMP, windows, menu, icon and so on.

With the development of pen device, there is an increasing using of pen in computer application, thereby emergency many pen-based applications. From the view of the application, the most widely acceptable type of using pen in the computer is to using pen to writing the document or editing the text and paper. With the change of interaction device, from keyboard to pen, it is requirement that the interaction mode and the interface should changed correspond, from the menu to a more free type of the interface.

Many former studies of multimodal user interfaces had been done in other fields and their research focus were not set on the pen-related interaction mode, such as text processing, package sorting and Computer Aided Drafting [1], and in the communication environment. Study on the device interaction mode such as speech and keyboard input [2] [3], mouse and

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speech input [4], speech and gesture input have also been conducted [5] [6]. Some research and experiments have studied that the pen-based interface and voice-based interface to be efficient and intuitive [7]. However, there has been little experimental evaluation on a practical interface style and interaction mode of typical pen-based systems.

In the study reported below, our intent is to contribute some useful results for the design of interface style of pen-based word editing systems. We designed an evaluation experiment to investigate the interaction preference under four given interface styles.

Section 2 gives a brief description of the multimodal environment, which we developed, and the interface style and the basic interaction task type of our pen-based text editing system. Section 3 gives a description of our experiment. Section 4 shows the results based on analyses of the experimental data, as well as a discussion.

2. WORD PROCESSING

With the post-WIMP and Non-WIMP is coming forth [8]. The more user pay attention is on the usability and freedom of the computer program. They don't want to work with the computer in computer-way. They wish the computer could work in a more humanistic mode. They want computer can hear, look, and even smell [9]. The new-fashioned interaction devices pen and voice, are just feasible. With the usable of pen and voice in word-processing program, end-user can told program to "change a segment", with writing down the correct words he want get. Research had been performed which announced that the pen+voice is the best mode in the multimodal interaction mode. Pen is the main implement in the interaction task. So, we evaluate the interface style when we employed the pen as the main interaction tool in computer usage.

We proposed a pen_based writing edit program, which enabled the pen to perform the word input and gesture command in the task performance. There are some gestures used in the text edit program. They are insert, select, delete, and exchange gesture. For example, user use the pen to locate a position, writing a insert gesture, and input texts, then this segment of text was inserted at the desired location.

2.1 Overall System

The writing edit program provided many basic tasks, which include word input, select, insert, delete, and exchange. In our programs, we set four typical interfaces to facility the user to fulfill their task. Below are the details of the interface style when using pen interaction.

In the word processing program, we separate the screen into 3 parts, which are the menu, the main input area, and a prompt section. Also, user who do not like to use pen to input gesture would like to use menu to operation when in their evaluation. The purpose of adopting a prompt section is to provide user with a dynamic feedback, which can hint user what gesture can be used in the current operation style.

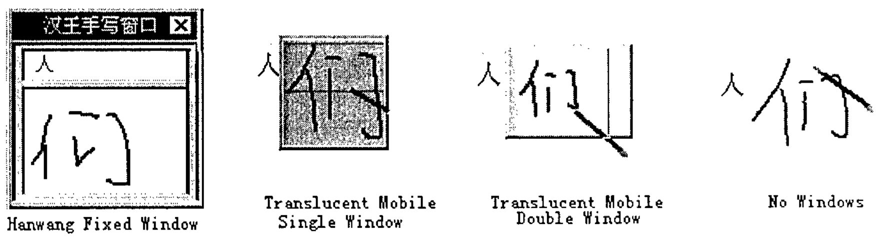

Figure 1. Four Interface Styles

2.2 Interface Styles (Figure 1)

- *Hanwang Fixed Window (HFW)*

In this interface mode, user can write down at the word-input area of Hanwang hand-recognition program, which is provided by Hanwang Corp.. After the word is written down, the recognition engine would be recognised and set the word in the text line.

- *Translucent Mobile Single Window (TMSW)*

User can write down in a translucent mobile window. When the beginning point of the input stroke is set down outside the right region of the translucent window, it means user would continue the writing, then the word he writing down is located on the tail of the text line. When the beginning point of the input stroke is set down at the left, up, down side of the translucent window region, the stroke would be recognised as the modification gesture.

- *Translucent Mobile Double Window (TMDW)*

This interface style is similar with the TMSW. However, because the single input window is always hop together with the pen stroke during the input period, we adopt the double window strategy. The translucent window is aligning with the text line, moving smooth without intensive leap.

- *No Window (NW)*

User can write down freely at any location o the screen. By analysing the size and the relationship between the strokes user write at the beginning, system can distinguish the gesture and word input.

3. METHOD

3.1 Subjects

The participants consisted of 12 female and 12 male college students. They are all right handed and between 20 and 30 years old. Considering that word compile process is one of the most common tasks at the daily life and work, we have not affiliated some professional worker into the experiment. All of them have no experience in using this kind of word system.

3.2 Equipment

The hardware used in the experiment was a pen-input tablet (WACOM), a stylus pen, and a personal computer (PII350, IBM Corp.). All experiments were run on Windows 98. The software used in the experiment mainly include a word process system which is developed based on PenBuilder (a development platform support of pen usability), a gesture recognition system (developed by us), a handwriting recognition system (provided by Hanwang Corp.)

3.3 Task Design

Because we are focused on the word process, the most common task style. So we consider the familiar property and the common task performance. In the experiment, subjects are instructed to perform a succession of task. Five sentences to be input, which include one hundred words. Five sentences to be inserted, which include 30 word to be inserted. Five sentences to be delete, which include 30 words to be deleted. Five sentences to be exchanged, which include 30 words to be exchanged.

During entire task performing period, we set a counting machine in the testing program. We record the operation time user used as the main efficiency parameter testing. Whenever user end their atom task, the task performance was compared with the criterion of the task, set the percentage of correct as the validity parameter of testing.

3.4 Procedure

In the evaluation experiment, the task of subject is writing and modifying the element word in the sentences and the section in the segment in term of the instruction. Firstly, the experiment system was explained to each of the subjects. Then, system will play a 20 minutes presentation demos to subjects, which include a brief introduction of four-interface style, including the usage of pen to input word and gestures. The purpose of this presentation is to make the user more familiar with the interface feedback mapping between the hand movement and the pen gesture visualisation.

After about 20-minute time to be used to familiar with experiment system, subjects began their tests. Experiment system will first set an interface, which include a four-interface style list. Subject can select corresponding item to begin the test. Once they select their testing mode, counting machine begin working. Once users end their task, subjects' performance data in terms of their working time will be recorded by system. The additional item system would measure include how much degree the text user written is familiar with text draft.

With the continued insert task performance, its performing time was added with the time of the input task. We set this group data as the input+insert time parameter. Also the accomplished task which include input task and insert task was calculated and the performing accuracy of the "input+insert" was set as the second group data for the accuracy rate of tasks.

After the exchange task was performed, the time data is the total time accumulation of the input, insert and exchange, which was set as the "input+insert+exchange" time of the third group evaluation data. The another part of the third group task data is the accumulated accuracy rate of all tasks. After subject finished their experimental task, they were questioned about their preferences about mode of interaction just tested. They were asked to rank (on a scale of 1-10) each mode according to their satisfaction and desire to use.

There was another a point that should be mentioned. Because the select task was included in the exchange task, we did not set a separate select task as one of the task.

4. RESULTS AND DISCUSSION

We performed an ANOVA (analysis of variance) with repeated measures on the with-in subject factors on the interface style used, with perform time and perform accuracy as dependent measures in the formal evaluation, with the total time, perform accuracy and subjective performance as dependent measures in the evaluation experiment.

Table 1 displays the means and standard deviation of task performance time and task accuracy when subjects perform the word input, insert and exchange tasks under different interface style.

- *Task Performing Time*

There are significant differences in the mean value of the "input" performing time. (F (3,95)=58.89595, p<0.05). We found that the mean value of the performing time of the HFW mode is the shortest (6.854167), with the following with the NW mode, TMDW mode, and the TMSW mode. With eliminating of the HFW mode, we applied ANOVA analysis on the TMDW, TMSW, and NW mode. There is also significant difference within three interface style (F (2,69)= 37.1214, p<0.05). By applying parewise mean comparison, we found that there is an exception within the significant differences between the interface style (TMSW and TMDW, F(1,46)= 74.1435, p<0.05; TMSW and NW, F(1,46)=48.42517, p<0.05). There is no significant difference between the TMDW and NW (F(1,46)=0.035949, p<0.05).

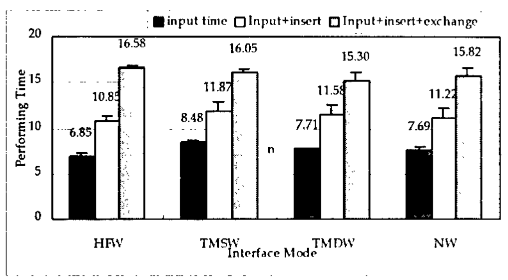

Figure 2. Performing Time

The second group data of performing task was analysed by ANOVA. We found that there are significant difference within these four interface style, F(3,95)=2.788971, p<0.05. HFW mode is the shortest, with its mean time is 10.85417. While compared the HFW mode with the former NW mode, there still have significant difference, F(1,46)= 2.208953, p<0.05. With parewise analysis, there are significant difference exited within NW, TMDW, and TMSW mode (TMSW and TMDW, F(1,46)= 1.0403; TMSW and NW, F(1,46)=4.8105; TMDW and NW, F(1,46)=1.460099).

Within the third group data, we found that there are significant difference in the mean value of the performing time as a function of four interface style (F (3.92)=12.52562, p<0.05). However, this time the most efficiency mode is the TMDW followed by the NW, followed by TMSW followed by HFW.

From the analysis result, we found that subjects can perform the basic input task by employing the HFW mode. But if the task evolved more complexity task, such as insert and exchange, the efficiency would be dropped. On the other way, TMDW and NW would perform more efficiency. With the composed task setting, TMDW is performing best.

- *Task Performing Accuracy Rate*

The mean value of the performing accuracy rate of the HFW mode in the first group is the highest which is about 78.8333, followed by the TMDW mode followed by NW mode followed by the TMSW mode. The ANOVA analysis found there are significant differences in the mean accuracy rate (F(3.95)=165.0248, p<0.05) as the function of the interface style.

Within the second group of data, there are some differences from the second group of data. The mean value of the accuracy rate of the TMDW mode in the second group is the highest which is about 73.75, followed by the NW mode (72.75) followed by HFW mode (72.29167) followed by the TMSW mode (72.41667). And the ANOVA analysis found there are significant differences in the mean accuracy rate ($F(3.95)=2.788971$, $p<0.05$) as the function of the interface style.

The total accuracy rate of the three-type task (input, insert, and exchange) is presented in the figure 3. The ANOVA analysis reveals that there is significant difference in the total accuracy rate of the three-type tasks (input, insert, and exchange) ($F(3,95)=4.652$, $p<0.05$). The result shows that the performing accuracy rate of TMDW is the highest (72.083).

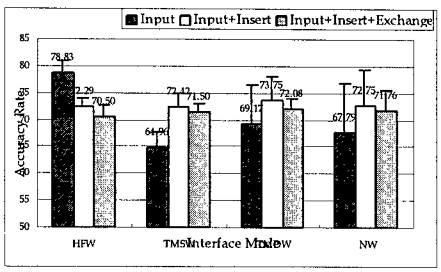

Figure 3. Performing Accuracy

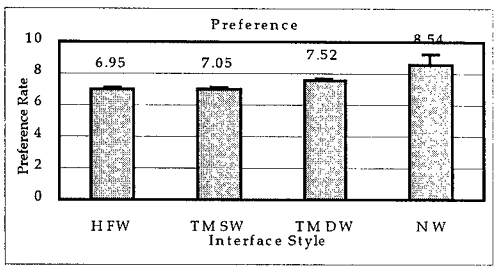

Figure 4. Subjective Preference

- *Subjective Preference*

There were significant difference among the four interface style for the subjective evaluation, $F(3,92)= 198.077$, $p<0.05$. The HFW mode is the last mode subject would prefer. After eliminate the HFW mode, there is also difference between the remained three interface styles, $F(2,69)= 184.911$, $p<0.05$. From the data of experiment, there are two main styles that are suitable to meet the subject requirement, which are TMDW mode, whose mean preference rate is about 30.08333 and NW mode, whose mean preference rate is 34.16667. After analysed the TMDW and NW mode, we found that there also exist significant difference, $F(1,46)= 122.446$, $p<0.05$. The experimental results show that NW mode is the most satisfactory modes, followed by TMDW mode.

5. CONCLUSION

This paper presented an evaluation experiment based on a word process system. The experimental results show that TMDW interface style may perform efficiency in text edit systems. It provides clear evidence that the proper employment of interface styles may result different efficiency, accuracy, and satisfactory of the usability of word system. The analyses also show that the NW interface style is most suitable for nature usage in the pen user interface environment of word systems. We recommend that more attention should be paid to the balance of the efficiency, accuracy and preference aspects on the pen for word systems.

Overall, we have contributed to the information about how users exhibition under each of four interface styles, and the future develop direction of interface style in order to suit the nature of interaction.

REFERENCES

1. Zhang Gao, Guan Zhiwei, Dai Guozhong, A comparison of Four Interaction Modes for CAD system, APCHI'99, July 15-17, 1998
2. Gale L.Martin, The utility of speech input in user-computer interfaces, International Journal of Man-Machine Studies, 1989, No. 30, 355-375.
3. H. Ando , H. Kikuchi , and N. Hataoka, Agent-typed Multimodal Interface Using Speech , Pointing Gestures and CG , Symbiosis of Human and Artifact, 1995, 29-34. J.J.
4. Mariani, Speech in the Context of Human-machine communication, ISSN-93, 1993, Nov, 91-94
5. Steve, W. Patrick, H. & Myrtle, W., Flochat: Handwritten Notes Provide Access to Recorded Conversations, Human Factors in Computing Systems , 1994, April 24-28
6. Luc J. and Adam C., A Multimodal Computer-augmented Interface for Distributed Applications, Symbiosis of Human and Artifact, Elsevier Science B.V., 1995, 237-240.
7. Ren X., Moriya S., The Effect of Target Size, Pen-Movement-Distance and Pen-Movement-Direction on Target-Selection Strategies for a Pen-based system, Workshop on Computer in Beijing, 247-254
8. Andries. Van Dam, Post-WIMP User Interfaces, Communications of the ACM, Vol. 40, No. 2, (February), 1997, 63-67.
9. Yang L., Zhiwei G., Youdi C. and Guozhong D., 2000, Research on Gesture-based Human-Computer Interaction, Proceedings of Chinagraph'2000, China.

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A Specification Language for Post-WIMP User Interfaces Based on Hybrid Automaton*

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Post-WIMP (i.e. Windows, Icons, Menus and Pointer) interface as the next generation user interface has substantial differences from WIMP interface, which dominates the current human-computer interaction. It provides more natural and effective way for interaction. In order to construct post-WIMP interface effectively, it is a better way to specify it at an abstract level without concerning the details of the implementation before construction. In this paper, the essence of post-WIMP interface is discussed. The most distinguished attribute of post-WIMP is the property of continuous interaction. We analyze post-WIMP interaction from the point of view of hybrid system, which can give accurate and strict analysis to post-WIMP interface. We employ hybrid automaton to specify the interaction in post-WIMP interface. A semi-formal specification language LEA2F is introduced for specifying post-WIMP interface by the combination of the text-based specification and figure. Some open issues are also discussed. The construction of the user interface can be easily fulfilled by the instruction and assistance of the specification.

1. INTRODUCTION

With the development of the interactive devices, the improvement of the hardware's performance and the evolution of the computing model, the traditional WIMP interface (i.e. Graphical User Interface, GUI) that is a dominant interactive paradigm presently is not capable of making a good use of them. The computing model shifts from centralized model to distributed model and the interactions in mobile computing environments have become more and more popular. More powerful and natural interactive devices carrying with magnificent information emerged, such as data gloves, data headpieces. As a result, there are two directions for user interface evolution relative to desktop-based user interface: one is evolving towards "larger" interactive environment, such as virtual reality and the other is towards "smaller" interactive environment, such as mobile computing. WIMP interface is a desktop-oriented interactive paradigm primarily based on mouse and keyboard which are obviously cumbersome for these future user interfaces. WIMP interface can not meet the requirement of real-time information processing for these two interactive environments and it isn't competent

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for achieving natural and effective interaction. In order to solve all above matters, it is necessary to introduce a new interactive paradigm.

The term post-WIMP interface refers to the user interfaces coming in the future, after the current generation of WIMP interfaces. The term doesn't give an unambiguous and strict definition for future user interface but just a catchall for the next generation user interface. Post-WIMP interfaces provide "non-command", parallel, continuous, multimodal, real-time interaction and have a higher degree of interactivity than previous one. The design of the interactive behavior in post-WIMP interface is based on the users' mental model so that it can provide a natural, effective way to communicate with computer without much cognitive effort of users. So it is also an intention-based interaction. It releases the users from the frustrating mode switching and gives a broader communication band between human and computer. There are several typical user interfaces belonging to post-WIMP interface, such as virtual reality, new types of games, intelligent agent interfaces, interactive entertainment media, pen-based interfaces, eye movement-based interfaces, speech interface, and ubiquitous computing [1][2].

Post-WIMP interface is more complex than any previous user interface. Consequently, it is difficult to be constructed. It has been turned out to be an effective way to specify user interface at an abstract level without concerning the details of the implementation before programming [3]. It is especially important to clarify the relationship of the controls in post-WIMP interface. In the following sections of this paper, the essence of the post-WIMP interface will be argued and a detailed analysis for post-WIMP interface will be presented from the point of view of hybrid system [4]. We model post-WIMP interface as a set of hybrid automata. A semi-formal specification language based on hybrid automaton is presented in order to simplify the formal specification. The example of specification for post-WIMP interface is given and some discussions are preformed.

2. ESSENCE OF POST-WIMP USER INTERFACE

The interaction in post-WIMP interface is based on the user's existing skills for interacting with the real world. We should identify the structure of post-WIMP interface as the user sees it. Post-WIMP interface has the following characteristics.

- Continuous interactions blending with discrete actions

From the user's point of view, in post-WIMP interface, there are continuous behaviors, such as movement of the hands, and discrete behaviors, such as pressing buttons. It has essential difference from WIMP interface which treats all interactive information as discrete token. But in post-WIMP, it is difficult to tokenize all interactive information [2]. This attribute is the most distinguished difference from any previous user interface.

- Parallel Dialog threads

Post-WIMP interface generally has multiple dialog threads which communicate with each other and they are executed in parallel and asynchronous way [3].

- Multimodal interaction

Users can submit their intention through different modalities, such as hands, mouth and eyes. The information from different modalities is integrated for execution by modal integration [5]. The interactive feedback is also achieved by the information fission to several output modalities. Consequently, the user interface has multiple I/O streams.

- Real-time requirements

The processes of inputs and outputs in post-WIMP interface are based on dead-line-based computations [1]. Time is a significant factor in interactive intention extraction and execution. Most of relationships in post-WIMP interface are temporal.

- Inaccurate interaction

Probabilistic inputs take great percentage of the inputs in post-WIMP interface [1]. Unlike traditional mice and keyboards, the input/output devices used in these interfaces, such as speech or gesture recognizers, may produce a probability vector rather than a single token for a user input.

Post-WIMP interactions convey a sense of continuous interaction to the user. Here we analyze a pen-based interaction based on tablet. When we submit a multi-stroke pen gesture, feedback of pen's ink track is related to the position of the pen's cursor. This relationship is operative when pen gives a pressure to the tablet and ceased when the pressure disappeared or the inter-stroke's interval delay is out. So this continuous relationship is temporal. But there is also a relationship defined between the pen's position and cursor's position on the screen that is permanent because the cursor makes a immediate movement whenever pen is moved. Once the gesture is submitted, it will be recognized and a discrete token will be generated, which will trigger the transition from one interactive mode to another. By above analysis, the post-WIMP interface can be abstracted as a set of continuous relationships, some of which are permanent and some of which are engaged and disengaged from time to time. These relationships accept continuous input from the user and typically produce continuous responses or inputs to the system. The actions that engage or disengage them are typically discrete.

3. MODELLING POST-WIMP USER INTERFACE AS HYBRID AUTOMATON

The structure of post-WIMP interface accords with multi-agent model which each agent acts for a dialog thread. Traditional user interface has single input/output stream but post-WIMP interface has multiple modalities for interaction as mentioned in the section 2. The result of the modal integration will be submitted to the related agents according to the user's intention of interaction and the outcome of the agents' processing will be dispatched to multiple modalities. So post-WIMP interface has the multi-to-multi structure, which means that multiple modalities serve for multiple agents.

Traditional specification techniques for user interfaces are compiler-based, such as BNF (Backus-Naur Form), ATN (Augmented Transition Network) and AG (Attribute Grammar) [3][6]. These formal or semi-formal specification techniques work well for command-line-based user interface or GUI which are discrete-token-based. However, there are interactive behaviors which is inherent to be continuous from the user's point of view in post-WIMP user interface. A well-defined specification method should specify the user interface from the user's point of view but not the system. As a result, the traditional specification techniques are no longer compliant for post-WIMP user interface. A new model for post-WIMP is required.

Post-WIMP interface has the continuous property and it equals to a hybrid system from the point of view of formal techniques. A run of a hybrid system is assumed as a sequence of steps. Within each step the system state evolves continuously according to a dynamical law until a transition occurs [4].

Hybrid system is modelled as a set of hybrid automata (the formal definition of hybrid automaton is omitted here), which is characterized as a finite automaton equipped with a set of variables. The control locations of the automaton are labeled with evolution laws. At a location the values of the variables change continuously with time according to the associated law. The transitions of the automaton are labeled with guarded sets of assignments. A transition is enabled when the associated guard is true, and its execution modifies the values of the variables according to the assignments. Each location is also labeled with an invariant condition that must hold when the control resides at the location [4]. The property of real-time can be easily specified in hybrid automaton because every variable can be time-based, which is usually presented in the form of time's derivative.

Post-WIMP interface can be modelled as a set of hybrid automata which coordinate with each other by the external variables in the locations and labels on the transitions. The situation of post-WIMP interface can be quantitated as a state vector. The continuous interaction behaviors can be specified in the locations and discrete behaviors can be specified by the transition between locations.

4. SPECIFICATION LANGUAGE LEA2F

A specification language LEA2F (LEA2F is an abbreviation of variabLe, Event, Action, Flow, Function,) for post-WIMP interface is introduced here based on the analysis of previous sections. A specification template is shown in figure 1.

```
Interactor interactor_name
{
    InputVariable variable11 [variable type], variable12 [variable type]...
    FeedbackVariable variable21 [variable type], variable22 [variable type]...
    ControlVariable variable31 [variable type], variable32 [variable type]...
    SemanticVariable variable41 [variable type], variable42 [variable type]...
    Event
    {
        event1 { ... }
      event2, { ... }
    }
    Action
    {      ...      }
    Flow
    {
        flow1 { ... }
    flow2 { ... }
    }
    Function
    {      ...      }
}
```

Figure 1. Specification template

Each agent in a post-WIMP interface can be specified by a "**Interactor**" module named as "*interactor_name*". Actually, it is a text-based form for a hybrid automaton. A module is composed of the definition of the variables, events, actions and flows. There are four kinds of variables: "**InputVariable**" for input modalities, "**OutputVariable**" for output modalities, "**ControlVariable**" for control information and "**SemanticVariable**" for application semantics. Every variable has its own data type, such as "Integer", "String" and so on. Specification for events is accomplished in the section "**Event**" in the form of "*event_name {premise → conclusion}*". "**Flow**" section is used for the specification of the continuous interactions. Each flow is identified as a conjunction of a set of continuous functions per location. The specifications for these functions are completed in the "**Function**" section. "**Action**" section is for the specifications of semantic actions. The way for specifying in "**Function**" and "**Action**" sections is not regulated here. The designer even can specify it using natural language. In order to make the specification more intelligible, LEA2F employs figure specification which will be shown by the examples in section 5.

5. EXAMPLE: Gesture-based Interaction in PUI (Pen-based User Interface)

PUI is applied in mobile computing environment. Pen-gesture is efficient way for expressing interactive intention in PUI, which provides information of pressure, orientation and button [7]. Alterations of pressure and orientation are continuous from the user's point of view, but button is discrete which the user only cares about whether button is down or up. Here we only use pressure and position information. A tool for word processing (named EasyEditor) [7] has been implemented based on tablet devices (a kind of digitizer), which employs pen-gesture as major interactive ways. User can use pen-gesture to fulfill deleting, inserting, selecting and so on. Most of these devices are magnetic inductive. The pen is activated as soon as it enters proximity of the tablet. When user moves the pen without touching the pen tip to tablet, the cursor is positioned according to the pen, and if the user moves the pen with pressure to the tablet, a track of red ink will occurred. A stroke is produced in a continuous way which starts with pen tip touching to the tablet and ends with pen tip

Interactor *paper*
{
InputVariable *pen_pos [POS], pen_pres [REAL]*
FeedbackVariable *cursor_pos [POS], track [ARRAY]*
ControlVariable *t [REAL]*
Event
{
$GestureStart\{ pen\_pres = 0 \rightarrow pen\_pres > 0 \}$
$GestureEnd\{ pen\_pres = 0 \wedge t < 0.5 \rightarrow t \geq 0.5 \}$
$StrokeEnd\{ pen\_pres > 0 \rightarrow pen\_pres = 0 \wedge t < 0.5 \}$
$StrokeStart\{ pen\_pres = 0 \wedge t < 0.5 \rightarrow pen\_pres > 0 \}$
}
Action
{
recognize&execute : recognize the gesture and execute actions
}
Flow
{
$idle\{ \ell_0 : pen\_pres = 0 \rightarrow f \}$
$stroke\{ \ell_1 : pen\_pres > 0 \rightarrow f \wedge g \}$
$Interval\{ \ell_2 : pen\_pres = 0 \wedge t < 0.5 \rightarrow f \wedge \dot{t} = 1 \}$
}
Function
{
f: modify the cursor's position according to pen's position
g: add a point to the track buffer
}
}

Figure 2. Text-based Specification based on hybrid automaton

leaving the tablet. In this example, a gesture may consist of multiple strokes and intervals between these strokes are not more than 0.5 seconds, which means that once the time is out the gesture will be recognized and some actions will be executed.

This example employs five variables: variable "*pen_pos*" refers to pen's position on the tablet, "*cursor_pos*" refers cursor's position on the screen, "*pen_pres*" is for pen's pressure to the tablet, "*track*" is a buffer for strokes and "*t*" is for the interval of strokes. "*pen_pos*" and "*cursor_pos*" are variables with type "POS" represented as (x, y), "*pen_pres*" and "*t*" are real-valued. "*t*" complies with the law that its derivative equals to *1* (i.e. a clock-compliant variable). The specification of this example based on LEA2F is given in figure 2 and figure 3.

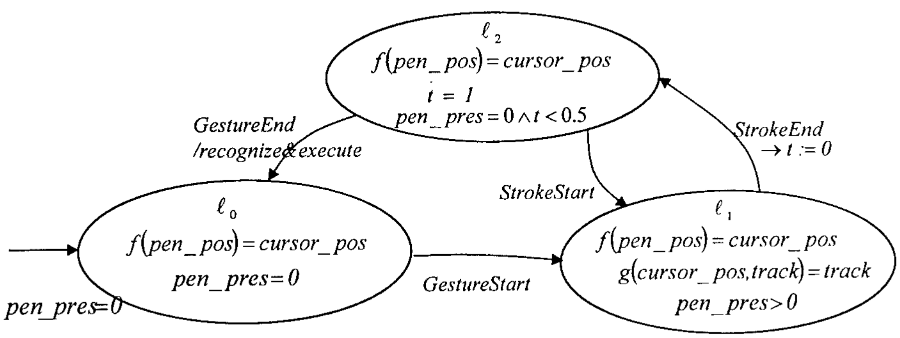

Figure 3. Figure specification for pen-gesture interaction

6. DISCUSSION

The specification of LEA2F can instruct the designers to construct user interface step by step. The functions and actions of LEA2F can be implemented as "*functions*" of programming languages and the variables can be mapped to "*variables*" of programming languages. At present, the transformation from specification to interactive system is manually achieved and it will be improved for automatic conversion.

In post-WIMP interface, there are two parallel situations. One situation happens among dialog threads, which is reflected by the relationship among a set of parallel hybrid automata. Synchronization is a major problem in parallel and is resolved by the labels binding with the transition edges in hybrid automaton. The other one is multimodal interaction [5]. The states of modalities can be specified by a set of variables and the alterations of these states in the same location are taken place simultaneously. The aspect of multimodal integration in LEA2F will be furthered in the future work. One of the benefits of formal specification is to testify some properties of the systems. Some attributes, such as real-time property, can be testified by shrinking the problem into a certain domain.

7. CONCLUSION

We employ the formal method to model and specify post-WIMP interface. A specification model and a specification language LEA2F based on hybrid automaton have been presented in this paper. It is based on the analysis for the essence of post-WIMP interface. We have modelled post-WIMP interface as a set of hybrid automata. LEA2F specify post-WIMP interface by the combination of the text-based specification and figure. An example of PUI is specified by LEA2F. Some open issues and future works have been referred. The construction of the user interface can be fulfilled by the instruction of the specification.

REFERENCES

1. Andries. Van Dam, 1997, Post-WIMP User Interfaces, Communications of the ACM, Vol. 40, No. 2, (February) 63-67.
2. Mark Green and Robert Jacob, 1991, Software Architectures and Metaphors for Non-WIMP User Interfaces, Computer Graphics, Vol. 25, No. 3, (July) 229-235.
3. Yang LI, Zhiwei GUAN, Hongan WANG, Qingyi HUA and Guozhong DAI, Design and Implementation of a UIMS for Component-based GUI Development, Proceeding of ICS of WCC2000 organized by IFIP.
4. R. Alur, C. Courcoubetis, N. Halbwachs, T.A. Henzinger and P.H. Ho, 1995, The Algorithmic Analysis of Hybrid Systems, Theoretical Computer Science 138, 3-34.
5. Zhiwei GUAN, Hongan WANG, Zhiming NIE and Guozhong DAI, 1999, Agent_Based Multimodal Scheduling and integrating, CAD/CG 99, Shanghai, China.
6. Harry R. Lewis, Christos H. Papadimitriou, 1999, Elements of the Theory of Computation, Tsinghua University Publisher.
7. Yang LI, Zhiwei GUAN, Youdi CHEN and Guozhong DAI, 2000, Research on Gesture-based Human-Computer Interaction, Proceedings of Chinagraph2000, China.

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Multimodal Integration Using Complex Feature Set*

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Multimodal integration is an important problem of multimodal user interface research. After briefly surveying research on multimodal integration, this paper introduced a natural language processing method to resolve the problem of integration. It introduced the unification operation on complex feature set and extended this operation in order to represent the information from input modalities and implement multimodal integration.

1. INTRODUCTION

Multimodal integration is the keystone and nodus of multimodal user interface and its solution is the precondition of multimodal interaction [1] Cu rrently, the main solutions for this problem are: the integration method based on time designed by Coutaz and Nigay[2] EDWARD project's method for anaphora resolving [3]; the ATOM model which described HCI sequence and all kinds of grammar constraining information using CFG (Context Free Grammar)[4]; hierarchical integration algorithm[5]. Among these methods, it is difficult to guide the multimodal integration using the semantic constrains between modalities because there is not a consistent describing format for every modality's semantic. This paper introduces the representing method of complex feature set which is used in natural language understanding into the representation of multimodal input information in order to provide a kind of consistent representation form for every modality. Then it extends this unification operation to fulfills multimodal integration so as to make it to take full advantage of the semantic, grammar and time constraints between modalities, finally realize the integration of multimodalities.

The rest of this paper is organized as following: section 2 introduced complex feature set, unification operation, extended unification operation. The 3rd section gives the example that uses this method. Finally, the 4th section summarizes this paper.

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2. EXTENDED UNIFICATION-BASED MULTIMODAL INTEGRATION ALGORITHM

As far as the problem of multimodal integration concerned, we do not think all the modalities are equally important for resolving this problem. We consider speech modality the predominant modality in multimodal HCI because normally it can provide more information than other modalities for expressing user's interaction intent. Some efficiency evaluation experi-ments of multimodal systems have also proved that users prefer speech modality in the multimodal interactive systems which have more input devices, such as speech, pen, keyboard, mouse, and so on[6].

In order to perform the task correctly corresponding to user's intent, the computer should not only transfer the speech signal into text strings, but also understand the meaning of the strings. This requires the supporting of computer natural language understanding. So, in order to solve the problem of multimodal integration, we can start from the text strings that get from speech recognition, and introduce some grammar and semantic representation methods which are used in natural language understanding area to unify the information representation of multimodalities. On the basis of the unifying representation we can realize the understanding of user interaction semantic which would lead to the multimodal integration.

According to this idea, we reviewed some natural language understanding method and choose the complex feature set (CFS) to represent the information from multimoda-lities and used the unification operation on CFS to realize multimodal integration. Just following the introduction of some related concepts, we will present the corresponding algorithm.

2.1 Basic Concepts

Definition 2.1 Complex feature set (CFS): A is a complex feature set, only if A can be expressed as the following format:

$$\begin{bmatrix} f_1 = v_1 \\ f_2 = v_2 \\ \ldots\ldots \\ f_n = v_n \end{bmatrix} \qquad n\square 1$$

in which f_i represents feature name, v_i represents feature value, and the following conditions are satisfied:

(1) Feature name f_i is atom, feature value v_i is either atom or another complex feature set.

(2) $A(f_i) = v_i$ (i=1,…,n) shows that in complex feature set A, feature f_i's value is v_i.

It is obvious that CFS is a multi-value function in fact. We can use $dom(A)$ to represent A's definition domain which is the set of all feature name, and if definition domain is null, we can only get a null CFS which can be represented with□.

In addition, we call **Atom Feature** whose value is an atom and **Complex Feature** whose value is a CFS.

Definition 2.2 The unification operation on CFS:

If we use symbol $\overline{U}$ to represent unification operation, then:

1. If a and b are all atoms, then a $\overline{U}$ b = a, only if a = b; otherwise a $\overline{U}$ b = Φ 。

2. If a is atom, B is complex feature set , then $a \bar{U} B =$; and if A is complex feature set, b is atom, then $A \bar{U} b =$.

3. If A and B are both CFS, then:

(1) If f dom (A) $\cap$ dom (B), and $A(f) = v$, $B(f) = v'$, then

if $v \bar{U} v' =$, then $A \bar{U} B = \Phi$;

if $v \bar{U} v' \neq \Phi$, then $f = (v \bar{U} v')$ $A \bar{U} B$;

(2) If f dom(A) – dom (B) and $A(f) = v$, then $f = v$ $A \bar{U} B$.

(3) If f dom(B) – dom (A) and $B(f) = v$, then $f = v$ $A \bar{U} B$.

From the above two definition we can obtain:

1. By introducing appropriate features in CFS, we can use different features to describe words, phrases and syntax and semantic of sentences, and so on. And the syntax and semantic constraints can be expressed by the relations between the features among CFSs. Unification operation can use these constraints to exclude ambiguity and finish the analysis of sentence during the process of unifying small component into larger component. While in multimodal interaction, the interactive means between user and computer not only include natural language but also mouse, keyboard, handwriting and so on. The input primitive of these interactive devices has similar functions when compared with natural language words. Therefore, we can generalize the CFS to represent not only the info of speech modality's natural language sentences, but also the info of the interactive vocabularies from other input modalities such as mouse, keyboard etc. This will establish the basis for every modality's input information.

2. Unification operation is suitable for multimodal integration. During the process of multimodal interaction, every modality's input info usually represents partially the overall interaction intent. Here the relations between modalities are complementary. Sometimes redundancy may be occurred [7]. The process of integration is just the process of getting user's intention from this complementary or redundant information. And the CFS representation of the complementary or redundant partial info coming from different modalities will include corresponding complementary or redundant features, the unification operation on which just realizes representing process of unifying these partial info into an integrated info. The 3rd item's (2)(3) in Definition 2.2 describe the integration of such complementary info, while (1) describes the integration constraint of redundant info.

Therefore, CFS can provide united representing format for every modality's partial info, and unification operation on it provides a kind of capability for the integration of these partial info. The combination of the above two provides a power means for multimodal integration. But when considering the character of multimodal interaction, simple unification operation can't satisfy the need for integration completely. The (1) in definition 2.2 will succeed only when the values of two atom feature are equal, otherwise the unification will fail. This condition is too strict for the info integration of multimodality, because some features might not be equal completely in multimodal interaction, but their unifications are expected to succeed. For example, when some info is input from two modalities, the time features of the two partial info are not necessarily equal, but if they locate in near time interval (the interval can be obtained from experiment), they are still expected to succeed in unification. Similarly, there are unequal but compatible cases between some semantic genus. Therefore, it is necessary for us to extend the simple unification operation to resolve this problem. Our idea is to weaken the equal judge to compatible judge. However, the compatible judge might be different for different atom feature, so we extend unification operation on the basis of introducing a compatible judge function for each atom feature.

2.2 Extend Unification Operation and Multimodal Integration

Firstly, we introduce the corresponding Compatible Judge Function (CJF) $Comp_i()$ for every atom feature f_i. If A(f_i)=a, B(f_i)=b, then CJF $Comp_i$(a,b) should judge whether atom a is compatible with atom b according to the character of f_i. If compatible, then return a non-null value of a and b's fusion result. If not compatible, return NULL. The realization of function $Comp_i()$, including the representation of the value after a and b fuse, should be designed by algorithm designer according to the practical condition. Thus, extend unification operation can be defined as following:

Definition 2.3 Extend Unification Operation on CFS:

If we use symbol to represent unification operation and A and B are all CFSs, then:

1.If A(f) = a， B(f) = b，a and b are both atom，and the corresponding CJF of atom feature f is Comp(); then: a $\bar{U}$ b = $Comp$ (a,b) .

2.If a is atom, B is CFS，then a $\bar{U}$ B =□; if A is CFS, b is atom, then A $\bar{U}$ b =□.

3.(1) If f □ dom(A)∩dom (B)，and A(f) = v, B(f) = v', then:

if v $\bar{U}$ v'=□,then A $\bar{U}$ B=Φ；

if v $\bar{U}$ v'≠Φ，then f= (v $\bar{U}$ v') □ A $\bar{U}$ B;

(2) If f □ dom(A) – dom (B)，and A (f) = v，then f= v □ A $\bar{U}$ B.

(3) If f □ dom(B) – dom (A)，and B (f) = v，then f= v □ A $\bar{U}$ B.

$$\begin{bmatrix} Category = Sentence \\ Predicator = \begin{bmatrix} Modality = Voice \\ Category = Verb \\ Word = \text{"拷贝"} \\ Time = [11:25:42, 11:25:43] \\ Action = Copy(obj1, obj2) \end{bmatrix} \\ obj1 = \begin{bmatrix} Modality = Voice \\ Category = Pron \\ Word = \text{"它们"} \\ Type = File \mid Folder \\ Time = [11:25:41, 11:25:41] \\ Name = [] \end{bmatrix} \\ obj2 = \begin{bmatrix} Modality = Voice \\ Category = Adv \\ Word = \text{"这儿"} \\ Type = Folder \\ Time = [11:25:45, 11:25:45] \\ Name = [] \end{bmatrix} \end{bmatrix}$$

(a)

$$\begin{bmatrix} Category = Phrase \\ obj1 = \begin{bmatrix} Modality = Mouse \\ Category = Click \\ Type = File \\ Time = [11:25:40, 11:25:40] \\ Name = [test1.exe, readmetxt, \\ test1.cpp, test1.dsw] \end{bmatrix} \\ obj2 = \begin{bmatrix} Modality = Mouse \\ Category = Click \\ Type = Folder \\ Time = [11:25:44, 11:25:45] \\ Name = [d:\backslash user \backslash xiao \backslash test] \end{bmatrix} \end{bmatrix}$$

(b)

Figure 2.1. The representation of complex set created by speech and mouse

According to this definition, the operation can deal with more complex feature, then can be applied in multimodal integration. Here, we use speech modality as the primary modality of integration. User's input speech(Chinese language)can be transferred to corresponding Chinese character strings after speech recognition. Then syntax, semantic analysis module decompose the strings into words and analyzes the grammar, semantic according to the word knowledge library and got a CFS representation. At the same time, other modalities which receive user's input can also form CFSs corresponding to input info by each interpretation mechanism. Multimodal integration uses extend unification operation to integrate this CFS information. If succeed, then executes the corresponding task. If the complete information of related task can't be obtained from the existing inputs, it tries to find corresponding information from the interaction context, if can not find, reports error or prompts user for the remedy input.

For instance, in the example of the multimodal file manager we have developed, user can say, "Please copy them to this (folder)" (in fact in Chinese 请把它们拷贝到这儿"), at the same time using mouse to select the files and target folder. The CFS can be created as in figure 2.1(a)(b) after system receive such input.

In this figure, (a) is the representation of complex feature set of speech modality information; (b) is the representation of mouse modality information. Feature category represents syntax component, Predicator represents the predicate verb of sentence, obj1, obj2 represent the necessary parameters corresponding to predicate verb. It is not difficult to get the meaning of other features from the respective English words, so we don't interpret them here. Although some atom feature values of the two complex feature sets (a)(b) are not equal completely, we can use extend unification to unify the two complex feature sets by defining their CJFs for the atom features. The result is shown as figure 2.2. At this time the parameters needed for the action "Copy" are all obtained, so system can execute user's action.

We can also deal with some cases when some modality has some error. For example (still

$$
\left[\begin{array}{ll}
Category & = Sentence \\
\Pr edicator & = \left[\begin{array}{l}
Modality \ = Voice \\
Category \ = Verb \\
Word \ = \text{"拷贝"} \\
Time \ = [11:25:42, 11:25:43] \\
Action \ = Copy\ (obj1, obj2)
\end{array}\right] \\
obj1 = & \left[\begin{array}{l}
Modality \ = Voice \ \& \ Mouse \\
Category \ = \Pr on \ \& \ Click \\
Word \ = \text{"它们"} \\
Type \ = File \\
Time \ = [11:25:40, 11:25:41] \\
Name \ = [test1.exe, readme.txt, \\
test1.cpp, test1.dsw]
\end{array}\right] \\
obj2 = & \left[\begin{array}{l}
Modality \ = Voice \ \& \ Mouse \\
Category \ = Adv \ \& \ Click \\
Word \ = \text{"这儿"} \\
Type \ = Folder \\
Time \ = [11:25:44, 11:25:45] \\
Name \ = [d:\backslash user \backslash xiao \backslash test]
\end{array}\right]
\end{array}\right]
$$

Figure 2.2. The Result of Extended-Unification

based on above example), if the speech recognition result is "Please copy them to" ("请把它们拷贝到'), it is obvious that "this"("这儿") is emitted. But the mouse pointing are correct, then the system can put the feature obj2 in figure 2.1(a) to null, while the representation of mouse modality doesn't change. At such case, extend unification can succeed too, the result (obj2's feature Modality=Mouse，Category=Click，no feature Word) is similar to the figure2.2. The system can still execute user's action.

3. SUGGESTION

Based on the above idea, we develop the application Multimodal File Manager, providing a multimodal user interface to carry out file operations by speech (speaking Chinese) and mouse. When user want do some file operation, he can avoid using the multi-level menus in traditional WIMP interface, instead, directly describes his intent by speech cooperating with other modalities. The system's usability is enhanced and easy to learn.

4. CONCLUSION

This paper introduces the unification operation acting on complex feature set into the research of multimodality and extends the unification operation according to the actual requirement of multimodal integration. Such a kind of info representation and the corresponding multimodal integration mechanism are provided. The demo instance proved that this method is feasible. Currently, we are doing more research on the way for describing more complex task and dealing method.

REFERENCES

1. Dong ShiHai, Wang Jian, Dai Guozhong: Human-Computer Interaction and Multimodal User Interface, Science Publishing House, 1999
2. Nigay L., Coutaz J.: A Generic Platform for Addressing Multimodal Challenge. In Proceedings of ACM CHI'95 Conference on Human Factors in Computing Systems, 98-105
3. Bos, E.: A multimodal syntax-directed graph-editor. In L. Neal & G. Szwillus, Eds. Structure-based editors and environments. New York: Academic Press
4. Chen Min, Luo Jun, Dong Shihai: ATOM—Task Oriented Multimodal Interface Structure Modal, J. of Computer Aided Design and Graphics, 1996, 9：61-67
5. Zhang Gao: Multimodal User Interface Develop Method and Environment, Doctoral Dissertation of Software Institute of SAC, 1999
6. Sharon Oviatt, Antonella DeAngeli, Karen Kuhh: Integration and Synchronization of Input Modes during Multimodal Human-Computer Interaction. Proceedings of Conference on Human Factors in Computing System CHI'97, Atlanta, GA, ACM Press, New York, 1997, 410-422
7. Sharon Oviatt: Ten myths of multimodal interaction, Communications of the ACM, Vol. 42, No 11, November, 1999, 74-81

PART SEVEN

Ergonomics Tools, Techniques & Policy

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Mutual Benefit Ergonomics Cooperation: a Must in South-East Asia and the Pacific Region

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In a report issued by the Economist Intelligence Unit Limited 1996 , it is indicated that among ASEAN countries as well as between ASEAN and Hong Kong, Taiwan, South Korea, China and other developed countries like Japan, USA, Germany and France, there are goods being imported and exported by ASEAN members countries in quite a big numbers. Experiences in Indonesia showed until recently that these goods, perhaps also in term of machines, are not ergonomically assessed or designed before being exported or imported. It is understandable that there must be various impacts emerged to the users, although are not reported ever since, as there is no data or knowledge about the impacts. Most are accepted as it is, and no complaints have been reported so far although possible created risks were in existence.

SEAES as an association of the region can't keep quiet on such matters, and steps to anticipate must be carried out. It should start with collecting more data in detail about the goods or machines being imported or exported by each member countries as well as by neighboring and developed countries. With all those data cooperative steps can be followed-up, like collecting related anthropometric data, social cultural differences, custom and habits in using or operating the goods or machines especially which may develop possible accidents and other injuries. Existing cases must be collected and finding the root cause must also be noted. Of course in all those steps coordination must be launched, under SEAES leadership, among ergonomists in the region. ASEAN ergonomists must be able to send significant data to neighbor and developed countries to be used in designing the goods / machines which shall be exported to ASEAN countries.

Through this mechanism, it is hoped that SEAES and International Ergonomics Association as well as its members, not only be able to organize good and successful scientific meetings as well as published excellent papers, but also help the people at large to solve their daily ergonomics and OSH problems through their expertise.

1. INTRODUCTION

In relation to enhance their people quality of life, each country in SEA has to import and export goods/ machines from and to their neighbor countries (Taiwan, Hong Kong, China, South Korea) and other developed countries like Japan, USA, Germany, France, etc.(Report of the Economist Intelligence Unit Limited 1996). Experiences in Indonesia up to now show that in this mechanism, goods/machines being imported or exported are not ergonomically sound in particular and not appropriately assessed in general. Therefore possible accidents, injuries and adversely impacts could emerge among the users and their environment. But as always, due to their ignorance of the problems, no complaints have been reported, and the people accept the consequences as it is. For them the most important is to get the job, to use the goods, and go to hell with the negative consequences. If what has happened were still within their adaptation capability, there will be no feeling of the impacts. But with frequent impacts consequences and due to their better education and knowledge, this undercover problems shall emerge to the surface and create problems.

This paper tries to illustrate pro-active steps that must be taken by ergonomists in the region to overcome the problems at the right time and with the right effective way.

2. CHALLENGES

Information and data related to import and export of goods/machines from each country from/to other ASEAN member countries as well as from neighbor and developed countries must be collected through SEAES members in their own respective countries. By doing so, a detailed data base could be gathered for further use.

Special delivery of typical anthropometric data for each member country related to the use of the above goods / machines must be collected and done by ergonomists in each country, which then can be distributed to the exported countries to be utilized in designing their goods / machines. Wise step must be carried out by each country in using all those data from economic point of view, as for example using the percentile of all those data than handling one by one.

Similar data must also go to the neighbor and developed countries for similar purpose. Of course this mechanism is not as easy as it was expected because it needs willingness, capability and courage of all parties related. There must be political will from each member country, available budget and expertise to conduct the study. But with the recent condition of ASEAN, especially with the founding of OHS Net among ASEAN countries, this idea must be possible to carry on. Again it is the mission of SEAES and IEA and its members countries like HFES, Ergonomic Society, Japan Ergonomic Research Society and Japan Human Ergology Association as well.

If everything goes well, and the data could be applied as it was expected, trade between the respected countries shall have competitive as well as welfare aspect in the real sense in this global decade.

3. STEPS TO BE TAKEN

Anthropometric data shall be used to design goods / machines for export purposes by each country. Of course significant data on social cultural aspects as well as habits and customs on how the users shall utilize the goods / machines must also be reported. Environmental data where the jobs will be carried out should also be informed as well as how the organization will be developed and managed. The goods and machines must also bring about healthy, safety and efficient characteristics like free from noise, accident and disadvantage possible risk.

Target dates must be given to each country when the deadline of all those activities must be applied and warning up to law enforcement must be conducted for those incapable in doing so. Competitiveness outside of ergonomics application still could be given in term of attractiveness looks as well as reasonable prices based on innovation and creativity owned by each product center. By so doing the buyers still have their own freedom to make the choice, but whatever the choice will be it is always ergonomically sound.

This activity certainly has another benefit for all parties, especially for the ergonomists. As a challenging mission it will enforce ergonomists to enhance their capability as well as their sense of what is really happening in the community. And this will give advantages to the educational process of ergonomist through a double feed back loop, a tool to survive in this global decade. It is good also to use this activity as one of the election criteria of the coming president of the associations. Capability in presenting good or excellent papers in an AC meeting rooms should also be added by capability in the application of all those information to the community at large who are really needed the information.

4. POTENTIAL

Through the last five SEAES conferences it was clearly indicated that there are available academic potential among ASEAN ergonomists to carry out the mission. Especially with the participation of quite a number of ergonomists from other parts of the world in SEAES conferences, which showed interest and sympathy to ergonomics activities in the region, the available potential unquestionable. The question is how to use this potential and opportunity effectively and efficiently. And this is the task of the SEAES to carry out with the help of IEA and its members. ASEAN, the association of countries in the region must also be involved as much as possible, as they have very strong link especially in political and economical issues as well. In this context, Singapore should take the lead as one of the most economically advanced country in ASEAN as well as in fact most of its products also exported to other ASEAN countries.

5. CONCLUSION

It is a fact that among ASEAN countries and also between ASEAN and neighbor and developed countries there are import and export of goods and machines which are not mostly being assessed from ergonomic point of view. This situation might create and develop adversely negative impacts to the users, which must be stopped from happening continuously. It is a must for ergonomists from both sides, especially through ergonomics association like SEAES as well as IEA and its members, to take initiative in minimizing the impacts by developing cooperative joint effort to overcome the root cause. Exchanging ergonomic data like anthropometric, social cultural characteristics, habits and customs, etc., would be fruitful and helpful. By doing so, beside exchanging excellent papers in various scientific conferences in AC meeting rooms of five star hotels, it is also a must and a duty for every ergonomist in this decade to do something real for the community at large

REFERENCES

1. A. Manuaba. Developing Ergonomics Sound Technology Transfer from Japan to ASEAN countries, the Role of Ergonomics Societies
   Designing for Everyone. Proceeding of the 11th Congress of the International Ergonomics Association, Paris, 1991 : 1395-1397
2. A. Manuaba. Appropriate Technology Approach with Its "Built-In" Ergonomics Aspect is a Must in Technology Transfer to Attain Sustainable Development in Industrially Developing Countries
   Global Ergonomics. Proceedings of the Ergonomics Conference, Cape Town, South Africa, 1998 : 57-62

Table 1
Principal Exports and Imports of Malaysia

Principal Exports 1995		*Main destination*	
Electronics & electrical machinery	38.8 US$ bn	USA	20.7 % of total
Textile, clothing & footwear	2.6	Japan	12.7
		UK	4.0
		Germany	3.2
		Singapore	20.3
		Thailand	3.9
		Hong Kong	5.4
		Taiwan	3.1

Principal imports 1995		*Main origin of imports*	
Manufacturing inputs	30.2 US$ bn	Japan	27.3 % of total
Machinery & transport equipment	13.2	USA	16.3
Metal products	4.7	Germany	4.4
Consumer durables	2.3	France	2.9
		Singapore	12.4
		Taiwan	5.1
		South Korea	4.1

Table 2
Exports and Imports of Laos

Principal exports 1993		*Main destination 1994*	
Timber and wood products	47 $ m	Thailand	20.8 % of total
Textiles & garments	37	Japan	8.6
Assembled motorcycles	22	France	5.5
Electricity	17	Germany	5.5
		Netherlands	2.8

Main origins of imports 1994	
Thailand	48.5 % of total
China	6.4
Japan	6.2
France	3.6
USA	1.7

Table 3
Exports and Imports of Myanmar

Principal exports 1994 Mostly agricultural products 878.8 $ m , destination to Thailand, India, Singapore & developed countries.

Principal imports 1993		*Main origin of imports 1992*	
Raw materials	297.5 $ m	Japan	25.5 % of total
Transport equipment	223.3	China	15.9
Foodstuffs	137.7	Thailand	10.9
Machinery & equipment	134.9	Singapore	10.3
Construction materials	83.1	Malaysia	7.2
		Indonesia	4.1

Table 4
Exports and Imports of Vietnam

Principal exports 1995		*Main destination of exports 1995*	
Crude oil	19.7 % of total	Japan	28.5 % of total
Textiles & garments	15.4	Germany	9.4
Marine products	11.9	France	5.1
Rice	10.6	China	5.2
		Singapore	7.5
		Taiwan	4.5

Principal imports 1995	
Fuel, raw materials & machinery	87.8 % of total
Consumer goods	15.6

Main origin of imports 1994	
Japan	8.8 % of total
China	6.2
Singapore	17.0
South Korea	12.9
Taiwan	9.6
Hong Kong	6.1

Table 5
Exports and Imports of Brunei

Principal exports 1993		*Main destination of exports 1994*	
Crude oil	1,786 Br$ m	Japan	50
LNG	1,591	UK	19
Refined products	122	Thailand	10
		Singapore	9
		Taiwan	3

Principal Imports 1991		*Main origin of imports 1994*	
Electrical & industrial machinery	339 Br$ m	USA	13 % of total
Road vehicles	159	UK	19
Iron & steels	124	France	6
		Singapore	29
		Malaysia	9

Table 6
Exports and Imports of the Philippines

Exports 1994 to		*Imports 1994 from*	
USA	37.2 % of total	Japan	24.3 % of total
Japan	15.1	USA	18.5
Germany	4.9	Taiwan	5.7
UK	4.7	South Korea	5.2
Hong Kong	4.8	Hong Kong	5.2
Singapore	5.3	Singapore	6.8
Rest of Asean	4.2	Rest of Asean	4.8

Sources : The Economist Intelligence Unit Limited 1996

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A Cognitive Process Model for Usability Testing

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A cognitive process model is proposed in terms of the usability testing situation for the purpose of explaining the errors that may occur in the user's behavior during the testing. Compared to the conventional cognitive analysis of the usability testing results that frequently adopts the content analysis of the protocol data, this approach proposes a cognitive process model that will give us the information on how and why such inadequate behavior occurred during testing. Empirical verification of the model revealed that the model is more useful in understanding the user's behavior than the conventional approach.

1. PURPOSE

The content analysis of the protocol data of the usability testing (Rubin 1996) that is frequently used to find out the inadequate aspects of the user interface design lacks the explanation on the reason why the user behaved inadequately and thus why such interface design is inadequate. More cognitive psychology oriented approach is required in order to understand the generation process of such inadequate behavior. This paper proposes a cognitive process model in terms of the user's behavior in the usability testing situation.

2. COGNITIVE PROCESS MODEL

In this model, user is assumed to have four parameters in his/her working memory, i.e. the goal to achieve, the action rule (A-rule), the operation sequence model (O-model) and the cognition of the current status of the system.

As the first step, user may have the goal to achieve. This goal could be a set of sub-goals as was supposed by Card et al. (1983) and Norman (1986). The goal then triggers the retrieval process of the adequate set of actions from the long-term memory. This set of actions is named as the O-model. Each action in the O-model corresponds to the A-rule that can be regarded as a kind of the production rule that will also be retrieved from the long-term memory. This A-rule determines the user's actual behavior. At the same time, the application process of the A-rule is influenced by the current status of the system of which information is provided by the cognition of the current status of the system. Then at last, it will be decided what kind of action is to be performed. When the user starts some action, the system also starts the processing. The information in terms of the status of the system will be given to the user through the cognition process, and it will be accumulated in the cognition of the current status of the system.

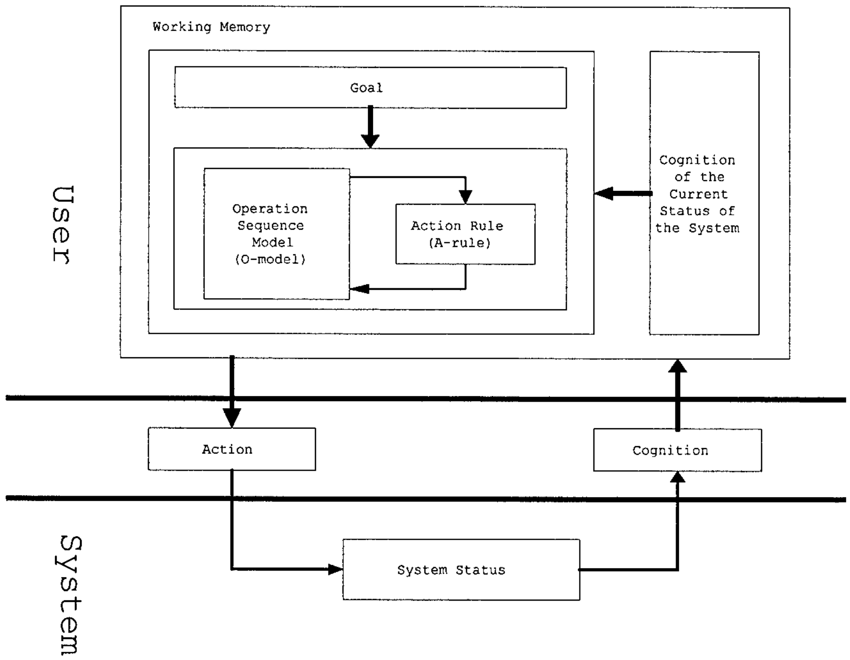

Figure 1. Cognitive Process Model

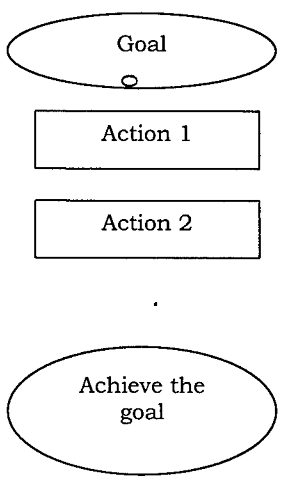

Figure. 2 Operation Sequence Model (O-model)

As show in Figure 2, O-model is a set of actions to achieve a specific goal. For the goal of recording some music from CD to MD, for example, some user may have such a correct O-model as "(1) set a CD, (2) set an MD, (3) push the dubbing button and (4) push the play button". But some user may have such an incorrect O-model as "(1) set a CD, (2) set an MD and (3) push the play button". This may cause an error behavior at the level of O-model. The diagrammatic representation of Figure 2 can be represented in such an expression as

(O1, O2, O3 (O3-1, O3-2), ... On)

where Oi represents the i-th operation. The inner parenthesis means that O3 is a combination of O3-1 and O3-2 at the lower level.

As shown in Figure 3, the action rule is a combination of the pre-status, the action and the post status. This means that the action at some pre-status may change the state of the system into the post status. For the recording from CD to MD, for example, a user may have a correct A-rule as "pushing the dubbing button may change the system into the waiting status for the recording button to be pushed". But another user may have an incorrect A-rule as "pushing the dubbing button may finalize the dubbing process". This may cause an error at the A-rule level. The diagrammatic representation of Figure 3 can be represented in the conditional expression as,

(A | S1) -> +/- S2

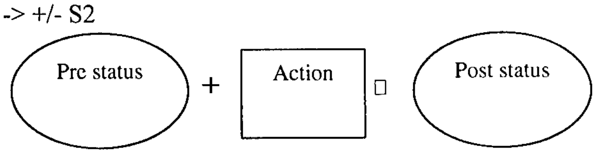

Figure 3. Action Rule (A-rule)

where A represents the user action and S the system status. The combination of A and S1 is represented as a conditional expression. The plus-minus sign in front of S2 means that some action may add some new status to the system and that another action may deduce some old status.

Table 1 shows the full list of the state, the action and the event for the case of the VCR. Examples of A-rules based on this table are as follows,

(A1|/S1) -> +S1+S4 ... Put on the TV

(A2|/S2) -> +S2 ... Put on the VCR

(A16 | S1) -> +S6-S4-S5 ... Put the game button

And table 2 shows a part of the state transition of the cognitive process for VCR operation.

Table 1.
Complete list of the States, the Actions and the Events for the VCR

State	Action	Event
/S1: TV power off	A1: Push the power button on TV	E1: Time display will show an advanced time
S1: TV power on	A2: Push the power button on video	E2: Channel display will be changed
/S2: Video power off	A3: Insert a cassette tape	E3: Reservation will be cancelled
S2: Video power on	A4: Push the eject button	E4: The cursor goes to the next item
/S3: No video tape inserted	A5: Push channel + button	E5: The reservation will be cancelled
S3: A video tape is inserted	A6: Push channel – button	
S4: Input channel of TV is TV	A7: Push play button	
S5: Input channel of TV is Video 1	A8: Push input select button	
S6: Input channel of TV is Video 2	A9: Push stop button	
/S7: No menu is displayed on TV screen	A10: Close the cover of the remote controller	
S7: A menu is displayed on TV screen	A11: Open the cover of the remove controller	
S8: A cursor on the menu is at time adjustment	A12: Push menu/reserve button	
S9: A cursor on the menu is at the reservation	A13: Push cursor button	
S10: Time adjustment is displayed	A14: Push OK button	
S11: Just clock setting is displayed	A15: Push channel button	
S12: Reservation is displayed	A16: Push game button	
/S13 : Cover of remote controller is closed	A17: Open the cover of video	
S13: Cover of remote controller is open	A18: Close the cover of video	
/S14: Cover of video is closed	A19: Push the start time button	
S14: Cover of video is open	A20: Push TV/video button	
/S15: Start/End time is not displayed	A21: Push end time button	
S15: Start/End time is displayed	A22: Push complete button	
S16: Input source is video	A23: Push cancel reservation button	
/S17: Reservation is not displayed	A24: Push cancel setting button	
S17: Reservation is displayed	A25: Push numeric button	
S18: Recording is in process	A26: Push record button	
S19: Playing is in process		

Table 2.
State transition of the cognitive process for VCR operation (part)

		User				System		User
Action		O-model	Cognition of the system	Status memory before action	Action	Action Rule	System status after action	Cognition of the system status after action
(1)	Put the power switch of TV	O1	/S1	/S1	A1	1	S1,/S2,/S3,S4, /S7,/S13	S1,S4
(2)	Put on the power switch of VCR	O2	/S2	S1,/S2,S4	A2	2	S1,S2,/S3,S4,/ S7,/S13	S1,S2,S4
(3)	Change the input of TV to VCR1	O3		S1,S2,S4	A8	3	S1,S2,/S3,S5,/ S7,/S13	S1,S2,S5
(4)	Open the cover of the remote controller		/S13	S1,S2,S5 ,/S13	A11	9	S1,S2,/S3,S5,/ S7,S13	S1,S2,S5,S13

Table 3.
State transition of the actual user for the same task with Table 2.(part)

		User				System		User
(1)	Put the power switch of TV	O1	/S1	/S1	A1	1	S1,/S2,/S3,S4, /S7,/S13	S1,S4
(2)	Put the power switch of VCR	O2	/S2	S1,/S2,S4	A2	2	S1,S2,/S3,S4,/ S7,/S13	S1,S2,S4
(3)	Change the channel	O3		S1,S2,S4	A5	8	S1,S2,/S3,S4,/ S7,/S13,E2	S1,S2,S4,E2
(4)	Put the input change button			S1,S2,S4	A8	3	S1,S2,/S3,S5,/ S7,/S13	S1,S2,S5

3. DESCRIPTION OF USER ERRORS IN THE MODEL

Based on this process model, errors in the usability testing situation can be classified into three categories; (1) O-model error, (2) A-rule error and (3) state cognition error.

Table 3 shows the example of O-model error in which the wrong action sequence can be seen in the third step and fourth step. Although the correct action sequence is (1, 2, 3, 9), the user behaved as (1, 2, 9, 3). As a result, the actual system status and the perceived system status are quite different from the correct one in Table 2 after the third step.

A-rule error could be seen if the user mis-understands the consequence of the specific action. Although there are no A-rule errors in Table 3, they could be found for the action where the intention is correct but the assumption of the result is different from his/her intention. This type of error can be found rather frequently by the subject's utterance, e.g. "What happened? I did it in the right manner!" The model will give us the explanation what were actually happening in such a case.

And the state cognition error can be seen in table 3 by comparing the system status column and the cognition of the system status column. This type of error can be found in the actual usability testing situation when the user takes the wrong action after the correct sequence of actions. Although this type of error is similar to O-model error as an apparent phenomenon, this could be differentiated from it by asking the user what kind of action he/she was going to take. If the user's intention was wrong, the error could be classified as the O-model error, and if the intention was correct, the error could be classified as the state cognition error.

4. CONCLUSION

Conventional analysis of the protocol data will give us the information on what happened in the course of user's action. But it does not give us the explanation what was happening in the cognitive process of the user. The cognitive process model will give us such information as to how and why such an action was taking place. This information is quite useful in understanding the reason for the errors, thus in improving the user interface design.

REFERENCES

1. J. Rubin, "Handbook of Usability Testing", John Wiley and Sons (1994)
2. S.K. Card, I.P. Moran, and A. Newell, "The Psychology of Human-Computer Interaction", Lawrence Erlbaum (1983)
3. D. Norman, "Cognitive Engineering" in D.A. Norman and S.W. Draper (eds.) "User Centered System Design", Lawrence Erlbaum (1986)

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Usability Evaluation in Malaysia: An Exploratory Study of Verbal Data

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"... Asianized English has more charm than the boring original version,... Malaysian English 'Manglish' is far more efficient and economical than British English"

Briton: Am I allowed to enter through here? Malaysian (pointing): Can or not?
Briton: Put your wallet away. This one's on me. Malaysian: No nid la!
Briton: Hi. Sit down. Make yourself at home. Malaysian: Don't shy, leh.
Briton: Why are you looking at me like that? Do you have a problem? Malaysian: See what?
Briton: I'd really rather not. Malaysian: Doe-waaaan!
Briton: Now what shall we do? Malaysian: So how?
Excerpt from Traveller's Tales, Far Eastern Economic Review (Vittachi, 1998)

This paper describes an exploratory study conducted to examine Malaysian participants' verbalisations recorded in think aloud and interview sessions. Idiosyncratic speech characteristics of Malaysians were identified in the verbalisations. The implications of these findings on conducting usability assessment are discussed.

1. INTRODUCTION

One of the integral components, in the development of software for the international market, is that the localised product has to be usability tested with the target markets' users (Fernandes, 1995; Uren, Howard and Prenotti, 1993; Russo and Boor, 1993; Nielsen, 1990). The usability evaluation is conducted to ensure that the product is usable and accepted by the target culture –culture is defined as "a group of people who feel, act, and think similarly". Besides employing locals (natives of target cultures) as participants, it is also recommended, where possible, to recruit local usability experts to conduct usability evaluations (Nielsen, 1996). Local usability experts are recruited, as they would know how to interact in that culture as well as understand the local language. The local usability experts' understanding of the target language is especially important when the verbal data collected is not comprehensible to the usability experts from the country of origin of the product. (Verbal data is commonly collected in usability evaluations; examples of sources of verbal data include think aloud and interview –two important usability assessment techniques. The focus of this paper is on verbal data; video data, although important, is not examined).

Verbal data can be broken down into the message, and the method by which the message is conveyed. For example, a message, "Software X is very good" can be conveyed in many different ways, e.g. in English, in French –"Le logiciel X est très bon", or mix of English and French – "Software X est très bon". While the message is still the same, the manner in which the message is conveyed is different. By exploring and understanding how these messages are conveyed, insights on ways to optimise usability evaluations may be realised. For example, messages conveyed by a British as compared to a Malaysian is different (shown in the above excerpt, albeit facetiously). Thus, usability evaluators must not only be able to converse in English and BM (Bahasa Malaysia, Malaysia's national language), they should also be familiar with the idiosyncratic Malaysian English or "Manglish".

Given that Malaysians possess their own idiosyncrasies in conversations be it in the workplace or at home (Morais, 1995; Nizar, 1995; Ozog, 1995), it is hypothesised that these idiosyncratic speech characteristics will also transgress into the usability evaluation domain, that is, idiosyncratic speech characteristics will be present in verbal data collected in the usability evaluation. If the hypothesis is true, the usability evaluations should be optimised accordingly taking into account the speech idiosyncrasies of Malaysians.

2. METHOD

To test the conjecture, an exploratory (grounded theory) approach adapted from Pidgeon and Henwood (1996) was used to identify the various speech characteristics in the data collected from a usability evaluation experiment. In the usability evaluation experiment (conducted in Sarawak –a Malaysian state on the island of Borneo), seventeen Malaysian participants –representative users– evaluated a spreadsheet with a BM interface –the localised product. Bahasa Melayu is Malaysia's national language and is spoken by almost all Malaysians. (The majority of Malaysians also speak English, a "legacy" of British rule in Malaysia.) The participants were required to think aloud while completing a set of six spreadsheet tasks. The participants were also asked in an interview, their opinions and suggestions for improvements of the spreadsheet they had just used. The choice of the language (BM or English) used to verbalise and respond in the usability evaluation was left entirely to the participants. Both the think aloud and interview sessions were audio recorded. The author of this paper, a Sarawakian fluent in English and BM, was the experimenter in all usability evaluation sessions as well as the transcriber of the think aloud and interview audio records.

3. RESULTS

Analysis of the transcripts revealed the presence of a number of speech characteristics of the participants. The speech characteristics found included: code-switching between English and BM, the use of Sarawak dialect, use of expressions, use of exclamations, use of "lah" particle, and use of sound effects. These speech characteristics are documented in Ozog (1995) Gaudart (1995) and Jamaliah (1995). Examples and descriptions of the speech characteristics are detailed in Appendix 1. It was also noted that all the speech characteristics were present in at least one of the participants' verbalisations (see Appendix 2).

4. DISCUSSION

From the results it would appear that idiosyncratic speech characteristics from conversations do transgress into the usability evaluation domain. As such, the recommendation by Nielsen (1996) to employ locals in usability evaluation is vindicated. Only a local would be able to interpret correctly the various expressions and exclamations.

For example, the exclamation, *Matilah aku!* ("Die-lah me") [P12] did not (literally) mean death. In that context, the exclamation was meant to indicate the difficulty of the task. This local knowledge is not only useful during the think aloud or the interview session, but also during the transcription of the data.

Furthermore, the experimenter present at the usability evaluation must also be a local of the target (sub-)culture. From the data in this study, not only English and the national language, BM, was used, the local Sarawak dialect, endemic to Sarawak, was also used. (Participants used the dialect probably because some of the participants knew the experimenter could understand the Sarawak Dialect), see Appendix 1 for examples of Sarawak Dialect. Thus, if a non-local, say a Malaysian from another State, were to conduct the usability evaluation in Sarawak, the participants may only use English and BM. This means that the choice of experimenter may also influence the language the participants are able to use. One implication of the language limitation is that, if the participants are required to use a language that they are not fluent in, they may not be able to communicate well in the usability evaluation; as such, important and useful data may not be expressed.

In addition, if a non-local experimenter was employed in the usability evaluation, information imparted by the locals in the Sarawak Dialect may be missed or misinterpreted by the non-local experimenter. As such, wrong conclusions may be drawn from the misinterpreted data. Moreover, important information which could be utilised to improve the product being evaluated may also be lost. Thus, a local usability expert employed must not only be aware of the national languages spoken, but also, languages endemic to the target sub-cultures as well. This recommendation not only applies for usability evaluation of near-completed products (as in the case of this study) but also in the evaluation of product designs where verbal feedback via interviews are commonly employed.

5. CONCLUSION

The study shows that speech idiosyncrasies of Malaysians, present in conversations, also encroach into field of usability evaluation. The study also supports the use of a native to conduct usability evaluation, and also transcribe data. Furthermore, the local usability evaluator recruited must not only know the languages used nationally; he or she must also know the languages endemic to the target sub-cultures, which may include languages used at the State, city, town, or even village level.

6. FURTHER WORK

More exploration of the data is being conducted to identify other speech characteristics, which may impact the utilisation of usability evaluation techniques.

7. ACKNOWLEDGMENTS

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REFERENCES

1. Fernandes, T. (1995). *Global Interface Design.* AP Professionals.
2. Gaudart, H. Some Ways of Speaking Among Mother-tongue Speakers of English in Malaysia. (1995). In Zainab A.M. and Baskaran, L. M. (Eds.). *Verbal Interactions at Play: Rules of Speaking.* Pelanduk Publications, Petaling Jaya, Malaysia.. p26-46.
3. Jamaliah M. A. (1995). The Pragmatics of Cross-Cultural Communication in a Malaysian Context. In Zainab A.M. and Baskaran, L. M. (Eds.). *Verbal Interactions at Play: Rules of Speaking.* Pelanduk Publications, Petaling Jaya, Malaysia. p112-124.
4. Morais, E. (1995). Some Preliminary Observations of Business Communication in Malaysia: A Cross-cultural Perspective. In Zainab A.M. and Baskaran, L. M. (Eds.). *Verbal Interactions at Play: Rules of Speaking.* Pelanduk Publications, Petaling Jaya, Malaysia. p94-111.
5. Nielsen J. (1990).*Usability Testing of International Interfaces.* In Nielsen, J. (Ed.). Designing User interfaces for International Use. Elsevier, New York. p39-44.
6. Nielsen, J. (1996). International Usability Engineering. In Del Galdo, E. and Nielsen, J. (Eds.). International User Interfaces. John Wiley & Sons.
7. Nizar Idris (1995). Language as a Means of Business Communication. In Zainab A.M. andBasaran, L. M. (Eds.). *Verbal Interactions at Play: Rules of Speaking.* Pelanduk Publications, Petaling Jaya, Malaysia. p61-72.
8. Ozog, A. C. K. (1995). In Zainab A.M. and Baskaran, L. M. (Eds.). *Verbal Interactions at Play: Rules of Speaking.* Pelanduk Publications, Petaling Jaya, Malaysia. p73-93.
9. Pidgeon, N. and Henwood, K. (1996). Grounded Theory: Practical Implementation. In Richardson, J. (Ed.). *Handbook of Qualitative Research Methods.* The British Psychological Society Books. Leicester, UK. p86-101.
10. Russo P, Boor S. 1993. *How Fluent is your Interface? Designing for International Users.* INTERCHI '93 Conference on Human Factors in Computing Systems: INTERACT '93 and CHI'93. (Amsterdam, 24-29 April). ACM Press. p342-347.
11. Uren E, Howard R, Preinotti T. (1993). *Software Internationalization and Localization: An Introduction.* Van Nostrand Reinhold.
12. Vittachi, N. (1998). Travellers' Tales. *Far Eastern Economic Review.* 24 September 1998. http://www.feer.com/Restricted/98sept_24/tales.html
13. Zainab A.M. and Baskaran, L. M. (Eds.). *Verbal Interactions at Play: Rules of Speaking.* . Pelanduk Publications, Petaling Jaya, Malaysia.

APPENDIX 1

Examples of speech idiosyncrasies of Malaysians detected in verbal data collected in usability evaluation. The symbols < > indicate some words were inaudible. See description in Code Switching below for more information.

Code Switching between English and Bahasa Melayu

The English words are not formatted. English translations of Bahasa Melayu speech are placed within round brackets and quotes e.g. ("Translated to English from Bahasa Melayu"). The Bahasa Melayu words have been *italicised* to contrast the English and Bahasa Melayu words.

[P5:E36] Umm... no... *Campur* ("Add") <> one five... *empat satu* ("four one")... Oh! ... I try to total up all the amount... *tiga 'tu* ("three") [values]... *dengan menggunakan* ("using a") formula... *ataupun... dua* ("or... two.."). *Biasanya kita gunakan* sum *kan*? ("Usually we use sum right?") Just sum the total on Excel... *Jadi tak ada kan?* ("But don't have right?") [Laughs]

Sarawak Dialect

In the think aloud and interview sessions, words from a dialect were used. The dialect is known as the, Sarawak Dialect, a dialect of Bahasa Melayu (Asmah Haji Omar, 1993). It is a regional dialect and is spoken in Sarawak, a state in Malaysia. The Sarawak Dialect comprises mainly Bahasa Melayu words as well as variations of Bahasa Melayu words. Words from local languages, such as Iban (language of the largest ethnic group in Sarawak), have also been absorbed into the dialect.

Participant P14 used the word *engkah* which means "to put". *Engkah* is an Iban word with the same meaning.

[P14:E42] Total? Total... *engkah ke Hamparan...* ("put into the spreadsheet")

Cell address C *duak* is C2. The word *duak* probably derived from the word "dua", the Bahasa Melayu word for "two".

[P9:E27] Ummm... B *duak* ("B two")... *tekan...* ("press") yes... C *duak* ("C2") C *duak* ("C2")... *campur C tiga* ("add C3")... ...

Expressions

Some expressions have developed from cross-cultures and transfers e.g. 'this die' ("now we've had it") (Gaudart, 1995). For example,

[P16:E10] *Matilah aku!* ("Die-lah me!") [Laughs] Don't < > do anything! Is there aaa... no. Ah... how do I total this? [Pause]

Exclamations

Although these are simple sounds, they need to be uttered with the correct intonation to be understood (Gaudart, 1995).
For example, "wah" /wa/ can mean surprised, impressed, or dissapointment (Gaudart, 1995).
Participant P12 was "impressed" that the spreadsheet worked, that is, the value he entered was accepted by the spreadsheet and the value was displayed in the cell.

[P12:E21] Two hundred. Wahhhhh. [Laughs]

The "Lah" particle

Ozóg (1995) noted that it is most commonly used particle in the mixed language.

[P12:E8] Amounts of... umm amount of... cells, I think so lah. Cell and... January months...

Sound Effects

Gaudart (1995) describes that Malaysian English speakers use sound effects liberally. E.g. "zing" or "boing" used by young children who have been influenced by American comics, adults use more precise sound effects: This example appears in participant P11's description of mouse use.

[P11:Q3] ... *biasa gunakan* ("familiar with using") mouse tik tik tik ... [sound of clicking mouse button]

APPENDIX 2

Participant's Speech Characteristics in the Think aloud and Interview Sessions

Participants	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
Ethnic Group	M	M	I	I	M	M	M	M	M	M	M	M	M	M	C	M	M
Code switch: TA	-	-	-	-		-									-		
Code switch: Int.	n/a		-	-		-									-		
S'wak dialect: TA	-	-	-	-		-		-		-					-		
S'wak dialect: Int.	n/a	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
Expressions: TA	-	-	-	-	-	-	-		-	-	-			-	-		-
Expressions: Int.	n/a	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-
Exclamations: TA															-		
Exclamations: Int.	n/a	-	-	-		-	-			-	-	-	-	-	-	-	-
Used "Lah": TA	-					-											
Used "Lah": Int.	n/a		-	-			-		-				-		-	-	
Sound effects: TA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sound effects: Int.	n/a	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-

KEY: Ethnic Group: M = Malay, C = Chinese, I = Indian; Source of data: TA = think aloud, Int. = Interview; = speech characteristic is present in the transcripts of participant, - speech characteristic is absent; n/a = participant P1's interview was not available

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Measurement of Perceived Participation in Decision-Making: Analysis of Group Data

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A series of judgement studies were conducted with the aim of measuring perceived participation. Perceived participation was viewed as: (1) a conscious, calculated reflection on actual participation in a concrete situation, (2) a multidimensional and complex construct composed of both individual and organizational aspects, and (3) an individual characteristic with possibly large variation among persons. Sixteen participation factors were used in a multidimensional scaling study. The solutions for each individual in the first experiment showed high explained variance (56% - 87%), while the group solution showed low explained variance (26%). However, in a replication study with the same 16 factors but on a different group the same pattern of results appeared. The overall correlation between the two group solutions was as high as .83 ($p<.001$). The results supported the view of participation as an individual, cognitive, and multidimensional construct, but also as a common stereotype, corresponding to conventional definition of PDM.

1. INTRODUCTION

Participation in decision-making (PDM) has been an important area of research in organizational psychology. Reviews and meta-analysis (Locke & Schweiger, 1979; Dachler & Wilpert, 1978; Miller & Monge, 1986; Wagner & Gooding, 1987a, 1987b) on PDM research have pointed out the lack of consistent results. Participation has been viewed in different ways, first, participation has been considered as an independent variable, i.e. cause of satisfaction at work and productivity. Secondly, participation is a vital part of organizational-development and is a goal to achieve and is given a concrete form to individuals by increased democracy and third, participation is also a model for explaining persons cognition in a concrete decision-making situation. All this focus on the necessity to specify the concept of participation and its content in order to be able to measure it. In this research the concept of participation is viewed as (1) a conscious, calculated reflection on actual participation in a concrete situation rather than a simple response on organizational stimuli, (2) a multidimensional and complex construct composed of both individual and organizational aspects, and (3) an individual characteristic with possibly large variation among persons.

2. METHOD

2.1. Subjects

The experiment was conducted on two different groups (A and B) at two successive years. The groups contained persons with different occupations from different organizations and were quasi randomly chosen (attending a university course in work- and organizational psychology). There were 17 persons in group A and 13 persons in group B.

2.2. Procedure

16 factors were used in a multidimensional scaling procedure. The persons were to judge how similar two different factors were regarding to their influence on participation. The factors are shown in Table 1.

Table 1. 16 participation-factors used in multidimensional scaling.

Legend	**Influence participation by...**	**For example**
1	right to reward/punish individuals	wages, warnings
2	Communicate in groups at informal meetings	in corridor, on breaks
3	to have special knowledge/ experience	expert
4	settle goals, criteria, work-demands	quality, tests
5	be part of institution for decisions/consulting	board, committee
6	Formulate written documents, petitions	keep records, make applications, appeal
7	plan/ organize work-activities	process chart, scheme
8	natural leadership	charismatic personality
9	Communicate in groups at formal meetings	board meetings, conferences
10	utilize trade-union means	union representative, negotiation
11	do ones work in a certain way	make extra effort, work to rule
12	have the formal right to make conclusive decisions	formal managership
13	have private negotiations with key persons	manager, representative
14	Participate in voting, elections	election to formal boards, committee
15	Manage/control work-activities	labor management
16	use personal relations, contacts	Friends

Bold texts are factors corresponding to the PDM-variable defined by Locke & Schweiger (1979).

Each person were to make 120 judgements (all possible pairs of factors) on a scale from 0 (not similar at all) to 10 (completely alike). The task was to compare all pairs of factors with reference to their similarity in participatory power.

3. RESULTS

A 3-dimensional multidimensional analysis (MDS) (Kruskal & Wish, 1978) on each person showed high explained variance (RSQ) ranging from 53% to 87%. The stress index (badness of fit) was low. The results indicated that the persons were able to make these judgements in a consistent way and that the solutions were consistent with the raw-data matrices. The group-solutions on the other hand showed low explained variance (26%) and a rather high stress index. The results indicate a considerable amount of errors in the group solutions but when comparing the different groups, a very consistent pattern emerges which contradicts the error explanation. In both groups the same three dimensions appears.

Table 2. The three dimensional solution for group A and B respectively.

Dimensions/Groups	The continuum
Dimension 1/A Dimension 1/B	**Collective – Manager**
Dimension 2/A Dimension 3/B	**Indirect - Direct means**
Dimension 3/A Dimension 2/B	**Formal - Informal means**

For dimension 1, the factors were arranged in the following order:

14, 2, 9, 10, 16, 3, 13, 5, 11, 8, 6, 1, 12, 7, 15, 4

As can be seen the PDM-factors are well spread out over the whole dimension (bold text) indicating a good correspondence to the PDM-variable defined by Locke & Schweiger (1979). See appendix A for an example on graphical solution from MDS-analysis.

Table 3. The correlation between groups for the three dimensions respectively.

		Group A		
		Dim 1	Dim 2	Dim 3
Group B	Dim 1	.8864*		
	Dim 2			.7139*
	Dim 3		.7797*	

* (p< .002)

These proximity data may be analyzed in different ways to find out if the underlying data structure are stable and reliable. Pathfinder-network-analyze (Dearholt & Schvaneveldt, 1989) uses proximity data to find network pattern. This analyze tries to find the strongest connection between each and every factor. The more inconsistent and randomly the connections, the more connections are found. For an item list of 16 factors the worst solution contains 120 connections while the best solution contains 15 connections. The results from the pathfinder-network analyze are shown in Figure 1 and 2.

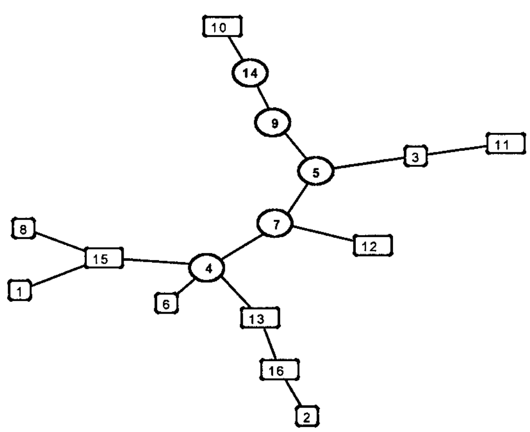

Figure 1. Pathfinder-network graph for group A. Round nodes are PDM-factors.

The correspondence between the two graphical solutions are as high as .8297 ($p<.001$). Furthermore one can see that the PDM-factors forms a central linkage in the graphs. In the peripheral part of the graph the informal factors are located while the formal factors are focused at the center of the graph.

When using multidimensional scaling analyze, cluster analyze can be used as a complement. A hierarchic cluster analysis was done on each of the datasets and the rank-correlation between the entering sequences of the 16 factors were .8912 ($p<.001$).

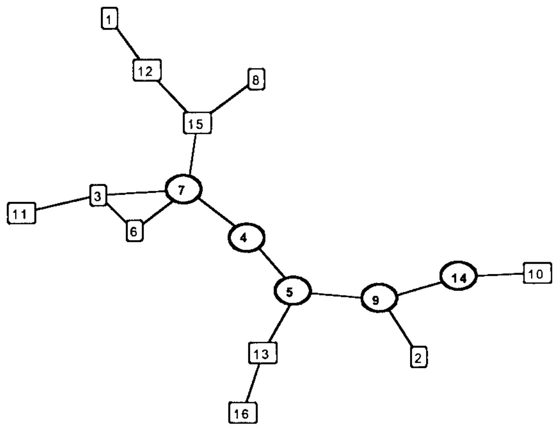

Figure 2. Pathfinder-network graph for group B. Round nodes are PDM-factors.

4. DISCUSSION AND CONCLUSION

The results from the two experiments supports the view of participation as an individual, cognitive, and multidimensional construct. This means that unidimensional PDM-variables and global responses about participation gives little information about the multidimensionality of participation. Thought the MDS group solutions gave low RSQ one can not interpret it as lack of reliability or due to error because solutions are consistent and correlation between groups are high and significant. Both results from pathfinder-network analyze and cluster analyze give support for that conclusion. One explanation to the results is that individuals perceives participation as an individual construct rather than a collective one. The explained variance in the group solution are to be seen as the common denominator and conceptually one can see it as the stereotype of participation. The characteristic of the PDM-variable can be described as: (1) the PDM-variable is a part of the participation-concept and is closely linked to the "collective - manager" dimension, (2) the PDM-variable is concentrated to the formal aspects of participation as can be seen in the pathfinder-network where the PDM-factors forms the central part of the graph.

Since organizational design, organizational development, and organizational change depend heavily on communication, there is of great concern that people, involving in these activities, share the deeper meaning of crucial concepts. Lacking this shared meaning, i.e. depending on a common stereotype will result in misunderstandings and non-goal oriented discussions of subjective interpretations of the concepts. To improve communication in the organizational design process as well as the organizational design processes itself all design and development tasks should start with defining and discussing goals, means, and not least the central concepts to establish a common conceptual platform.

REFERENCES

1. Dachler, H.P., & Wilpert, B. (1978). Conceptual dimensions and boundaries of participation in organizations: A critical evaluation. *Administrative Science Quarterly, 23*, 1-39.
2. Dearholt, D.W., & Schvaneveldt, R.W. (1989). Properties of Pathfinder Networks in Schvaneveldt, R.W. (Ed) *Pathfinder Associative Networks. Studies in Knowledge Organization* Norwood, New Jersey: Ablex Publishing Corporation
3. Kruscal, J.B., & Wish, M. (1978). *Multidimensional scaling*. Beverly Hills: Sage Publications
4. Locke, E.A., & Schweiger, D.M. (1979). Participation in decision-making: one more look. *Research in Organizational Behavior, 1*, 265-339.
5. Miller, K.I., & Monge, P.R. (1986). Participation, satisfaction and productivity: A meta-analytic review. *Academy of Management Journal, 29*, 727-753.
6. Wagner III, J.A., & Gooding, R.Z. (1987a). Shared influence and organizational behavior: A meta-analysis of situational variables expected to moderate participation-outcome relationships. *Academy of Management Journal, 30*, 524-541.
7. Wagner III, J.A., & Gooding, R.Z. (1987b). Effects of societal trends on participation research. *Administrative Science Quarterly, 32*, 241-262.

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SAMSA: Evaluation of a Cooperative Social Welfare Project

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Reported are the results of a pilot project designed to rehabilitate chronically unemployed. The project was funded by the European Union and sponsored by three public authorities that cooperated and combined resources. Representatives from the three worked as a team. This approach was seen as important. Participants whose primary problem was chronic, long-term unemployment benefited from services by finding employment or starting a job-search. Participants who had the additional problems of long-term substance abuse and/or mental illness were less likely to benefit. Recommended was that the pilot project be converted to a permanent programme using multiple teams.

1. BACKGROUND

The Department of Human Work Science at Luleå University of Technology was commissioned to follow-up on and evaluate the SAMSA Project. SAMSA was a cooperative project involving the Kiruna municipality social welfare service (Socialförvaltning), the Swedish Employment Service (Arbetsförmedlingen) and the Kiruna regional social insurance office (Försäkringskassan).

The project utilised a team made up of staff from each of the cooperating authorities. The team operated outside of established interauthority lines of communication. The project's goal was dual: first, to develop stronger working relationships between each of the authorities and second, to develop cooperative methods for the management or prevention of chronic unemployment and attendant problems among the population common to all the authorities. The project's target group were those individuals experiencing long-term unemployment due to medical and/or psychosocial causes.

For the project, the following quantitative goal was adopted: a minimum of thirty persons would be selected to participate. Of those, 5% were to be employed or actively seeking employment, 20% participating in a recognised training programme, 40% participating in a government sponsored employment-preparation or job search scheme for a designated high-need region, 15% having just completed some form of treatment sponsored by a public authority, and 20% ready to actively search for employment. An additional goal was that a minimum of 55% of project participants were to be women. The qualitative aims of the project were that, through the testing and use of new, non-traditional cooperative strategies and methods, new methods and techniques would be developed that use a holistic approach to increase the overall quality of life and self-esteem of participants. Anticipated was that the

1.1 Project Elements

The idea for the project was conceived by Kiruna's social welfare service where the chief had the idea of a team-based, cooperative, interauthority effort. The heads from the three authorities had earlier discussed the general idea of a cooperative effort and so were interested in new ideas.

Staff from each of the authorities were directed to prepare a project plan and to apply for funding through the European Union's Social Fund. Monies for the SAMSA Project were subsequently allocated under the Social Fund's Objective 6 funding base. Funding under Objective 6 ran from January 10, 1998 until the end of the year. During 1999, project costs were funded through budgetary allocations from each of the three authorities.

Overall direction and management of the project was under a combined leadership comprised of the heads of the three cooperating authorities. Services to the target population were planned and provided by the three team members. The team worked out of space physically separate from the parent organisations. The team members were given the authority by their organisations to act independently within the parameters of project guidelines. All of the team members were selected from among each authority's most experienced staff. The authority granted to the three permitted them to use their independent judgement in the furtherance of project goals without having to seek prior approval or to question whether their decisions would be later challenged. Each followed the same documentation requirements of their parent authority. The team used its own common record system for shared management and tracking of services and activities. After the project had been in operation for a period of time, the services of a doctor and psychologist were retained.

The clients (those receiving project services) were referred by staff from the three participating authorities. Prior to initial contact with the client, the team met and planned strategies and identified what services would likely be appropriate. All three team members were present during the initial and second appointment with the client. These meeting were called the "mapping out" or planning meetings. The goal of the meetings was to help the client to begin to acknowledge self-defeating behaviours, build rapport with team members and to make a commitment to participate in the SAMSA Project.

2. EVALUATION METHODOLOGY FOR PROGRAM ASSESSMENT

The evaluation assessed the SAMSA Project's impact upon individual participants and its affect upon the participating authorities. The evaluation of the project is qualitative and includes data collected before the start of the project, during project operation, and after. Areas covered and steps taken during the assessment were:

2.1 Evaluation Contact

The first 34 persons whom the SAMSA team contacted and who agreed to participate in the project as clients were interviewed by the evaluators at the time they started receiving services. Of those 34, there were 27 who were interviewed again after they had participated in the project for at least three months. There were 21 men and 13 women in this group. It was not possible to have a second interview with three of the participants due to difficulty in scheduling a contact time. Information on those participants was acquired through contact with team members. Four participants did not complete their planned scheme of services and were dropped from the assessment. This made the number of participants who where included in the evaluation to be 30.

3. RESULTS

3.1 Barriers to Inter-Authority Cooperative Work?

There were four areas noted during the pre-project assessment that were viewed by the evaluation team as potential barriers to effective cooperation. These were: 1) Differences in procedural rules, 2) Organisational cultures, 3) Differences in Scope of legal authority, and 4) Differences in organisational structures.

3.2 Management's View of SAMSA

The team was allowed to operate without having to answer to their respective authorities on their day-to-day decisions. The combination of allowing an adequate degree of autonomy to the team and a high, supportive interest in the work had a positive influence on the work of the team; they could try new ideas while knowing that they had necessary interest and support. As mentioned previously, that the authority heads agreed to locate the team and project at a separate location underscored their commitment to allow the team the freedom to operate independently. Focusing on the individual participants and making them the centre of effort rather than simply following procedural guidelines was an area where the impact upon participant success was considered and incorporated into the original design. What would also have made the project's success rate higher would have been if the project had been scheduled to be longer in duration.

3.3 The Team as a Working Group

The three individuals that made up the team had a high interest in working in the project. By being able to allocate responsibilities among themselves, the team was able to create evenly distributed, well-defined areas of individual responsibility and authority which in turn caused the workload to be balanced. They found that a cooperative, team approach permitted problem-sharing and a concomitant improvement in problem resolution. This also meant that they were able to follow the progress of individual clients rather than, as was often the case in their previous assignments, passing responsibility on to another when a developing problem-set was outside of their customary sphere of responsibility. The team experienced a "changed perspective" due to the project's approach of placing the clients "in the centre" instead of the customary tactic of rules and practices dictating decisions and actions. Learning about the philosophies, practices, procedures and rules of each other's systems helped the team to function effectively together and to maximise the provision of services to project clients. The team members found that the collective resources of their respective agencies being used in a combined approach was the actual non-traditional aspect of the project. They were able to follow existing rules otherwise.

3.4 Client Perceptions of the SAMSA Project

It was apparent to these evaluators that the clients were generally cooperative and positive about the programme. Almost without exception, they kept appointments and followed-through in carrying out assigned activities. Reducing organisational contact from three to one had a positive impact upon attitude; not having to repeat negative histories seemed to reduce pessimism and self-defeating perceptions. Rather than the existing pattern of focusing on personal complaints during organisational contacts, the clients shifted behaviours to focus on activities that would eventually lead to their being able to secure employment in the open labour market.

The project clients were, on the whole, those who had a long history of contact with various social welfare organisations. The project, in a sense, represented a last hope for these persons.

At the start of the project, the employment status of the participants was as follows: 9 were classified as unable to work due to medical problems, 15 were unemployed, not receiving monetary benefits and not seeking work, 2 were unemployed and receiving monetary benefits, 3 were underemployed and one was receiving a pension. When participants were reassessed a second time (second contact was made over a period that was 3 to 12 months after the first contact) their employment status was as follows: 6 were actively seeking employment in the open labour market, 8 were underemployed, 1 was in a training programme, 3 were in a treatment programme, 5 were receiving a pension, 4 were in a job search preparation programme and 3 had moved or dropped out of the programme. During the second interviews with participants, many commented that the combination of greater availability of team staff (in providing supportive services) combined with their own increased efforts had a direct relationship to their perceived success in beginning to finding solutions to their problems. It is important to note here that the second interviews occurred after a relatively short period of program participation.

The participants could be divided into two broad groupings by problem type. These are:

- Those with psychosocial problems and unemployed or who were experiencing health problems that they felt kept them from being able to seek employment.
- Those with a diagnosed psychological problem and/or a history of substance abuse.

Those in the first group appeared to gain the most benefit from project services. Their array of problems were not so deeply rooted as to block their being able to participate. They tended to accept and participate in planned activities. This group tended to express satisfaction with efforts made by the team. They were serious about their project participation.

Those individuals (the second group) who had diagnosed psychological problems and/or a history of substance abuse were generally negative in their descriptions of the SAMSA Project. They generally felt that they had been coerced into participating in the project. Negative descriptions of how team members treated them were the norm. This group tended to believe that the team held a critical and disparaging attitude towards clients. This group did perceive individual SAMSA team members differently. One team member had university-level training. Comments regarding this team member were somewhat more positive.

The qualitative goals established for the project with respect to client characteristics were met and exceeded. At the time of referral, participants were more isolated from the open labour market than envisioned in the original plan. The majority was unemployed and not actively seeking employment. After 3 to 12 months of services the majority were actively participating in a job search process. Some had secured, albeit marginal, employment or entered a training programme. A general, positive change in attitude and behaviour was evident among many of those interviewed. Problem type could be related to participant success. Those in the group with psychosocial problems, unemployed and possibly having a minor character disorder were much more likely to complete planned services and become active in seeking employment.

4. DISCUSSION

4.1 SAMSA as a Future Methodology for Cooperative Work

The three authorities that combined resources were highly satisfied with the outcomes; inter-organisational communication improved and positive behaviour changes among long-term clients was observed. The success of SAMSA as a pilot project now raises the questions as to whether the lessons and methods learned can be generalised for use by the entire parent organisations. And if so, how to implement change. If it is possible to adopt the methods and approaches to the parent organisations will determine if the lessons of SAMSA have a future.

Three broad factors were critical to the project's success. These are:

- Team members participated in the project throughout. They felt project ownership.
- Management had a genuine interest in and provided strong support for the project.
- The individual team members were able to develop a group working relationship.

Some of the project strong points are:

- Participant action plans that combine the resources and services of three organisations.
- Communication between team staff from three organisations and the client.
- Generous amount of time available for each client.
- Rapport among team members.
- Speed in decision-making among team members from the three organisations.
- Services provided in a location geographically separated from the parent organisations.

4.2 Is the SAMSA Team-Approach Necessary?

There are factors to consider that relate ultimately to the question of whether the team approach is necessary. These are:

- The team provided intensive services that were time consuming to a population that possibly required such intensive services; a level of service not previously provided to individuals caught in a "revolving door" of dependency on social service systems.
- The possibility exists that once the strong structure provided by the team is removed that the self-defeating behaviours of participants are so deeply ingrained that they will return to their cycles of dependency.
- Will the type of individuals served by the team turn out to have a life-long dependency on services in order for them to be able to maintain the level of success achieved?
- Was the real role of the team that of a "dumping-ground" for problem clients?
- If project participants had been referred earlier, before becoming dependent would as much time per individual have been necessary and/or could more individuals been served?
- What should be the referral criteria to programmes such as SAMSA?
- If the SAMSA Project is converted into a permanent operation, what minimum competencies should staff possess for work with what typical participant characteristics?
- Should those with alcohol and/or substance abuse problems be required to abstain and participate in a substance abuse treatment programme as a condition of participation?

The team operated within a uniquely tailored environment. Transfer of the conditions in which they operated and translation of methods/techniques to the larger parent organisations appears on the surface to be, at the minimum, challenging. An alternative to direct transfer is to involve more social service providers (or units of social service authorities) and to use

SAMSA in its present form. Through coordination, potential problem individuals could be identified early and be kept from falling into a vicious circle of dependency on social services. Early referral to a team such as SAMSA would then cause services to be in the nature of prevention rather than being remediation. Rather than depending on one team, the number of teams could be 2 or 3 for an area. This would prevent a single team from becoming overloaded and being unable to provide the level of individualised services needed.

That approximately two-thirds of participants interviewed were extremely positive about the efforts of the team underscores the value of cooperative work and the relatively high quality of service outcomes. It is also apparent that quantitative goals such as numbers becoming employed can be deceptive indicators of success. Measures such as quality of life, improved ability to strive for long-term objectives and independence are equal or greater indicators of a programme's rate of success. A one-year period is an inadequate length of time for the accurate measurement of project impact. The influence of cooperative work upon a population having deep-seated and profound problems is more accurately measured over a several year period. The length of time needed to first resolve problems brought about by years of maladaptive behaviours and then time to work on personal and employment related issues.

In summation, over the one year in which the SAMSA Project was in full operation the goals of the project's sponsoring organisations to cause change in a difficult population was achieved and those who received services were, on the large part, extremely positive about their experiences with the project.

REFERENCES

1. Angelöw, B. (1991). Det goda förändringsarbetet (Positive Work Inovation). Lund, Sweden: Studentlitteratur.
2. Ajzen, I. & Fishbein, B. (1977). Attitude behavior relations: A theoretical analysis and review of empirical research. Psychological Bulletin, 84 (5), 888-918.
3. Ajzen, I. & Fishbein, B. (1980). Understanding Attitudes and Predicting Social Behavior. Englewood Cliffs, New Jersey, USA: Prentice Hall.
4. Gustavsen, B. (1990). Vägen till ett batter arbetsliv (The road to a better working life). Stockholm: Arbetslivscentrum.
5. Gustavsen, B. (1995). Utvecklingslinjer i arbetslivet och Arbetslivsfondens roll (Trends in working life and the role of the Working Life Fund). Stockholm: SNS
6. Menzies, I. E. P. (1970). The functioning of social systems as a defence against anxiety. London: The Tavistock Institute of Human Relations.

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SoftMatch: A Prototype System for Understanding User's Mental Model

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The concepts and overview of a tool called SoftMatch is being discussed. This tool is created towards the understanding of users mental model. A newly defined Hierarchical Task Analysis (HTA) charts are used to capture the requirements of a system. A Matching Schema, Goal, Operators, Methods and Selection Rules (GOMS) and Natural Language are elements of the systems to help users understand the requirements captured.

1. INTRODUCTION

SOFTMATCH is a tool which applies Hierarchical Task Analysis (HTA) charts, Goal Operators, Methods and Selection Rules (GOMS) and Natural Language to assist users and designers towards the understanding of users' mental model through what is called as "A Matching Schema".

The understanding of how a task is being performed by users is very important in designing a user interface system. Often a system is designed and users are forced to adapt to the system making it hard for users to use the system without going into proper expensive training. In building a computer interface, the designers need to know what, if any, pre-existing conceptions of a task the users of a system may have. If the designed interface functional layout does not meet the user's pre-existing conception then a user may perform poorly with the system. This result was found in an experiment done (Terwilliger and Polson, 1997) on individuals who are computer literate and some that are highly skilled with certain applications in manipulating an unfamiliar interface.

There are many ways of designing a system, which can be looked from the Human Computer Interaction (HCI), and Software Engineering (SE) field. In the HCI field, task analysis is incorporated in the system development life cycle of designing a system. It is a technique, which had been used as early as the 1950s. It had been used by industrial engineers in time and motion studies. There was the need for task analysis since then because of the development of an increasingly sophisticated system, which required human interaction (Day, M. C. and Boyce, S. J., 1993).

In the SE field, there exist a number of methods of designing a system; the Object Oriented Technique, the Jackson System Development (JSD), the Data Flow Diagram (DFD) and others. Software engineering methods had been known to be integrated with task analysis techniques to provide a more accurate method in developing a system. It was based on the realisation that user interface design methods in HCI did not focus on system development and it is also true that SE design methods do not focus on human factors in system development. Rather than creating a stand alone HCI method that takes into consideration system development, it is better to try to incorporate system development and HCI methods.

1.1. User-Centered design

In order to produce a system which meets users requirements, designers need to capture the requirements as accurate as possible. Often what the designers have in mind of the system do not match what the users really have in mind. There are problems in documenting tasks to be performed using system. Therefore there is a need for a system which will compare the designers and the users mental model or at least help users understand a system to be built or already built. A series of communication between the users and the designers are needed in order to achieve a usable system. We propose a technique of understanding users mental model using the concepts of the integration of Task Analysis (TA) and SE. The technique uses a modified HTA chart (Raja Jamilah and et. al, 1999) to capture the requirements of a system.

1.2. Task Analysis

Task Analysis (TA) is the study of what is required to be executed in terms of actions and/or cognitive process to achieve a system goal by an operator (or a team of operators) (Kirwan, Ainsworth, 1992). It is a critical process of examining the operator's resources, constraint and preferences, which will lead to the attainment of system's goal. HTA and GOMS are techniques in task analysis which are being used in different context. The former is in the charts and the latter looks more like a specification language.

Hierarchical Task Analysis (HTA) has the most general statement of the goal of a certain task at the top level. The goal can then be broken down into sub goals to occupy lower positions in the hierarchy. This involves the description of tasks, resources and products in the actual tasks. Plans are included in the HTA chart to define the way the tasks are executed. These plans are important to show the correct sequence in which the tasks are being executed. There are seven types of commonly used plans: fixed sequence, optional, wait for events, cycle, time sharing, discretionary and mixtures. However, in the context of SoftMatch, the newly defined HTA charts are used which uses symbols to identify the types of tasks are used.

GOMS however, is being used in a more specific context to represent procedural knowledge (how to do it). It can only be used to represent routine cognitive skills, which are developed after performing a problem solving activity routinely. In SoftMatch, however, GOMS are being used as a specification language which is directly translated from the HTA chart. It is being used to store the HTA charts in a specification typed language.

1.3 HTA charts in the Matching Schema and Natural Language

Using the newly defined HTA charts, a matching schema is created to understand users mental model. In the matching schema, the HTA charts done by the designers representing a system to be built or already being built are shown partially complete omitting the lowest level tasks. These tasks are listed in another section. The users will then be asked to match the listed lowest level tasks to the partially complete HTA charts. Users will then learned the usage of the system. Refer to Figure 1.

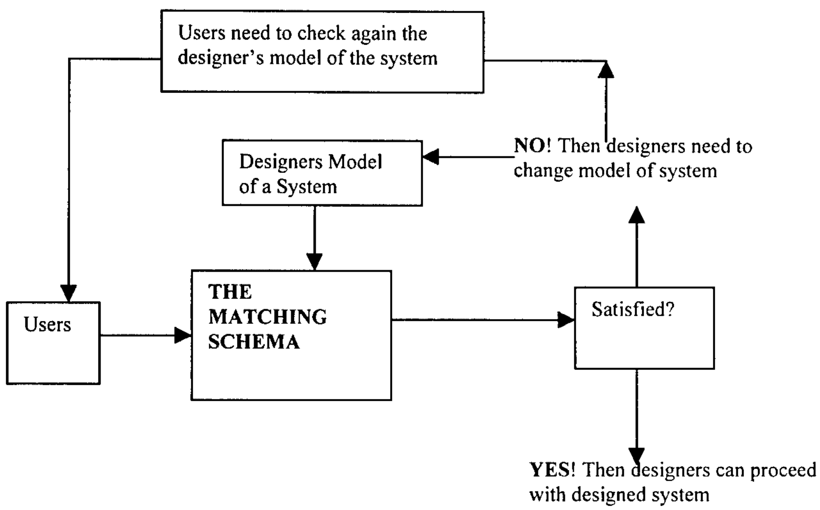

Figure 1. The Matching Schema towards Understanding the Users Mental Model.

If users found that the system represented in the HTA charts done by the designers are not meeting their requirement of a system to be built, then another series of discussion between users and designers can be conducted until they are satisfied.

2. AN OVERVIEW OF SOFTMATCH SYSTEM ARCHITECTURE

Figure 2 shows the SOFTMATCH system architecture. It consists of several integrated components:

1. *The Drawing Editor*, which consists of the Control Panel for drawing HTA charts, and the Drawing Canvas in which the HTA charts are drawn manipulated by using the Control Panel.
2. *The GOMS or the Natural Language Frame* to show the translated version of the HTA charts in GOMS or Natural Language.
3. ***SOFTMATCH Translator*** to translate HTA charts to CMN-GOMS notation, HTA charts to Natural Language, and GOMS to HTA charts.
4. ***The Matching Schema Frame*** to test the users understanding of a system model in the HTA chart form.
5. ***The Dialogue Panels*** for interaction with the users upon Opening and Closing files, Making Errors while using SOFTMATCH, and Needing Help while using the SOFTMATCH.
6. ***The Storing Units*** for storing data which consists of a temporary store, and a permanent store.

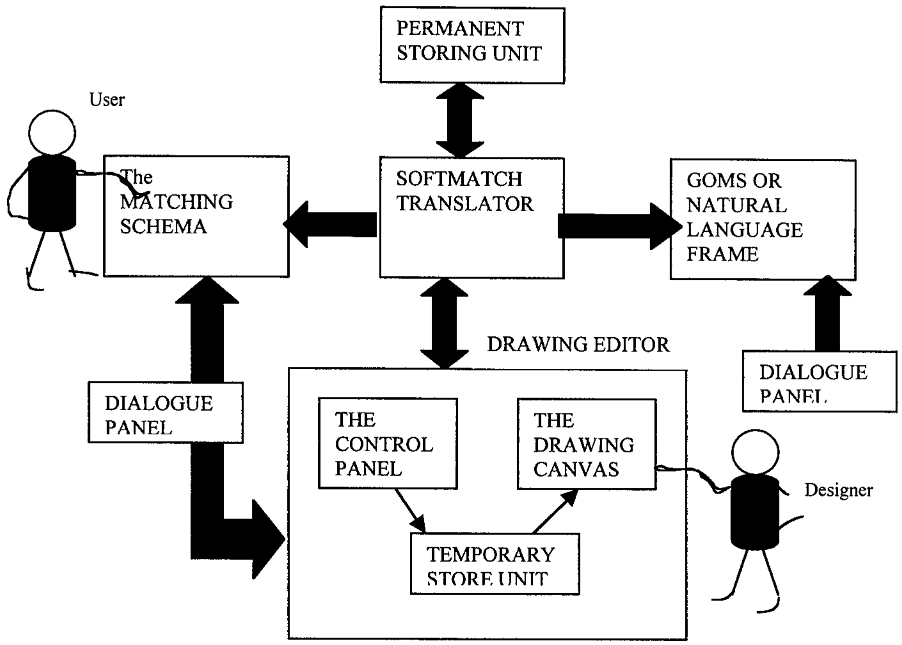

Figure 2. SOFTMATCH System Architecture

3. USER INTERFACE DESIGN

There is the usual dilemma of user interface designers to trade off limitations with all the good properties of an interface system – powerful functionality, simple and clear interface, consistency and many others. Although we try to produce a good user interface design, considering the constraints and limitations while the project is running, we focused more on the basic user interface which will be needed for the tool to run efficiently – the prototyped version. We try to make it simple and clear.

The SOFTMATCH user interface can be divided into the Control Frame (Figure 3), the Drawing Area for HTA Frame, the GOMS/Natural Language Frame, the Matching Schema Frame (Figure 4), and the Dialogue Frames.

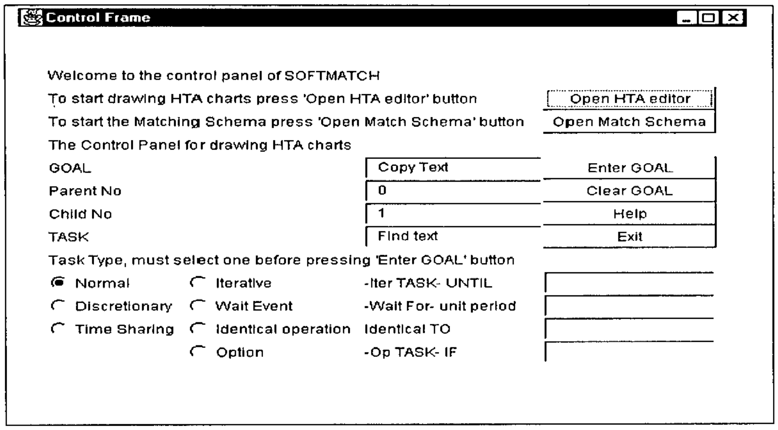

Figure 3 The Control Frame

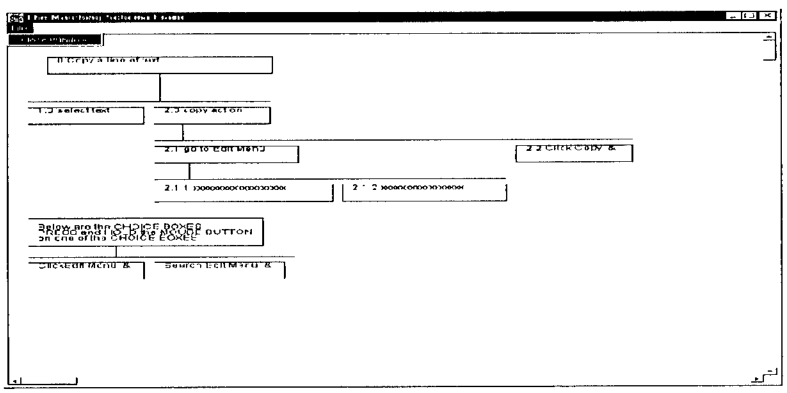

Figure 4 The Matching Schema Frame

4. IMPLICATIONS FOR DESIGN

There are many ways or methods to represent users' mental model; each method introduced is not perfect and has its own advantages and disadvantages. Task Analysis is said to be one of the most powerful methods used to capture the requirements of a system. Some argue that this claim is not entirely true. Instead, they argue that it is one method to capture the requirement of a system. Each method may be suitable for one or a few problems in the development of a system, not all. So it is up to the developers to choose. For this reason, it is good to have a whole variety of methods to cater for different situations and problems.

Our approach is to use the method defined in the HCI and SE fields. We analyzed the problems of the predefined HTA charts, GOMS and JSD methods to come up with a solution of representing users' mental model, which is another problem in HCI. A tool was needed for the solution of representing users' mental model. This is the purpose of the SoftMatch tool. The SoftMatch tool has its limitations which are mostly related to the situation when the chart gets too big. However, these limitations can be dealt with by setting the parameters in the program code to the length desired.

One of the ways of dealing with large and complex problems in designing a user interface is to decompose them into smaller manageable problems. Current research on the design of user interface discusses issues on decomposing the task objects and actions. These will then be matched with the interface objects and actions to produce a more usable system which will closely resembles the real world (Shneiderman B., 1998). SoftMatch as a tool supports this notion of design apart from having other objectives such as to eliminate the cumbersome process of drawing the HTA chart (Raja Jamilah and *et. al.*, 1999).

REFERENCES

1. Day, M. C. and Boyce, J. S. (1993). Human Factors in Human-Computer System Design. Advances in Computing, 36: 371-381
2. Hewett, T. T., Baecker, R., Card, S. and et. al. (1996). Curricula for Human-Computer Interaction (the web version) . http://www.acm.org/sigchi/cdg/.
3. Kirwan, B., Ainsworth, L.K.. A guide to Task Analysis. Taylor & Francis Ltd. (1992). pp. 1- 300.
4. Raja Jamilah R. Yusof, Kasirun Zarinah Mohd, Hashim Khairuddin (1999), A simpler approach to hierarchical task analysis, Proceedings of the IASTED international Conference (SEA '99).
5. Terwilliger, R. B. and Polson, P. G. (1997). Relationships Between Users' and Interfaces' Task Representations. CHI '97 Electronic Publications: Papers.
6. Shneiderman B., Designing the User Interface, USA, 1998.

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Design Concepts of Handy Ergonomic Checklists for Small Workplaces

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Design concepts of ergonomic checklists suited for improving small workplaces are discussed. Action-oriented checklists developed through inter-country networking for field workplace interventions were analyzed. These checklists were used for identifying and implementing simple improvements in small and medium-sized enterprises and in rural areas. Check items were presented in action forms showing simple improvements effective for improving both working conditions and productivity. Serial interventions using the checklists led to concrete improvements in different settings. We could confirm the usefulness of handy checklists listing low-cost improvements in multiple technical areas. As most small workplaces had numerous ergonomic problems, it was found essential to design each checklist so as to cover several technical areas including materials handling, workstations and teamwork environment. In designing a locally adjusted checklist, it was useful to select a few check items representing workload, tolerance and flexibility viewpoints for each of these areas. For a small workplace intervention, it is suggested to design a handy ergonomic checklist by listing 20-40 low-cost actions corresponding to the matrix concepts comprising technical areas and multiple remedial viewpoints. Such a checklist can best be utilized by organizing a checklist exercise followed by group discussion on checklist results and planning of new improvements.

1. INTRODUCTION

The effective use of action-oriented ergonomic checklists is spreading to various work improvement activities (Ahonen et al. 1989, Eastman Kodak 1983, Kogi 1995, Nag 1998). The application results of a checklist are known to depend not only on the ergonomic aspects covered but also on the overall design of the checklist used. Our recent experiences in applying ergonomic checklists to small workplaces demonstrate the importance of the action form of checklists combined with participatory steps (Kogi 1985, Rantanen et al. 1994, Phoon and Kogi 1997, Kogi 1998, Kawakami et al. 1999). The use of action checklists can lead to many improvements in different settings.

Design concepts of ergonomic checklists suited for improving small workplaces are discussed based on the experiences gained through our inter-country networking for field workplace interventions in several Asian countries. A variety of action checklists have been developed and used in small and medium-sized enterprises, small farm households and schools. These checklists usually cover multiple aspects of work space, operations, physical environment and teamwork situations. About 20-40 items corresponding to practical improvement actions are usually listed. The selection of check items is thus based on some common ideas. It is useful to examine the common features of these effective checklists including: (a) practical nature of check items; (b) multiple areas covered by an action checklist; and (c) ergonomic viewpoints suited for group work steps.

2. PRACTICAL NATURE OF CHECKLIST ITEMS

It is interesting that all the small workplace interventions by the participating groups of our networking used action checklists as a major intervention tool. These interventions included:

(a) participatory interventions for better safety and health in small and medium-sized enterprises in Japan, Thailand and Vietnam;

(b) action training by Work Improvement in Small Enterprises (WISE) projects in the Philippines, Thailand and some other countries; and

(c) training workshops for managers, workers and farmers including the Participation-Oriented Safety Improvement by Trade-union Initiative (POSITIVE) programmes in Pakistan and several other countries, Work Improvement in Neighbourhood Development (WIND) workshops in Vietnam, and those for die-casting and other industries in Japan.

Action checklists have been useful throughout these interventions. These action checklists are found to be more useful than analysis checklists, particularly in small workplaces (Thurman et al. 1988, Kogi 1995, Kawakami et al. 1999). Table 1 gives the practical nature of action checklists as compared with traditional analysis checklists.

Table 1 Comparison of analysis and action checklists.

	(a) Analysis checklist	(b) Action checklist
Purpose	- Evaluating work systems	- Finding practical improvements
Check items	- Components of a work system	- Remedial actions to be taken
Outcome	- Whether criteria are met	- Whether actions are applicable
Emphasis	- Profiling work systems	- Proposing simple solutions

As the table shows, action checklists are more advantageous in identifying actions adjusted to local conditions. While the users of analysis checklists are asked to see, for example, whether 'switches are adequately grouped' or 'lighting intensity is appropriate', the action checklist users are asked whether they propose an action to 'place frequently used switches within easy reach' or 're-position lights to get more light'. In the case of analysis checklists, the judgment about a check item requires detailed knowledge of corresponding criteria. The check procedures tend to become complicated. On the other hand, in the case of action checklists, the users are to respond whether they propose the listed action from practical points of view.

Our experiences show that attention to simple solutions can lead to many proposals that can improve both working conditions and productivity. For example, better materials handling can be proposed by means of using mobile racks and carts that can lead to quicker transport and better product quality. Improved work height can facilitate safer, smooth production. The usefulness of focusing on simple solutions is shown by the results of WISE courses that a few or more improvements can be achieved per enterprise during a short course period of 1-2 weeks. Most these improvements have had positive impacts on both working conditions and productivity in small enterprises (Kogi 1995, 1998).

The low cost of these simple improvements is also advantageous in promoting immediate workplace changes (Kogi et al. 1988, Noro and Imada 1991, Kogi 1998). Learning from locally achieved improvements ensures this.

3. MULTIPLE AREAS FOR AN ACTION CHECKLIST

In small enterprises, there are usually multiple ergonomic problems. In most cases, the checklist users may not necessarily know all these problems. Therefore, it is essential to cover multiple technical areas where small enterprises have problems in common. Thus, the IEA/ILO Ergonomic Checkpoints (ILO 1996) cover a broad range of technical areas. In applying these checkpoints to small workplaces, it is appropriate to select common types of such simple improvements since only about 20-40 items can be listed in a checklist.

The commonly selected technical areas are shown in Table 2. These areas are more or less common for the ILO checklist for the WISE approach (Thurman et al. 1988), the POSITIVE checklist (Kogi and Kawakami 1999), WIND checkpoints for farmers (Khai et al. 1996) and action checklists recently developed for small enterprises in the die-casting industry cooperatives in Japan. The technical areas covered by these checklists are notably similar.

Table 2 Technical areas covered and the number of items in each area in two ILO checklists.

(a) WISE checklist	(b) POSITIVE checklist	(c) WIND checklist	(d) Die-casting Industry checklist
46 times	54 times	32 times	43 items
Materials storage and handling (5) Workstation design(7) Machine safety (5) Control of hazardous agents (6) Lighting (6) Welfare facilities (5) Premises (heat, noise, Passages, wiring)(7) Work organization (5)	Materials storage And handling (8) Machine safety (6) Workstations (8) Physical environment (16) Welfare facilities (8) Environmental protection (4) Implementation of improvement (4)	Food and hygiene (5) Drinking water and Sanitation (4) Housing conditions (3) Child care (3) Family budget and Community Cooperation (4) Storage and handling of materials (4) Machine safety (2) Control of hazardous agents (3) Welfare facilities (4)	Premises/ layout (6) Machine safety (6) Hazardous agents (5) Materials handling(5) Physical environment (5) Workstations (5) Refreshing facilities (6) Work organization (5)

These checkpoints can be summarized into the four categories: (a) materials handling, (b) workstations, (c) safety and physical environment, and (d) organization of work and life. By knowing these categories, we can select several check items from each category in designing a locally adjusted checklist. There are many low-cost improvements applicable in various small workplaces in each of these categories as given in Table 3.

For example, improved materials handling can be attained in many small workplaces by simply marking transport routes, using carts or providing lifting devices. Workstation arrangements can be effectively improved by adjusting work height at elbow level, using fixtures to hold work items or making controls and displays easy to distinguish from each other. Similarly, safety and amenity in physical environment can be improved by screening hazard sources, repositioning lights or providing refreshing corners. Finally, teamwork organization is made more flexible by combining tasks, setting up buffer, using communication aids or inserting short breaks. An important aspect of these improvements is that multiple improvements can be planned and implemented in each small workplace.

Table 3 Typical low-cost ergonomic ideas for small workplaces in four main categories.

Main categories	Low-cost ideas
Materials handling	- Clear and mark transport routes.
	- Use carts, hand-trucks or rollers.
	- Use mechanical lifting devices.
	- Provide a "home" for each tool.
Workstations	- Adjust work height at elbow level.
	- Alternate standing and sitting at work.
	- Use fixtures to hold work items.
	- Make controls/displays easy to distinguish.
Physical environment	- Isolate or screen hazard sources.
	- Use interlocking safety devices.
	- Reposition lights or use local lights.
	- Provide comfortable refreshing corners.
Teamwork organization	- Combine tasks to make work interesting.
	- Set up buffer stocks between workstations.
	- Use communication aids.
	- Insert short breaks.

The merits of selecting simple actions are obvious as they meet the needs of small enterprises that operate with a variety of constraints. Especially important constraints are financial difficulties, lack of awareness and insufficient technical expertise. Low-cost ergonomic solutions have obvious advantages in addressing these constraints. By listing low-cost actions, we can motivate managers and workers to make voluntary improvements, help them implement improvements and indicate the ways to use local skills and materials.

The merit of listing low-cost solutions can be further confirmed by the high rates of implementation among improvements proposed. The results of WISE courses demonstrate that the percentage of implemented improvements among proposed ones has been as high as 80 percent or more in different technical areas (Batino 1997, Kogi 1995). This is true also for other training workshops for small enterprises (Kogi 1998, Kawakami et al. 1999).

4. ERGONOMIC RULES SUITED FOR GROUP WORK STEPS

The best way to use ergonomics checklists is to use them in group work. Participatory steps consisting of serial group work activities are especially suitable. Our experiences show the need to support group work by providing handy checklists. The easy-to-apply nature of such checklists is important as it can help the users identify practicable improvements on the basis of checklist results. Training for this purpose should organize checklist exercises so that the users can learn how to use the checklist. Then support must be provided to the participants by means of local good examples and guidance manuals on low-cost solutions. Typical group work steps combined with the use of support tools are similar in participatory programmes organized within our networking in Asian countries.

The relation between these steps for many participatory steps and the commonly used support tools is shown in Table 4. Usually, the group work steps included (a) a checklist exercise, (b) workshops to discuss locally practicable low-cost improvements, (c) small group work for selecting priorities, and (d) immediate implementation done jointly by managers and workers.

Table 4 The relation between group work steps and support tools in participatory programmes in some Asian countries.

Steps	Group activity	Support tools
(a) Checklist exercise	Walk-through/ discussion	Action checklists
(b) Low-cost improvement workshops	Learning low-cost ergonomic ideas	Local good examples
(c) Small group work	Agreeing on priorities	How-to manuals
(d)Implementation	Joint implementation	

There are basic ergonomic rules that are particularly suited for finding locally applicable improvements in small workplaces. For example, the ergonomic rules about organized storage and use of wheels can often be presented by check items such as use of mobile racks and push-carts. Obviously, these rules are useful as they take into account the action-oriented nature of low-cost ergonomic principles. Typical such rules are listed in Table 5.

Table 5 Basic ergonomic rules suited for group work steps in small workplaces.

a. Materials handling	c. Physical environment
- Organized storage	- Isolating hazards
- Use of wheels	- Safe feeding
- Use of lifters	- Re-locating layout
b. Workstations	**d. Work organization**
- Easy reach	- Varied tasks
- Elbow height	- Buffer stocks
- Use of fixtures	- Short breaks
- Easy-to-distinguish	- Well-informed work

These check items in each category represent the basic viewpoints of (a) reducing workload, (b) facilitating tolerance to work, and (c) promoting flexible adjustment. Reducing workload may be typically indicated by the use of carts and lifters, elbow height work, safe feeding or welfare facilities. Facilitating tolerance to work is exemplified by organized storage, easy reach, amenity at work or short breaks. Further, flexibility at work is promoted by autonomous arrangements of materials storage and handling, alternating work postures, re-locating layout or informed teamwork.

In designing an action checklist for small workplaces, it is suggested to include in the checklist at least one or more check items from each of these basic rules. For example, an action checklist for a small garment factory may include one or more items for each of the 14 ergonomic rules listed in Table 5, as all the rules are relevant to a garment factory. For organized storage, for example, we may include a few items such as the provision of multiple shelves, the use of pallets and containers and the provision of homes for different tools. In this way, an action checklist comprising about 20-40 low-cost actions can be developed. Such a checklist will help the users pay attention to the most common ergonomic aspects.

5. CONCLUSIONS

Action checklists can be used as a major tool in improving ergonomic conditions in small workplaces. The listing of simple low-cost actions can greatly facilitate the improvements adapted to each local situation. Group work steps with the support of local good examples and how-to-manuals are essential for effectively using such a checklist.

The design of action checklists for small workplaces should take into account low-cost ideas reflecting basic ergonomic rules in multiple areas. These rules presented in an action form can motivate people to look for locally adapted solutions. It is suggested to design a handy ergonomic checklist by listing 20-40 low-cost actions corresponding to the matrix composed by technical areas and multiple remedial viewpoints. We need to encourage the exchange of positive experiences in applying this kind of action checklists in different settings.

REFERENCES

1. M. Ahonen, M. Launis, and T. Kuorinka, Ergonomic Workplace Analysis, Finnish Institute of Occupational Health, Helsinki, 1989.
2. J.M. Batino, Work improvement in small enterprises (WISE) project in the Philippines, Proceedings of the Fifth Southeast Asian Ergonomics Society Conference on Human Factors (1997), 536-541.
3. Eastman Kodak Co., Ergonomic Design for People at Work: Volume 1, Eastman Kodak Co., Rochester, 1983.
4. International Labour Organization, Ergonomic Checkpoints: Practical and Easy-to implement Solutions for Improving Safety, Health and Working Conditions, International Labour Office, Geneva, 1996.
5. T. Kawakami, J.M. Batino, T.T. Khai, Ergonomic strategies for improving working conditions in some developing countries in Asia, Industrial Health, 37(1999) 187-198.
6. T.T. Khai, T. Kawakami, K. Kogi, N.T. Son, Ergonomic Checkpoints for Agricultural Working and Living Conditions, Cantho Department of Health, Cantho, 1996.
7. K. Kogi, Participatory ergonomics that builds on local solutions, Journal of Human Ergology, 24(1995) 37-45.
8. K. Kogi, Collaborative field research and training in occupational health and ergonomics, International Journal of Occupational and Environmental Health, 4(1998), 189-195.
9. K. Kogi, T. Kawakami, JILAF POSITIVE Program: Training Manual for Occupational Safety and Health, Japan International Labour Foundation, Tokyo, 1999.
10. K. Kogi, W.O. Phoon, and J.E. Thurman, Low-cost Ways of Improving Working Conditions: 100 Examples from Asia, International Labour Office, Geneva , 1988.
11. P.K. Nag, Checklists, Encyclopaedia of Occupational Health and Safety, International Labour Office, Geneva, 29.14-29.24, 1998.
12. K. Noro, and A. Imada (eds.), Participatory Ergonomics, Taylor and Francis, London, 1991.
13. W.O. Phoon. K. Kogi, Occupational and environmental health in the Asia-Pacific region, Environmental Management and Health, 8(1997) 149-209.
14. J. Rantanen, S. Lehtinen, M. Mikheev, Health Protection and Health Promotion in Small-scale Enterprises: Proceedings of the Joint WHO/ILO Task Group, 1-3 November 1993, WHO, Geneva; Finnish Institute of Occupational Health, Helsinki, 1994.
15. J.E. Thurman, A.E. Louzine, K. Kogi, Higher Productivity and a Better Place to Work - Practical Ideas for Owners and Managers of Small and Medium-sized Industrial Enterprises: Action Manual, International Labour Office, Geneva, 1988.

PART EIGHT

Human Factors of Product Design

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Supporting Collaborative Design by a Concurrent Engineering Team through a Virtual Environment

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This paper reports an on-going study on the use of virtual environment (VE) in collaborative evaluation of architectural design. The study compared the utility of virtual environment over 2D plan and 3D view of the interior design of a university building. The aim was to examine how a concurrent engineering team communicates and decides on design solutions with the support of these decision aids. The collaborative tasks involved evaluating specific features of the interior design which entailed inquiry, explanation, confirmation, negotiation, and discussion. The team's collaborative behaviour was recorded on video. The findings revealed the utility of VE over the other decision aids. Subjects could visualise better in VE than from 2D plan or 3D view alone. This was due to the availability of perceptual cues which enabled relative discrimination of design solutions.

1. INTRODUCTION

Design is a social process (Bucciarelli 1994), and a complex process that requires a variety of analytical approaches in order to be understood fully. Because of the role of human behaviour in the design process, it is necessary to rely on observations of humans in order to fully understand the design process. There have been some experimental studies of group processes in design (e.g. Tang and Leifer 1990, Cross and Cross 1995, Smith and Tjandra 1998). These experiments have shown that video-based observational techniques can provide a useful and rich record of the design process, which can then be analysed in a variety of ways.

Collaborative design involving a concurrent engineering team is an emerging field of study (e.g. Maxfield, Fernando and Dew 1998). Concurrent engineering is defined as a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developer to consider all elements of the product life cycle including quality, cost and user requirements (Stahl and Luczak 2000). A successful CE process requires, during the initial design stages of a project, the elimination of organizational barriers among groups and the involvement of individuals from all areas of the product development process. Crabtree et al. (1997) found that activities which involve coordination occupy 69% of an engineer's time in collaborative design, and include all but problem solving and thinking. Engineering designers have difficulties in communicating with their partners rather than with technical issues (Frankenberger and Auer 1997).

The design of a university campus is a collaborative activity, involving a team of individuals working concurrently on a design problem. In this study a virtual environment system was developed to support decision making in the evaluation of design solutions of a new building on a university campus. Virtual environments (VEs) have been used to support various perceptual tasks, such as assembly, learning, architectural evaluation and mission flights. However, VEs have hardly been used to aid decision making (Khalid and Helander 2000). Collaborative VEs such as DIVE, MASSIVE, GDSS have been used to support tasks involving negotiation (e.g. Kersten and Noronha 1999). Another trend is the popular use of the Internet for virtual collaboration in product development (e.g. Kao and Lin 1996). With efficient VRML browsers becoming available, a Web-based VE would be the future application in virtual collaboration.

Members of a CE team collaborate to make plans for the future (e.g. design the Unimas campus) using decision support aids (e.g. VE system). This may happen in the same time and physical space, or in 'virtual' time and place. For a CE team to collaborate effectively, we need to understand: How do individuals in a group make decision, how they communicate and collaborate, and how do they handle trade-offs in decisions? Therefore, there is a need to explore the effectiveness of decision making as a function of different decision support aids (e.g. 2D plan, 3D view, VE), and decision protocols (e.g. free-for-all, directed, team-based).

1.1. Research aims and hypotheses

This study investigated a CE team collaborating in the design planning of the Centre for Academic Information Services (CAIS) building. The CAIS building is part of the overall UniCaVE (**Uni**mas **Ca**mpus in **V**irtual **E**nvironment) environment. The aim was to determine the effectiveness of VE relative to 2D and 3D views. It was hypothesised that VE enables better decision making than 2D plan, with greater team participation than 2D plan or 3D. Decision making was based on the nature of communication (e.g. explanation, confirmation, etc), while team participation was gauged from the frequency of subject interaction in the design process (number of verbalisations per subject).

2. METHOD

2.1. Study and task environment

In this study, each participant was given the same task. The group design task involved evaluating CAIS interior design which entailed various communication protocols: inquiry, explanation, confirmation, negotiation, and discussion. There were three conditions: 2D plan, 3D view and VE.

2.2. Concurrent engineering team

The CE team comprised 5 Universiti Malaysia Sarawak (Unimas) personnel: a client, an architect, a civil engineer, a project manager, an end user, and an ergonomist who also played the role as project moderator. The moderator was the only non-Unimas person. The team discussed the design as part of a routine project meeting, together with a member of the research team, in order to enhance the ecological validity of the study. As such, subjects (with the exception of the project moderator) were not aware that they were involved in a research, despite they knew that they were videotaped.

2.3. Equipment

The VE system comprised a desktop personal computer with 3D model of CAIS in static graphics and Web-based VRML environment. The remaining equipment includes 3 video cameras, projection screen, data projector, and 2D floor plans of CAIS.

2.4. Procedure

Each condition was recorded on video. Three cameras were used to record the collaborative behaviour and communication patterns of the team. Each condition required 30 minutes to complete, with a brief pause between conditions. At the end of the session, subjects completed a questionnaire to obtain subjective information about their experience.

2.5. Data analysis

The videotape record for each condition was reviewed and analysed manually. The verbal and behaviour protocols of each of the participant were transcribed and classified into one of the categories listed in Table 1.

3. GENERAL FINDINGS

3.1. Analysis of verbal and behaviour protocols

Table 1 shows the frequency of interaction of CE team members in the 2D plan and VE conditions only. Clearly, the architect was more active in VE compared to 2D, while the client was more active in 2D than other conditions. In terms of communication content, the client made more explanation (e.g. the function of the sunken reading area, etc) in 2D condition, while the architect explained the design errors in VE. The engineer raised the accuracy of dimensions in the interior design on 2D and VE. Table 2 provides examples of verbal protocols in VE.

Table 1. Frequency of interaction and content type for 2D plan and VE conditions

Subject	2D Plan (35 mins)		VE (35 mins)	
	Frequency	*Content*	*Frequency*	*Content*
Client (C)	33	explanation, inquiry	25	negotiation, explanation
Civil Eng. (CE)	10	inquiry	17	inquiry
Architect (AR)	7	explanation	36	confirmation, explanation
Project Mgr (P)	1	inquiry	0	-
End User (EU)	0	-	8	inquiry
Moderator (M)	19	task direction, inquiry	20	inquiry, task direction

3.2. Analysis of subjective assessments

The contents of the questionnaire supported the verbal protocol analysis.

Comparisons between the 2D floor plan, 3D view and VE on the interior look of CAIS. About 82% of the subjects preferred the VE as a planning tool in architectural design at the conceptual stage. However 2/3 of the subjects agreed that they could visualise easily the interior look of CAIS around the void area using the 2D plan, while half of the subjects agreed that 3D view is useful to perform the same task.

Table 2. Examples of verbal protocols in virtual environment

Elapsed time			*Subject*	*Verbal Statements*	*Type of Content*
08	21	08	M	"Alright....here is the entrance"	Confirmation
08	25	22	AR	" We are looking at the void"	Explanation
08	33	17	M	"Are there blue sky on top of the roof?"	Inquiry
08	39	19	AR	"Yes there is a roof....with skylight."	Confirmation
08	40	10	C	" The roof there in the middle... skylight ... this is right."	Confirmation
08	54	02	C	"....Something like that, on the top floor they propose that they wanted to (make) something like a garden, the void area on the top floor....they haven't done."	Negotiation, Discussion
09	25	00	M	"You can walk up the stairs?"	Inquiry
09	52	24	AR	"I can see the void."	Confirmation
10	04	00	AR	"They have a bridge between the void."	Explanation
10	16	12	CE	"What is the width of the staircase?"	Inquiry
10	23	05	AR	"I think should be about two meters."	Negotiation
10	26	10	CE	"Two meters...so can you imagine how many students can go up the stairs during one time..."	Discussion
10	34	06	EU	"...it will collapse.."	Discussion
10	37	21	AR	"No...not this stairs..."	Confirmation
10	38	15	C	"No, we have a side stairs and the lift..."	Confirmation

Design decisions. All subjects thought that they could make better design decisions by using all three formats together - 2D plan, 3D view and VE. About 40% of the subjects had difficulty in making decisions from the 2D floor plan alone. However, the engineers and architect could read the 2D plan easily, and found the VE sufficient to support them in making some design decisions.

Comparisons between 3D view and VE in specific tasks. There was no differences between these formats in deciding the appropriate location of study area.

Overall appearances of the virtual environment. Most of the subjects accepted the resolution, colour and lighting used in the virtual environment. Four of the six subjects thought they could perform the navigation task in the VE, while five of the six agreed that the virtual objects created in the VE were appropriate.

Guidance needs. One of the subjects was not able to visualise the virtual view of CAIS on their own. However, 2 of the subjects felt they could perform the task better through collaboration with team members. Four of the subjects agreed that the project moderator is useful to provide guidance on the visualisation task. This showed that in a collaborative task with many members and different levels of expertise, a moderator is helpful to control and guide discussion to achieve the task goals.

Mixed expertise in decision making. All subjects agreed on the usefulness of collaborating in group face-to-face within a mixed group of relevant expertise in evaluating the virtual view.

Five of the subjects believed they would benefit in such concurrent collaboration. The remaining subjects felt 'helpless' if she/he tried to explore the virtual environments on their own.

3.3. Comments on the virtual environment

Subjects indicated that the VE should be improved as follows:

- Use a faster computer to generate the 3D model of VE
- Correct the viewpoint to coincide with the user's eye view
- Provide training on the navigation task
- Incorporate virtual objects (landmarks) in VE to help comparative evaluations
- Provide cross sections of the virtual models as in the architectural plan

4. DISCUSSION

In general the analysis of verbal protocols, in particular for VE, demonstrated an intense participation and communication between individuals of varied expertise. Several architectural design errors in the 2D plan were readily identified in VE. This was discovered by the civil engineer through his inquiry to the client, and the discussions between the architect, client and moderator. In other words, the VE was effective as a decision support aid for a CE team. The VE was also found to be useful as a visualisation tool in making complex design decisions. This was particularly well demonstrated in the analysis of a void area in the CAIS building. An "empty" area may be more difficult to evaluate than a "full" area, where there are many landmarks for comparison.

Subjects found it difficult to correctly estimate physical dimensions in VE (e.g. size of staircase, size of void area, etc.). The problem is more acute when making estimates of book shelf height and the number of study tables and chairs that can be arranged in a specific space. VEs should include reference objects, for example, a man model standing by the side of the shelf or sitting on a chair. Using the virtual man as reference point, judgments on height and width can be made more easily.

The suggestion to combine 2D view with VE to support collaborative decision making is important as users have a tendency to be lost in navigation in VE. This is because they have difficulty in knowing their current location while navigating, due to the narrow field of view in VE.

The modelled VE was found to be appropriate and provided realism to the CAIS plan. Subjects had no specific comments on the colour and resolution of the modelled VE. This is because the VE could convey adequate information, despite the less-realistic colour, to support them in making judgment about the actual design of CAIS. However, the VE can be improved by using more realistic textural effects (e.g. flooring, shelving, etc). Also, the rate of display conversion need to be enhanced by using a high-end and faster computer. In addition, reducing the number of polygons in the modelled VE will enable efficient navigation, although the quality of the VE may be slightly reduced.

The findings also showed that affirmative decisions (e.g. confirmation) can be achieved more easily if the task was performed collaboratively in real time. Members of a CE team can interact using the visualised models to arrive at appropriate decisions in good time.

However, in the real world, it is difficult to assemble the team in one place for face-to-face meeting. Therefore, the next study attempts to explore the use of VE in a synchronous setting – that is, 'face-to-face' conferencing via remote computers.

5. FURTHER STUDY

A follow-up study will examine the effects of decision strategy (free-for-all vs. turn taking), and navigation capability as a function of task complexity (simple vs. complex navigation) on collaborative decision making. It is anticipated that decision making in VE is better achieved via turn taking than free-for-all, and through simple tasks than require limited skills and easy navigation in a complex VE. Design principles from both studies will be used to specify a collaborative VE system for UniCaVE.

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REFERENCES

1. L.L. Buciarrelli, Designing Engineers, MIT Press, Cambridge, MA, 1994.
2. J.C. Tang and L.J. Leifer, An Observational Methodology for Studying Group Design Activity, Research in Engineering Design, 2 (1991) 209-219.
3. N. Cross and C. Cross, Observations of Teamwork and Social Processes in Design, Design Studies, 16 (1995) 143-170.
4. R.P. Smith and P. Tjandra, 1998, Experimental Observation of Iteration in Engineering Design, Research in Engineering Design, 10 (1998) 107-117.
5. J. Maxfield, T. Fernando and P. Dew, A Distributed Virtual Environment for Collaborative Engineering, Presence, 7, 3 (1998) 241-261.
6. J. Stahl and H. Luczak, Personnel Planning in Concurrent Engineering: A Case Study, Human Factors and Ergonomics in Manufacturing, 10, 1 (2000) 23-44.
7. R.A. Crabtree, M.S. Fox and N.K. Baid, Case Studies of Coordination Activities and Problems in Collaborative Design, Research in Engineering Design, 9 (1997) 70-84.
8. E. Frankenberger and P. Auer, P., Standardized Observation of Team-work in Design, Research in Engineering Design, 9 (1997) 1-9.
9. H.M. Khalid and M.G. Helander, Design Issues in Virtual Environments. In H.M. Khalid (ed.), Virtual Reality: Select Issues and Applications, ASEAN Academic Press, Subang Jaya, 2000 (in press).
10. G. Kersten and S. Noronha , Negotiation via the World Wide Web: A Cross-Cultural Study of Decision Making, Group Decision and Negotiation, 8 (1999) 251-279.
11. Y.C. Kao and G.C.I. Lin, CAD/CAM Collaboration and Remote Machining, Computer Integrated Manufacturing Systems, 9, 3 (1996) 149-160.

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Comparing Manual Task Performance Among Corresponding "Real", "Tele-Matic" and "Virtual" Environments Showing the Same Content

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This paper reports the effects of four experimental environments on the performance of manual manipulation tasks. The four environments were (i) Real Environment (RE), (ii) Restricted-view Real Environment (RRE), (iii) Tele-matic Environment (TE), and (iv) Virtual Environment. All four environments presented the view and sound of the same room, apparatus, and tasks to the participants. While the essential contents of the environments were the same, the presentation ranged from a computer-generated visual environment (i.e., the VE) to a physical environment (i.e. the RE). In between the two extremes, there was the TE – a visual environment made up of camera-captured scene. The task completion time, head and hand displacements were measured and 48 participants took part in the study. Initial results showed that RE had the best performance followed by RRE, TE and VE. Further analyses indicated that the degraded performance was mainly due to the lack of tactile sensitivity and the presence of image lag. Without the tactile sensitivity, the task completion time was longer ($p<0.01$) and with longer image lag (130 ms), the task completion time was also significantly longer ($p<0.05$).

1. INTRODUCTION

Studies have shown that human will have degraded performance in a virtual environment (VE) if the sensory interfaces in the VE are poor (e.g. visual lag: So and Griffin, 1995; System Responsiveness: Kenyon and Afenya, 1995 and Watson *et al.*, 1998; Stereoscopic/Monoscopic: Greon, 1998; Field-of-View: Barfield *et al.*, 1995). However, most of the studies only conduct the experiments in a VE (e.g., So and Griffin, 1995) or in both a VE and RE (e.g., Kenyon and Afenya, 1995; Barfield *et al.*, 1995). Therefore in this experiment we would investigate the effects of the experimental environments on Discrete Manual Manipulation Task from a completely computer-generated environment (i.e. Virtual Environment, VE), to a completely physical and natural environment (i.e. Real Environment, RE). Between the VE and RE, we would introduce two intermediate environments which were the Restricted-view Real Environment (RRE) and Tele-matic Environment (TE). The aim was to systematically degrade the sensory environments from RE to RRE to TE to VE, and measure the performance of discrete manual manipulation task along the way. Discrete manual tasks were chose because they were commonly found in VR simulation.

2. METHOD

2.1. Experimental Design and Approach

For this preliminary experiment, it was a full factorial design with 12 replications. The independent variable was the Experimental Environment with 4 levels: RE, RRE, TE and VE. Each experimental environment had 12 participants. They were randomly assigned to the experimental environment.

2.2. Participants and Apparatus

All the participants were Chinese university male students without color blindness, were right-handed and with normal or corrected eyesight. For each experimental environment, a Polhemus 3SPACE® tracker system was used to track the position of the head and hand movements. A SGI Onyxll workstation was used to generate the graphics for the VE condition and a CyberGlove™ was used in the VE to measure the right hand gesture. In both the VE and TE environments, participants viewed the environment via the VR4 head-mounted display (HMD). In the VE, scene presented on the HMD was generated by the Onyxll workstation. In the TE, scene was video of the RE captured by a camera. A special headset of the same weight as the VR4 HMD was used in both RE and RRE. The participants in the RE, RRE and TE wore a softball glove with a tracker located on the wrist so as to simulate the wearing of the CyberGlove™ in VE. Figure 1 illustrates the participants of the four experimental environments.

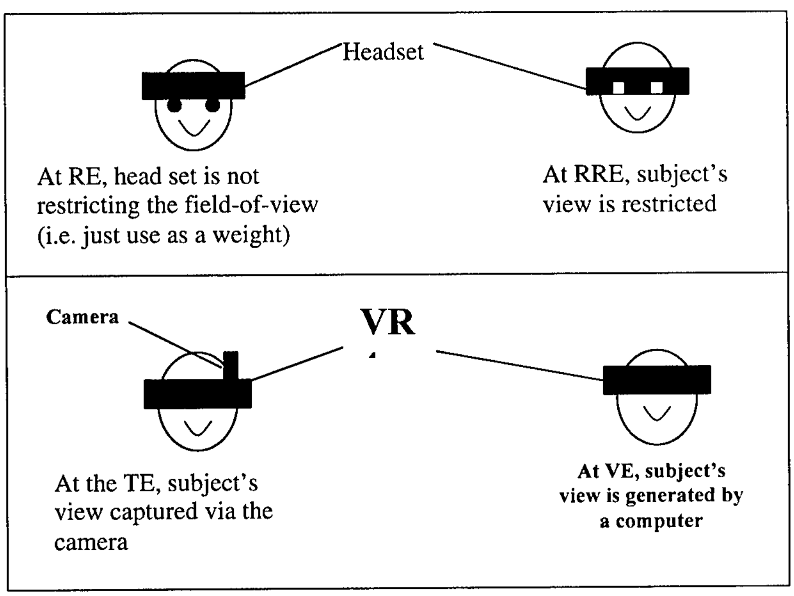

Figure 1. Illustrations of the front view of a participant with head-mounted display (HMD) or headset in the four experimental environments: Real Environment (RE), Restricted-view Real Environment (RRE), Tele-matic Environment (TE) and Virtual Environment (VE).

2.3. Independent variables

As mentioned before that the experimental environment was the independent variable. It has 4 levels: RE, RRE, TE and VE. The differences among the 4 experimental environments were classified using the sensory variables (see Table 1).

Table 1
The sensory variables for each experimental environment

Variables	Experimental Environments			
	RE	RRE	TE	VE
Field of View	Not Restricted	48x36	45x34	48x36
stereo/mono view	Stero	Stero	Mono	Mono
Image Lag	Without	Without	approx 130ms	approx 60 ms
Image Quality	Real	Real	Digital: camera	Digital: computer
Display's Resolution	High	High	Low	Low
Auditory	Spatial	Spatial	Spatial	Spatial
Tactile	With	With	With	Without

2.4. Task and Dependent Variables

The discrete manual manipulation task required the participants to grasp and pick up a cylinder and moved it from point A to point B and back. For one trial, participants were required to repeat this 5 times. In this task, participants were required to complete 5 trials which meant the participant needed to move the cylinder to and fro 25 times. The horizontal distance between points A and B was 72 cm. The time of completion of each trial (trial time), the hand and head movements were measured.

2.5. Hypotheses

The trial completion times for RE and RRE will be similar and comparatively less than the other two experimental environments. The reason for this hypothesis is that both TE and VE had longer time lags than RE and RRE. According to the research done by Watson *et al.* (1998), the time for grasping and placing the object increased as the frame rate and the system response time increased. In addition, in VE, there is no sense of touch, therefore, it was also hypothesized that VE will give the longest trial times. Kenyon and Afenya (1995) compared the performance of a " pick -and- place" task in a VE and a RE, the result showed that the task completion time in their VE were twice as those in their RE. Their VE did not provide tactile sensation.

3. RESULTS

Median trial time data as function of trials and experimental environments are shown in Figure 2. Inspection of Figure 2 shows no observable learning effects occurs in trials. However experimental environments seem to have observable influences on trial time.

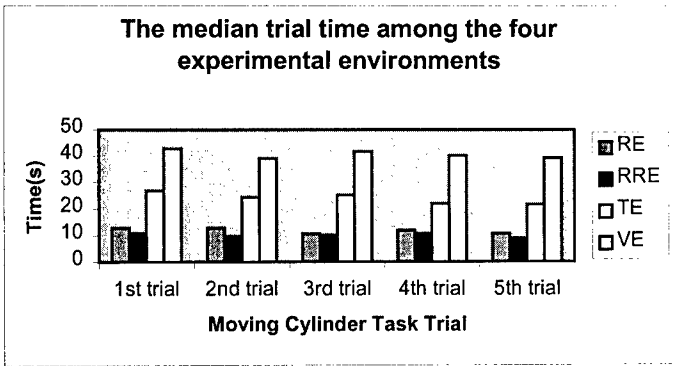

Figure 2. The median trial time among the four experimental environments (data of the first 24 subjects)

As the trial time data did not follow the normal distribution, a log transformation was applied so that ANOVA analysis could be conducted (Table 2).

Table 2
ANOVA Table of the trial time data (data from the first 24 participants)

Source	DF	Sum of Squares	Mean Square	F value	Pr>F
Experimental Environment (EE)	3	7.19	2.40	120	0.001
No. of Trial	4	0.07	0.02	1	0.25
EE x Trial	12	0.08	0.01	0.5	0.25
Error	100	2.34	0.02		
Corrected Total	119	9.69			

Table 3
Grouping of the trial time according to the experimental environment by the SNK method (in ascending order of trial time)

Experimental Environment	*Groups*		
RRE	A		
RE	A		
TE		B	
VE			C

Subset for alpha = 0.05

Table 2. Shows that Experimental Environment had significant effect on the trial time. However, the number of trial had no significant effect on the trial time. The Experimental Environment and the number of trial did not have a significant interaction either.

In order to investigate the effect of the experimental environment further, Student-Newman-Keuls (SNK) grouping analyses were performed and the ranking and grouping of the trial time according to the experimental environment are as shown in Table 3.

4. DISCUSSIONS

4.1. Effects of the Experimental Environment on the task trial time

Table 2 shows that Experimental Environment had significant effect on the trial times ($p<0.01$). SNK results (Table 3) indicates that RE and RRE are in the same group with the shortest time and followed by TE and VE. Inspections of Figure 2 and Table 3 show that trial times in TE were significantly longer than those in RE and RRE ($p<0.05$). Participants at VE spent the longest time to finish the work ($p<0.05$). It suggests that the poorer the sensory interface (the sensory interface degraded from RE to VE), the longer the trial time. There were no significant differences among the trials ($p>0.2$). This indicates that the participants' performances among each experimental environment were stable and no learning effect could be found.

4.2. Further analyses on the effects of the sensory variables on the task trial time

As mentioned above, the poorer the sensory interface, the longer the trial time. The SNK results indicate that RE and RRE were not significant from each other (Table 3). This suggests that the reduction of field-of-view did not significantly affect the trial times. As trial times in TE was significantly higher than RE and RRE, it suggests that either an individual effect or combined effects of stereo/mono view, display resolution, image lag and image quality could significantly affect trial times. The results also showed that the median trial times obtained in VE (the only experimental environment without the sense of touch) was twice of those from RE and RRE. This suggests that tactile was also an important contributing factor. In this task, the effect of tactile sensation was confounding with the effects of stereo/mono view, display resolution, image lag and image quality, further studies are needed to isolate their effects. In addition, the video recording of the study showed that nearly two-third of the participants had difficulties in holding the 'virtual' images of cylinder during the VE condition.

Analyses on the head and hand movements are still in progress and the results will be included in the presentation.

5. CONCLUSION

Manual manipulation task performances in a corresponding real environment, restricted-view real environment, tele-matic environment and virtual environment have been found to be significantly different. Analyses have shown that the tactile sensitivity and the image lag were among the important contributing factors in affecting the performance. However, the effects of these two variables have been confounded with the effects of image quality, stereoscopic/monoscopic view and display resolution. Further studies to investigate the isolated effects of tactile sensitivity and image lag are in progress. Also, only male participants were used in this study, future studies to include female participants are desirable.

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REFERENCES

1. So, R.H.Y. and Griffin, M.J. (1995) Effects of lags on human operator transfer functions with head-coupled systems. Aviation, Space and Environmental Medicine, Vol. 66, No.6, June, pp. 550-556.
2. Watson, B., Walker, N., Ribarsky, W. and Spaulding V. (1998) Effects of variation in system responsiveness on user performance in virtual environments. Human Factors, Vol 40, No 3., September, pp. 403-414.
3. Greon, P.J.W. (1998) Manipulation performance in interactive virtual environments. Human Factors, Vol. 40, No.3., September, pp 432-442.
4. Barfield, W., Hendrix, C., Bjorneseth, O., Kaczmarek, K. A. and Lotens, W. (1995) Comparison of human sensory capabilities with technical specifications of virtual environment equipment. Presence, Vol. 4, No. 4, Fall, pp 329-356.
4. Kenyon, R.V. and Afenya, M.B. (1995) Training in virtual and real environments. Annuals of Biomedical Engineering. Vol. 23, pp. 445-455.
5. Kozak, J.J., Hancock, P.A., Arthus, E.J. and Chrysler, S.T. (1993) Transfer of training from virtual reality. Ergonomics, Vol. 36, No.7, pp 777-784.

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A Review of Applied Ergonomics Techniques Adopted by Product Designers

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This paper addresses the ergonomics methods or techniques applied by designers. The review of applied techniques is highlighted against the product development process where its context of use originates from the design practice and industry, needs of the customer and from the practising designer. Many of these methods or techniques have been distilled from a considerable amount of practical experience, where significant amount of personal judgement is required in their application to meet specific needs, especially about human form, capabilities and limitations.

1. INTRODUCTION

In recent years, as global competition accelerated and business marketers strove to juggle consumer's aesthetic and functional product requirements with competitive demands for product differentiation, business marketers rediscovered the competitive advantage industrial and product design can deliver (Myerson 1993; Williams 1993). It is well documented that the Japanese have been ahead of the competition by looking at the role design can play, and by considering design as the key strategic issue in the competitive alignment for business and industry (Dale 1994; Drake 1993).

As such, many organisations spend significant amounts of money and time researching customer's needs and wants only to find that design information is not carried consistently through the product development process (PDP) (Hollins, Pugh 1990).

As the need to identify and satisfy customer requirements is associated with product quality, ergonomics in product design can play a wholistic role (Cushman, Rosenberg 1991) in helping to ensure that user performance is improved, product usability is improved, various users are accommodated, product safety is improved, user comfort is enhanced, and user satisfaction is enhanced. Thus, one method to drive this idea is by enhancing the ergonomics content in existing design practice.

2. PDP AND ERGONOMICS TECHNIQUES

Though there are many documented PDP models, the approach taken by individual designers and the design team can vary according to the organisational and personal preferences i.e., there are more than one successful product development approach depending on the available resources, the intentions of management and production constraints. Nonetheless, for all intended purposes, this study considers and assume the PDP model documented by Pugh (1991) as standard throughout the text. It is noted that the PDP model recorded by Pugh (1991) may not be entirely observed in practice, but it is assumed that the core stages of the described PDP will consider most of the design aspects as conducted in industry and professional practice.

According to Pugh (1991), the PDP consists of several core or main design stages, which consists of :

a) market (identifying users, user requirements and competition),
b) specification (product design specification),
c) concept design,
d) detail design,
e) manufacture (design for manufacture), and
f) sell (sales).

Currently, there is lack of formal documentation on the available ergonomics techniques employed by designers. However, various user-centred and individual techniques have been successfully adopted into practice (Stovell, Khong, Macdonald 1996) and reported on the open literature. They are :

1) static and dynamic simulation (Bonney, Case 1976; GMS Ltd. 1995; Topmiller, Aume 1978),
2) sketch analysis or tracing or life drawings (Arnheim 1996; Stolpmann, Roller 1993),
3) documentation methods- interviews, photography, etc.,
4) physical or computer-aided model making (Gregory 1966; Hoffman, Teeple 1990; Requicha, Voelcker 1983; Shelley 1992; Vince 1985),
5) ethnography/video ethnography (Crawford, Turton 1992; Hammersley, Atkinson 1995; Manoy 1995; Thornton, Garrett 1995),
6) empathy or role playing method (Allen 1993),
7) usability or use analysis (Allen 1993; Philips Corporate 1993; Nielsen, Mack 1994; Shackel 1986; Wiklund 1993),
8) user polling or surveys,
9) task analysis (Ainsworth, Kirwan 1992; Drury, et al 1987; Johnson 1992),
10) scenario building by narration or story telling (Moggridge 1993),
11) market research or trend mapping (Paré 1993; Philips Corporate 1993),
12) function diagrams or functional analysis (Geer 1981),
13) rapid prototyping (Evans 1997),
14) anthropometry (Bennet 1977; Defence Standards 1986; Pheasant 1984; Pheasant 1986).

The correct or even combined use of these methods will cause important user issues to unfold during the application, such as issues on user discomfort, displeasure, preference, etc.. These methods can also contribute to the identification of problems relating to noise, vibration, temperature, humidity, light, maintenance, safety, spatial considerations, perception, etc.. Hence, the application of these techniques serves to :

1) elicit information with regards to customer, social and global requirements and preferences, and

2) as a method for direct and instant information input towards components of design practice - for example, form, function, material selection and model-making.

However, the depth of application of these methods will inevitably vary, and, in most cases, be confined to the individual experience and knowledge of the product designer. As an example, applied anthropometry involves the measurement of the dimensions and other physical body attributes such as volume, centre of gravity, inertia and mass (Sanders, McCormick 1993). However, from personal experience, designers tend only to consider the results of applied anthropometry i.e., making references to certified lists of measurements as a representation of the end-user population, rather than carrying out specific measurement tasks themselves. As such, the ergonomics techniques described above are not all entirely, in terms of theory and practise, adopted by designers from the ergonomics field i.e., only a partial knowledge transfer.

3. CONTEXT AND CATEGORIES OF ERGONOMICS TECHNIQUES

Although most of the mentioned ergonomics techniques are adopted from the ergonomics field, there are others that are hybrid methods, comprising of a combination of methods from other fields of practice; for example, sociology, anthropology and engineering. Some methods adopted by the ergonomics field also do not belong exclusively to the ergonomics profession. Nevertheless, the author assumes the context of 'adoption' as the adaptation of the methods from the ergonomics field by the design profession. The two groups of techniques, hybrid and adopted, are shown in Figure 1.

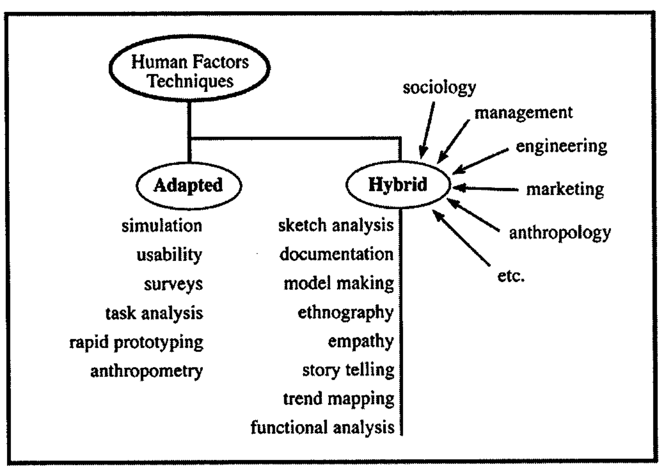

Figure 1 Human Factors Techniques Currently Employed by Designers

Chapanis (1995) charts a sequence of human techniques found useful during the PDP and Meister (1985) also indicated, though in a different perspective, several ergonomics techniques adapted by the behavioural sciences. On a more commercial perspective, Porter (1995) gave his personal insights into the value of ergonomics in the business sector and illustrated the possible ergonomics methods applied to the PDP.

Figure 2 highlight's the ideal scenario in which the mentioned ergonomics techniques are mapped against Pugh's PDP model. The role and nature of the applied techniques is seen as to identify and to elicit customer trends and preferences, and in mapping social and technological directions. Also, these techniques are usually depicted against the PDP, thus showing compatibility with the design profession.

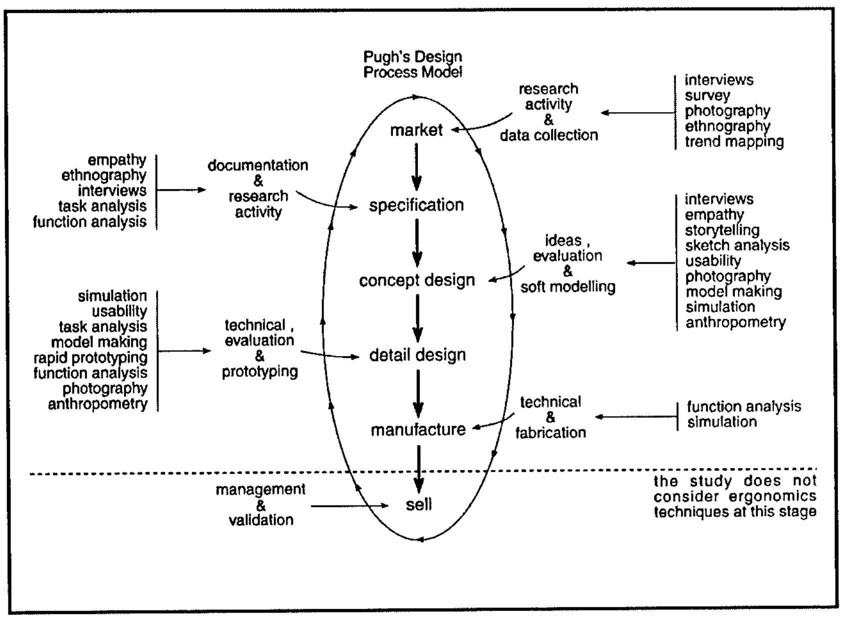

Figure 2 Outline of Ergonomics Techniques Against Pugh's PDP Model - An Ideally Applied Ergonomics Scenario

In most cases, however, these techniques are viewed from an ergonomics point of view. The open literature reports very little from the designer's, or any other ergonomics novice's method of consideration, interpretation and application. Through personal experience, the nature of the design project, customer requirements and the predicted nature of the final product usually determines the ergonomics content for the design activity.

4. CONCLUSION

This paper looked at applied ergonomics techniques by practising designers, its context and nature in view of design practice. Despite the long standing concern about product quality and the design practice in commerce and industry, there is little sign, from the author's experience in the field, of serious attention being paid towards ergonomics techniques. This is especially so for young designers of the future and by those who disseminate design in academia. This reflects on the quality of products and the *quality content* of products of the future. Although the practice of design is far-reaching, there is little evidence to show that the "human" factor is taken into account.

The techniques mentioned in this paper can be positioned and managed as a comprehensive aid for designers to enhance the effective soliciting of customer preferences (Khong 2000).

Currently investigations are being conducted at Multimedia University, Malaysia in further developing the proposed recommendation for a more thorough design of the solution, its sequence of use and proposed management solution. The author is also looking into the possibility of creating a framework in digital media as an electronic application of the solution, and for further investigations into the future of design practice.

REFERENCES

1. Ainsworth, LK; Kirwan, B (eds.). A guide to task analysis. Taylor & Francis: London, 1992.
2. Allen, C. Reciprocal evolution as a strategy for integrating basic research, design, and studies of work practice. In: Schuler, D; Namioka, A (eds.). Participatory design: principles and practices. Lawrence Erlbaum: New Jersey, 1993; pp239-253.
3. Arnheim, R. Sketching and the psychology of design. In: Margolin, V; Buchanan, R (eds.). The idea of design: a Design Issues reader. MIT Press: Cambridge, Mass., c1996; pp70-74.
4. Bennet, C. Spaces for people: human factors in design. Prentice-Hall: Englewood Cliffs, NJ, 1977.
5. Bonney, M; Case, K. The development of SAMMIE for computer-aided work place and work task design. Proceedings of the 6th Congress of the International Ergonomics Association and Technical Program. Human Factors Society: Santa Monica, California, 1976; pp340-348.
6. Chapanis, A. Ergonomics in product development: a personal view. *Ergonomics*. Aug 1995; v38, 8, pp1625-2638.
7. Context of use analysis: you have to actually go and look. Philips Corporate Design Annual Magazine. Philips Corporate Design: Eindhoven, May 1993; pp14-15.
8. Cushman, WH; Rosenberg, DJ. Human factors in product design. Elsevier: New York, 1991.
9. Crawford, PI; Turton, D. Film as ethnography. Manchester Uni. Press : Manchester, 1992.
10. Dale, BG. Managing quality (2nd ed.). Prentice-Hall: New York, 1994.
11. Drake, C. Refreshing the parts. *Design*. January 1993; pp22-24.
12. Drury, C; Paramore, B; Van Cott, H; Grey, S; Corlett, E. Task analysis. In: Salvendy, G (ed.). Handbook of human factors. Wiley: New York, 1987.
13. Evans, M. The application of rapid prototyping technologies for industrial design and ergonomic evaluation. In: Robertson, SA (ed.). Contemporary Ergonomics 1997. Proceedings of the Annual Conference of the Ergonomics Society, 15-17th April 1997. Taylor & Francis: London, 1997; pp370-375.
14. Geer, C. Human engineering procedures guide (AFAMRL-TR-81-35). Aerospace Medical Research Laboratory: Wright-Patterson Air Force Base, Ohio, 1981.
15. GMS Ltd. Jack™ Human factors. Middlewich, Cheshire, 1995.
16. Gregory, SA. Models in practical design. In: Gregory, SA (ed.). The design method. Butterworths: London, 1966; pp143-156
17. Hammersley, M; Atkinson, P. Ethnography: principles in practice (2nd ed). Routledge: London, 1995.
18. Hoffman, K; Teeple, J. Computer graphics applications: an introduction to desktop publishing and design, presentation graphics, animation. Wadsworth: California, 1990.
19. Hollins, B; Pugh, S.. Successful product design: what to do and when. Butterworths: London, 1990.
20. Human factors for designers of equipment. Defence Standards (DEF-STAN 00-25), Parts 1-12. Ministry of Defence: Glasgow, 1986.

21. Johnson, PP. Human computer interaction: psychology, task analysis, and software engineering. McGraw-Hill: London, 1992.
22. Khong, CW. A review of applied human factors techniques for product designers in identifying the Voice of the Customer. Proceedings of the 12th Symposium on QFD and 6th International Symposium on QFD, Novi, MI, 3-9th June 2000.
23. Manoy, R. The scholarly practitioner. *co-design Journal*. Jan-Mar 1995; v2, pp78-82.
24. Meister, D. Behavioral analysis and measurement methods. Wiley: New York, 1985.
25. Moggridge, B. Design by story-telling. *Applied Ergonomics*. 1993; v24, 1, pp15-18.
26. Moore, P. Disguised. Word Books: Waco, Texas, 1995.
27. Myerson, J. Totally successful. *Design*. February 1993; pp22-24.
28. Nielsen, J; Mack, RL (eds.). Usability inspection methods. Wiley: New York, 1994.
29. Paré, TP. How to find out what they want. *Fortune*. Autumn-Winter 1993; pp39-41.
30. Pheasant, ST. Anthropometrics: an introduction for schools and colleges. PP7310 Series, British Standards Inst.. BSI: Milton Keynes, 1984.
31. Pheasant, ST. Bodyspace: anthropometry, ergonomics and design (2nd ed.). Taylor & Francis: London, 1986.
32. Porter, ML. Quantifying and qualifying the value of ergonomics to business. In: Robertson, SA (ed.). Contemporary Ergonomics 1995. Proceedings of the Annual Conference of the Ergonomics Society, 4-6 April 1995. Taylor & Francis: London, 1995, pp15-29.
33. Pugh, S. Total design: integrated methods for successful product engineering. Addison-Wesley: Wokingham, 1991.
34. Requicha, AA; Voelcker, HB. Solid modeling: current status and research directions. *IEEE Computer Graphics and Applications*. October 1983; v3, 7, pp25-37.
35. Sanders, MS; McCormick, EJ. Human factors in engineering and design (7th ed.). Psychology Series. McGraw-Hill Inc: New York, 1993.
36. Shackel, B. Ergonomics in design for usability. In: Harrison, MD; Monk, A (eds.). People and computers. Cambridge University Press: Cambridge, 1986, pp44-64.
37. Shelley, T. CAD takes designers through the screen. *Eureka On Campus*. Spring 1992; v4, 2, pp48-49.
38. Stolpmann, M; Roller, D. Sketching editor for engineering design. Advances in Human Factors. Special issue on HCI: Software & Hardware from the Proceedings of the 5th International Conference on Human-Computer Interaction, Orlando, Florida, 8-13th August 1993; v19B, pp609-614.
39. Stovell, D; Khong, CW; Macdonald, A. Participating in the process: involving the elderly in the process of design. In: Allan, J et.al..Gilham, B (text ed.). The challenge of age. Bank of Scotland 300th/Glasgow School of Art 150th Anniversary Research Fund. Foulis Press: Glasgow, UK, 1996; pp68-78.
40. Thornton, S; Garrett, KJ. Ethnography as a bridge to multicultural practice. *Journal of Social Work Education*. Winter 1995; v31, 1, pp67-74.
41. Topmiller, D; Aume, N. Computer graphic design for human performance. Proceedings of the 1978 Annual Reliability and Maintainability Symposium, Los Angeles. January 1978; pp385-388.
42. Trend-Mapping: Trends and developments almost jump out at you. Philips Corporate Design Annual Magazine. Philips Corporate Design: Eindhoven, May 1993; pp16-17.
43. Vince, J. Computer graphics for designers. Frances Pinter: London, 1985.
44. Wiklund, ME (ed.). Usability in practice: how companies develop user-friendly products. AP Professional: Boston, Massachusetts, 1993.
45. Williams, G. Convenient solution. *Design*. May 1993; pp14-18.

Decision Making Process of Chinese Consumers: Tracking the Number of Products Remains a Function of Product Selection Strategies

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This study aims to investigate the Consumer Decision Making Process (CDMP) of Chinese when selecting products. In particular, the number of products remains at different stages of decision-making strategies and the effects of showing the same product more than once within one experiment session are studied. Two types of products (CD players and dormitory rooms), four initial numbers of alternatives (2, 4, 8, 16), three numbers of product attributes (e.g. price) (4, 8, 12), and two presentation styles (with and without repeated products) were used in the study. Sixteen males and sixteen females participated in the study. Results indicated that, similar to the previous results with Caucasian, CDMP strategies could be classified into two main categories: '*compensatory*' and '*non-compensatory*'. The former refers to the processes in which a customer would compare products by evaluating their attributes. The latter represents the processes in which a customer would eliminate unwanted products using certain criteria. Task completion times were found to be significantly affected by the repeated presentation of the same product within the experiment ($p<0.05$). This is an important finding as most of the previous studies used repeated presentation. The number of products remains at the moment when the participants changed their strategies from 'non-compensatory' to 'compensatory' was also reported. The importance of this number in relation to the understanding of the time-series behavior of CDMP on web-based shopping is discussed.

1. INTRODUCTION

The Consumer Decision Making Process (CDMP) research attempts to study how consumers make a purchasing decision when faced with product alternatives. The research aims to understand the consumers' cognitive processes on retrieving and filtering product information as well as making a decision. One of the approaches to study CDMP is through experiments. The theory of Consumer Decision Making Process (CDMP) has been studied for more than 3 decades (e.g. Simon, 1955). For comprehensive review of the decision-making strategies, please refer to Bettman *et al.* (1998).

The decision-making strategies can be classified into 2 main categories, which are '*compensatory*' decision-strategies, and '*non-compensatory*' decision-making strategies. 'Compensatory' strategy refers to the processes, where the consumers will evaluate the products by comparing their attributes, and filter out products with weaker combinations of attributes. '*Non-compensatory*' strategy refers to the processes in which the consumers evaluate the product by setting a criterion and eliminate products based on the criteria. For example, if a consumer eliminates all the products prized above a certain value, then the strategy is referred to as *'Non-compensatory'* (Payne, 1976 and Olshavsky, 1979).

Many experiments have shown that when faced with more alternatives, consumer used non-compensatory strategy to eliminate the alternatives, and when faced with fewer alternatives, customer used compensatory strategy to evaluate the remaining alternatives (Payne, 1976). Other researchers also replicated Payne's experiment and obtained similar results (e.g., Olshavsky, 1979). Others replicated Payne's with different participants, such as using business experts to choose business products (Biggs et. al., 1985). The results pointed to a similar relationship between the number of alternatives and types of CDMP strategies.

So far most of the previous studies used repeated product presentation. It means that the same set of products was presented more than once to the participants within the same experiment (e.g. Payne, 1976). It is one of the objectives of this experiment to study the effect of repeated product presentation. Also, the previous studies have been conducted with the Caucasian participants and the authors know of no study conducted using purely Chinese participants. In this study, all participants are Chinese.

2. METHOD AND DESIGN

The objectives of this experiment were to study (i) the effects of number of product alternatives and product attributes on CDMP with Chinese participants, and (ii) the effects of repeating product presentation within the same experimental session.

2.1. Independent variables

The independent variables in this experiment are:

- *Task complexity.* Refers to the number of alternatives and attributes in the product. This experiment employed 2, 4, 8, and 16 alternatives and 4, 8, and 12 attributes.
- *Product type.* Instead of using one product type, to avoid boredom, in this experiment, there are 2 products involved, which are dormitory room and portable CD player.
- *Gender.* To observe the difference between gender in the CDMP (16 male and 16 female participated the study).
- *Repeated and non-repeated product set.* Repeated product means that the set of alternatives presented to the participants in consecutive trials contain the same products. While non-repeated product means that there was no repeated product among all the trials.

2.2. Dependent variables

The dependent variables in the experiment are the CDMP strategy, completion time, and the percentage of information searched. The CDMP strategy was measured using verbal protocol. The results were translated into *'Compensatory' (C)* and *'Non-compensatory' (NC)* CDMP strategies by the experimenter according to the definitions of CDMP strategies. As participants might change their strategies before they made the final purchasing decision, different CDMP patterns were identified (e.g. a 2-stage pattern is NC followed by C).

Completion time was measured from the time a participant started to select until he/she made a decision to choose a product. The percentage of information searched was measured by recording the number of product information cards viewed by the participants (each card contained the value of an attribute of a particular product).

2.3. Hypotheses

The hypotheses of the experiment were:

H1: When faced with more product alternatives, consumers will use non-compensatory decision-making strategy, and when faced with fewer alternatives, consumers will use compensatory decision strategies

H2: Both CD player and dormitory room will result in similar decision-making patterns

H3: The use of non-repeated product presentation will have significant effects on the decision-making patterns, percentage of information searched and completion time.

H4: Gender will have significant effect on decision-making patterns, percentage of information searched and completion time

The first hypothesis was based on the assumption that the CDMP strategies and patterns identified for Caucasian (e.g. Payne, 1976 and Olshavsky, 1979) could be applied to Chinese. The second hypothesis assumed that all the participants had similar knowledge and interests towards both CD players and dormitory rooms. The third hypothesis assumed that participants could memorize a repeated product and the last hypothesis was based on previous studies of gender difference in shopping behavior.

2.4. EXPERIMENTAL PROCEDURE

Sixteen male participants and sixteen female participants took part in the experiment. They were university students. Eight males and eight females were assigned to repeated product condition, and the rest of them were assigned to non-repeated product condition.

In the experiment, the participants faced a board consisted of information arranged in a matrix form (Figure 1). The rows represented the product alternatives, and the column represented the product attributes. The information were physically written in information cards with every cards represented a value of an attribute of a product alternative, except for the cards in the first row which indicated the title of the attributes and the cards in the first column which indicated the title of the product alternatives (Product A, B, ...). In the initial state, all cards except the title cards were covered, and the participants needed to flip-open the cards in order to view the information (Figure 1).

Each participant was assigned to a set of 12 product selection tasks exhausting the combinations of 4 numbers of alternatives and 3 numbers of attributes. The presentation of the tasks alternated between CD players and dormitory rooms in order to minimize the boredom. The order of presenting 12 tasks was randomized.

The 12 tasks were divided into two one-hour sessions so as to maintain the concentration levels. The layout of the experimental room is illustrated in Figure 1.

The data recording used the think aloud method. Participants were told to verbalize whatever in their mind: which information they wanted to obtain, what was the reason, and what were their comments about the information after it was opened. The participants were told that there was no time limit in completing the experiment.

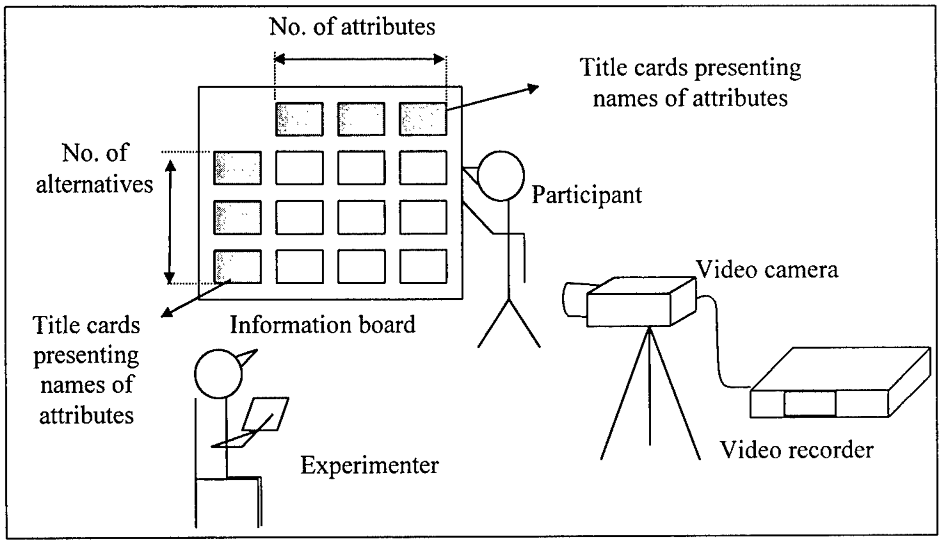

Figure 1. Experimental Layout

3. RESULTS

The data collected were in the form of verbal protocol scripts, time stamp, and time sequence of information searched. The verbal protocol data and the sequence of information cards opened were translated into the decision-making strategies and patterns used by the participants to complete a task (please refers to section 3.2 for definition of CDMP strategies). The amounts of information cards opened were translated into the percentage of information searched (between 0 to 100%). The time stamp data tracked the completion times of all tasks (e.g. ranged from about 1 to 15 minutes).

3.1. Effects of products, gender, repeated presentation, number of alternatives and attributes

The data analysis was conducted using SPSS. The data failed the normal distribution test. Consequently, the Kruskal-Wallis non-parametric tests were used to test all the data. Three significant levels are used, which are 0.01, denoted by (***); 0.05, denoted by (**); and 0.1, denoted by (*). The results are tabulated in Table 1.

3.2. Switching points between compensatory and non-compensatory decision-making strategy

The decision-making strategies varied among participants, but could be classified into 2 main categories, which were '*Compensatory' (C)* and '*Non-compensatory' (NC)* decision-making strategies. When the initial number of alternatives was 8 or more, in most cases, the CDMP consisted of only 2-stages: NC followed by C (i.e. NC-C). This is called the 2-stages patterns and 41% of the product selection process with 8 or more alternatives adopted this pattern. However, other patterns also occurred (see Table 2). The number of product remained at the point of switching from a NC to C strategy were recorded and the median values are shown in the Table 2 as a functions of number of alternatives.

Table 1
Effects of product type, repeated presentation, gender, and number of alternatives and attributes on the completion time, percentage of information searched (% Info), and decision-making (DM) strategies

Summary All	Time	% Info	DM strategies
Product	0.184	0.124	0.325
Repeated vs. Non-repeated	0.005 (***)	0.525	0.072(*)
Gender	0.019(**)	0.061(*)	0.058 (*)
Alternatives	0.000 (***)	0.000 (***)	0.000(***)
Attributes	0.000 (***)	0.000 (***)	0.026(**)

Table 2
The number of product remained at the switching points from a non-compensatory to a compensatory decision-making strategy (data with initial number of alternatives $\geq$ 8 are shown)

Patterns	No. of Alternatives	Median 1st switching point	Median 2nd switching point
2-stage (NC-C)	8	3	-
Switching point	16	3	-
3-stage (C-NC-C)	8	3	-
Switching point	16	4	-
4-stage (NC-C-NC-C)	8	4	2
Switching points	16	5	2

4. DISCUSSION

The first hypothesis was supported by the significant difference in decision-making patterns among different numbers of alternatives ($p < 0.0001$). When faced with 2 alternatives, in 95% of the total tasks, participants used pure compensatory decision-making strategy (i.e., a single stage of C). When faced with 4, 8, and 16 alternatives, in 71, 81, and 93% of the total tasks, participants used multi-stages decision-making patterns, which involved non-compensatory decision-making strategies to reduce the number of alternatives until it is below a certain threshold, and then switch to compensatory decision-making strategy. Table 1 also shows that there were no significant differences between CD player and dormitory room in terms of percentage of information searched, completion time, and decision-making patterns. These results supported the second hypothesis and enhance the generalizability of the results.

Inspections of Table 1 also show that there were significant differences in completion time and CDMP strategies between repeated and non-repeated product presentation. Participants used shorter time to complete the tasks with repeated product presentation ($p < 0.01$). Significant differences in decision-making patterns were also found ($p < 0.1$). These results supported the third hypothesis on the completion time and decision-making patterns. However there was no significant difference in the percentage of information searched between the repeated and non-repeated. Further studies are required to find out the reasons.

The test on the gender resulted significant differences on the completion time, percentage of information searched and the decision-making patterns. These results support the fourth hypothesis. Surprisingly, female searched less information than male participants ($p < 0.1$), and as the consequence, female used less time rather than male participants ($p < 0.05$). A possible explanation may be the lack of aesthetic attributes in this experiment. Nearly all of the attributes were functional related attributes (e.g. Electronic Shock Protection, random-play function) and none was related to aesthetic. Further investigations are desirable.

Using the results of this study, it can be predicted that in making a decision, consumers started with the initial number of alternatives (say, N), and reduced the number of alternatives to about 2 to 4 alternatives using non-compensatory CDMP strategies, then switch to compensatory CDMP strategies before making a decision. If this prediction also holds for Web-based shopping, then this time-series CDMP behavior will be important information for the development of a user-friendly Web-based shopping environment.

5. CONCLUSION AND FUTURE WORK

The replication of the previous experiments is aimed at validating the previous results in the Chinese participants. Further extension with the study of gender and repeated and non-repeated product is also investigated. The results showed the conformance with the previous studies with Caucasian. In addition, the switching point between non-compensatory and compensatory CDMP strategies is also investigated for different number of alternatives.

While the CDMP on traditional product selection environment has been the subject of many studies, CDMP on the web-based shopping is rarely studied. If the findings related to the switching of CDMP strategies can be extended to web-based shopping, different search engines can be made available to match the CDMP strategies. For examples, tree and keyword search can facilitate non-compensatory strategy, and browsing can facilitate compensatory strategy.

REFERENCES

1. Payne, J.W. (1976) Task complexity and contingent processing in decision making: an information search and protocol analysis. Organizational Behavior and Human Performance, 16, 366 – 387.
2. Olshavsky, R.W. (1979) Task complexity and contingent processing in decision making: a replication and extension. Organizational Behavior and Human Performance, 24, 300–316.
3. Simon, H.A. (1955) A behavioral model of rational choice. Quarterly Journal of Economics, 69, 99 – 118.
4. Betmann, J.R., Luce, M.F. and Payne J.W. (1998) Constructive Consumer Processes. Journal of Consumer Research, 25, 187 – 217.
5. Biggs, S.F., Bedard, J.C., Gaber, B.G. and Linsmeier, T.J. (1985) The effects of task size and similarity on the decision behavior of bank loan officers. Management Science, 31, 970–987.

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How Well Do Consumer Electronic Products Meet Human Factors Guidelines? The Case of Remote Control Handsets

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This paper reports the results of an expert walkthrough to uncover common human factors inadequacies of more than 30 remote control handsets currently in the market. Predictions of potential problems identified through the walkthrough were later verified via a small scale user survey and interview. Explicit examples of possible design modifications of the remote control handsets extracted from the expert walkthrough, were then proposed to help designers learn about the appropriate application of human factors guidelines.

1. BACKGROUND

Remote control handsets are small portable control panels which users manipulate at some distance to communicate with a device via a cable or electromagnetic radiation. The handsets support 4 basic input functions (see Figure 1), namely: discrete setting (e.g. mode setting to television or video recorder control); quantitative setting (e.g. volume control); device activation (e.g. power on/off) and continuous control (e.g. fast forward).

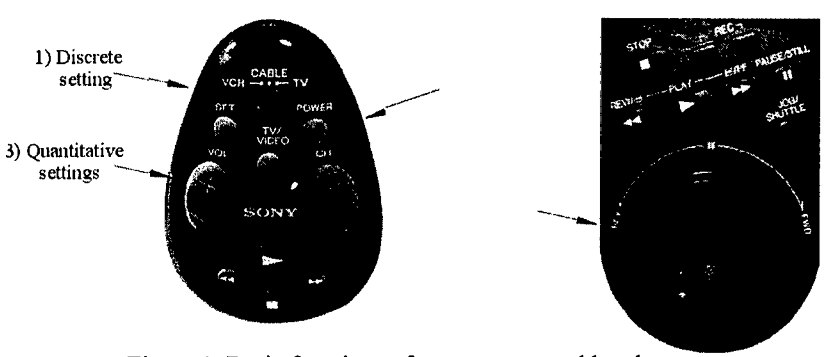


Figure 1. Basic functions of a remote control handset

Although these devices are simple, competitive market forces have in the past pushed companies towards building devices with an increasingly larger number of features and functions. This trend is particularly true for audio-visual devices and their remote controls, which are notorious for the inordinate number of buttons provided. The designs have stumped users who invariably end up using only a small subset of the functions provided. The situation is aggravated further by the average ownership of about three control handsets per household in Singapore.

Although usability problems with the handsets are well known, manufacturers seem to be taking apparently divergent solution perspectives depending on the sector of the market that they aim to address. For instance, simpler remote controls have begun to be offered by some manufacturers. These simplified control handsets can be contrasted with the inevitably more complicated integrated remote control handsets offered by third party vendors (usually) to control multiple devices. In the pursuit of these solution perspectives and in the absence of a good understanding of human factors design, designers have continued to come up with remote control handsets that vary widely in usability. Thus, a greater awareness of human factors design remains a vital concern in this industry.

This paper reports the results of an expert walkthrough to uncover common human factors inadequacies of more than 30 remote control handsets currently in the market. The objective of the evaluation is to determine the extent to which current designs of remote handsets, would fulfil human factors design guidelines. In this way, the current level of designer awareness of human factors concerns may be inferred indirectly. The expert walkthrough is followed later by a small scale user survey and interview to verify predictions of problems that may arise from the failure to comply with specific human factors guidelines. On the basis of problems established from the user survey and interview, some design modifications of the remote control handsets were then proposed. The objective is to raise the level of awareness, to help designers appreciate the importance of human factors. Explicit exemplars extracted from the expert walkthrough of various remote controls are thus used to illustrate cases of appropriate application of human factors design guidelines to support more effective learning by designers.

2. AN INFORMAL USER SURVEY

A survey was conducted to gather feedback from a group of 52 subjects from various backgrounds. The subjects were shown a remote control handset and presented a specific input scenario. They were then asked simply to indicate which button(s) they would press to execute the require input. If subjects were to indicate an incorrect input, they were interviewed briefly to uncover fallacies in their mental model of the remote control operation required. Typical input scenarios and associated problems observed for one of the remote control handsets (an integrated handset - see Figure 2) will now be presented as illustration:

1. To switch on the television (in standby mode), the TV, program or any of the numeric buttons may be depressed. In this input scenario, 33% of the subjects chose the standby button as they assumed that the standby button was activated by on/off toggling. Unfortunately, this handset did not support this method of activation.

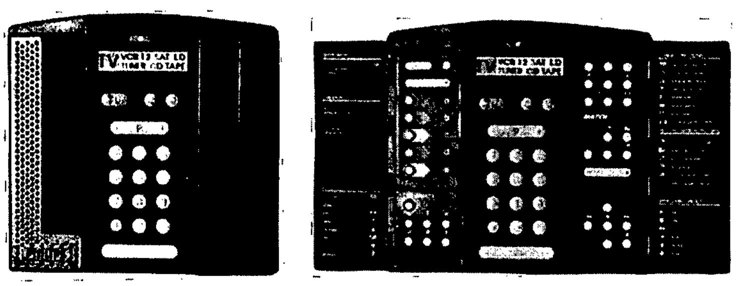


Figure 2. An integrated remote control handset

2. To view a video cassette recorder (VCR) connected to the television, the program button needs to be pressed. Most subjects could not guess which button should be activated. The interview revealed that subjects were searching for a TV/AV button for this input.
3. None of the subjects could work out how to operate the VCR using the integrated handset. Figure 3 shows the procedure required for this input which may be summarised as follows: press the *Peripherals* mode selection button ("M" button), followed by the Connection button ("C" button). As the button labels M and C were rather abstract with respect to their function, subjects could not understand what they were supposed to do. No explanation was given on the side panels. Some subjects reported that they understood the button labels C to mean Cancel or Clock and M for Memory.

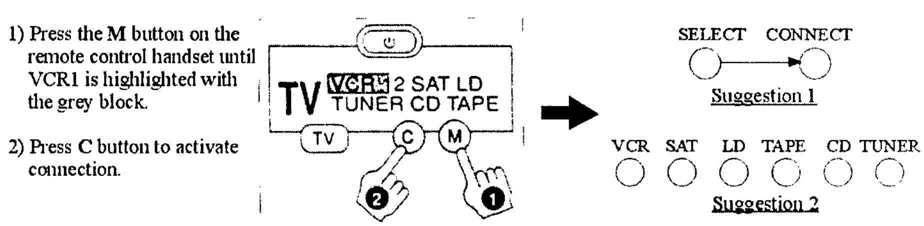
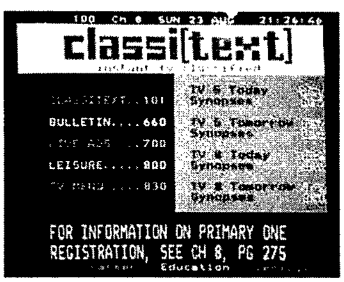


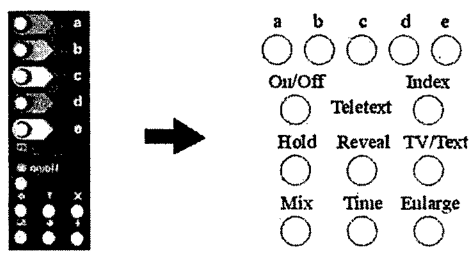
Figure 3. Input sequence for VCR control

Another violation of human factors guidelines comprised the location of buttons. The buttons were located away from the VCR function buttons, and thus subjects could not infer using the proximity of location cue, the relationship between the sets of buttons. The relative location of the M and C buttons were non-ideal as well. In particular, although the input sequence required the M button to be pressed before the C button, the latter was located to the left rather than to the right of the M button (minor violation of the left to right display compatibility guideline to cue sequence of operation).

4. The following screen display (from Teletext) was shown to subjects who were then asked to activate the quick access function for "Travel" (lower left hand corner of Figure 4). Subjects encountered difficulty in performing this task due to the following design inadequacies:

- there were no instructions on the Teletext page to guide users on how the quick access function may be activated.
- the colour coded buttons on the control handset were common for both the MENU and TELETEXT functions. Unfortunately, the buttons were grouped together only with the MENU function control buttons. As a result, subjects were led to believe that the buttons had nothing to do with teletext control.
- conflicting and inappropriate text labelling confused the subjects. For instance, the index page button had a tiny label "i" located below a colour coded button, which is also assigned a larger label "e". Other buttons were labelled abstractly (e.g "X") or technical jargon such as "interrupt" were used. The latter label was for a button to switch between TV/Teletext functions. Needless to say, subjects could not infer from the button label what its function was.





Suggested improvements to Teletext function buttons. The colour of the buttons is now made to match the colour of the Teletext menu items to be activated. Also, ambiguous icons have been replaced by more descriptive text labels.

Figure 4: Quick access function for teletext

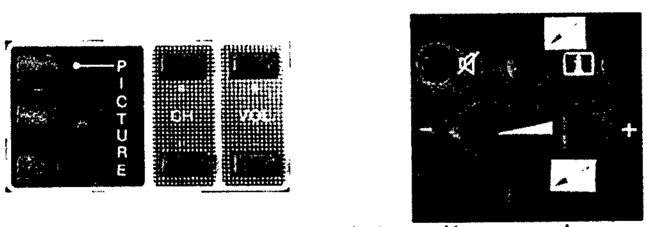
5. The handset design made extensive use of icons which were located on or above the buttons. The iconic representations of button functions were reinforced by textual explanations which were presented on side panels. This design solution was found to be inadequate in several aspects. First, the icons would most likely be viewed dim light (i.e. while enjoying a movie). The icons used for the control handset were small and very similar (a lot of rectangular boxes), and thus subjects encountered difficulties trying to differentiate them under low lighting. Second, some of the icons used were ambiguous in meaning. To compensate for this inadequacy, the designer had to use labels as redundant information reinforcement. The end result was clutter. To aggravate matters, some of the labelling used were inappropriate, e.g. "strobe effect" (see also point (4) above). Thus, subjects were left guessing the meaning of labels in their attempts to unravel the function of the buttons.

To inform designers on basic human factors design guidelines relevant to remote control handsets, explicit examples of good designs were extracted from the expert walkthrough of existing handset designs. In this way, appropriate interpretation and application of human factors guidelines may then be illustrated in context to facilitate effective learning and uptake by these designers. Some design examples of these human factors illustrations follow.

3. LEARNING BY EXAMPLE: ILLUSTRATIONS OF APPROPRIATE APPLICATION OF HUMAN FACTORS GUIDELINES EXTRACTED FROM EXISTING DESIGNS OF REMOTE CONTROL HANDSETS

1. Labelling of control buttons: well designed labels aid learning and activation as they facilitate user search and recognition of the function being controlled. Some human factors guidelines and their illustrations follows.

   ** orientation, location and standardization of button labels - labels should be oriented horizontally and placed on or near the button. Label location and orientation should be consistent for all buttons of the remote control handset. Design examples of poor button labelling extracted from existing remote handsets, are shown in Figure 5.



The 2 top and bottom arrow keys are ambiguous

Figure 5 Examples of poor labelling of buttons

   ** abbreviation and jargon – button labels should be clear, unambiguous, and concise. Avoid abbreviations and jargon unless they are familiar to all users.

   *** pictures and icons - when icons are used as labels, they have to be large and distinct enough to be clearly discriminated, since they might be viewed under low lighting. The icon should be recognizable, contextually relevant and unambiguous in meaning. Design examples of poor button icons extracted from existing remote handsets, are shown in Figure 6.*

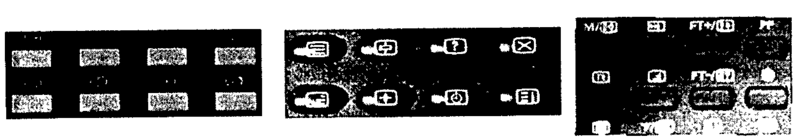


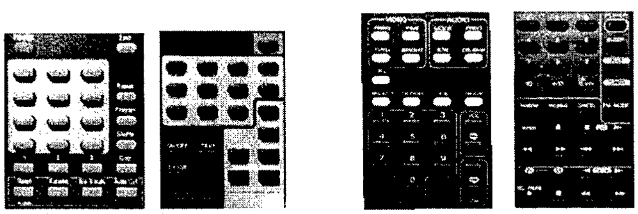
Figure 6 Examples of poor design of button icons

2. Colour coding control buttons: 3 distinct benefits result from the automatic characteristics of color processing:

** The speed of search for a target that is uniquely color coded in a cluttered field is independent of the size of field. Thus, color coding of targets or critical elements in a product is quite effectively for rapid location. This characteristic is particularly useful for handsets since they typically have numerous control buttons.

** The automaticity with which color is processed enhances its value as a redundant coding feature for signal information otherwise coded by shape, size or position.

** Color coding can act like a pre-attentive organizing structure that can be used to tie together multiple elements that may be spatially separated. Psychologists such as Wickens (1984) have argued that visual processing of multiple-elements is separated into 2 main phases: a pre-attentive phase which organizes the visual world into objects and groups of objects, followed by a focal attention phase which selects certain objects from the pre-attentive phase for further elaboration (Baxter, 1996). These 2 processes may be associated with the short-term sensory store and perception of the model of human information processing. Thus, users would be able to locate the required buttons more effectively if they are organized into appropriate groups. To this end, methods for organization of buttons into functional grouping comprise button colour (including shading), location and boundary lines (see Figure 7).

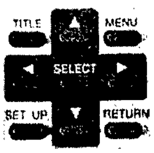


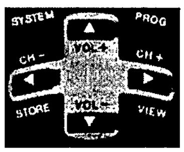
Full tone and half-tone shading for grouping.

Lines used to divide and group buttons.

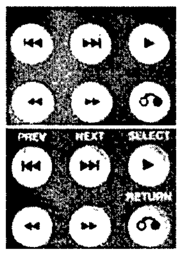
Figure 7 Examples of the use of location and line boundary to group handset control buttons

Colour is the most effective way to group buttons according to function. It can be used for labels, lines, background and on the buttons themselves. Design examples of good use of colour coding extracted from existing remote handsets, are shown in Figure 8. As colour vision depends on ambient or internal illumination (and some users may be colour blind or deficient - 8% of males and 0.5% of females), colour should not be used as the only or primary method for coding button function.

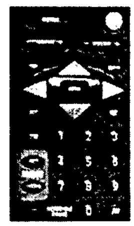




Arrow keys grouped by color shading.



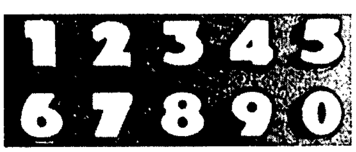
Contrast between label and base is important.



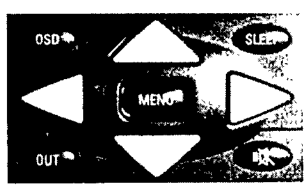
Colour aids rapid button location and serves as a redundant information coding.

Figure 8 Examples of good use of colour coding of handset control buttons

3. Coding control buttons by shape, size and location: This tactile and spatial method of coding buttons is particularly useful when controls must be identified without looking, such as during a session of movie/music enjoyment in the dark. Whenever feasible, select shapes that suggest the purpose of the control. Design examples of such use of tactile and spatial coding extracted from existing remote handsets, are shown in Figure 9.



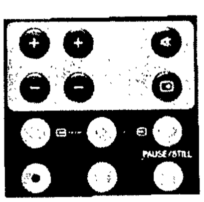
Number buttons in the shape of numbers.



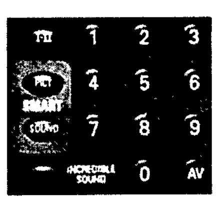
Arrow buttons in the shape of arrows..

Figure 9 Examples of good use of tactile and spatial coding of handset control buttons

4. Layout of control buttons: Unless buttons are organized in a logical and meaningful manner, a user is likely to activate the wrong buttons or lose valuable time hunting for them. For instance, the principle of proximity states that elements of a related array should be located close to each other and grouped. Design examples of button grouping extracted from existing remote handsets, are shown in Figure 10.



The + and - keys are separated from the mute and OSD by using physical proximity



The number keys are distinguished from the group of buttons on the left hand side by the use of shape

Figure 10 Examples of grouping used to highlight related handset control buttons

5. Display compatibility and sequence-of-use: The sequence of use of control buttons should follow the user's mental model. The arrangement of buttons should follow the operation sequence and should (if possible) be from left-to-right and top-to-bottom. The location of the buttons should also follow basic rules of display compatibility, for example, the button to increase volume is either above or to the right of the button to lower the volume. Design examples of button arrangements that follow the display compatibility and sequence-of-use principle, are shown in Figure 11.

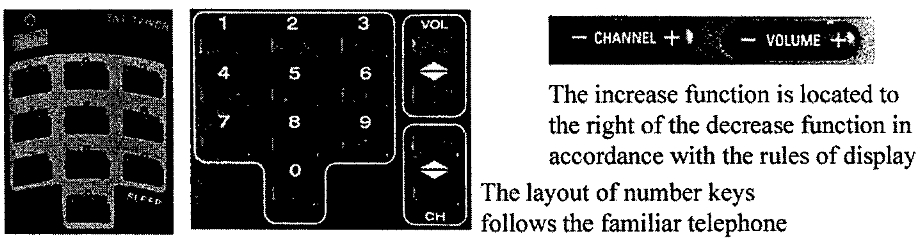


Figure 11 Examples of the application of display compatibility and sequence of use principle to layout handset control buttons

6. Importance and frequency-of-use: Important and frequently used buttons should be placed in convenient locations for ease of location, access and operation. Also, the buttons should be made larger for ease of activation. Buttons which are not used frequently may be concealed to minimize clutter. Design examples of button arrangements that follow the importance and frequency-of-use principle, are shown in Figure 12.

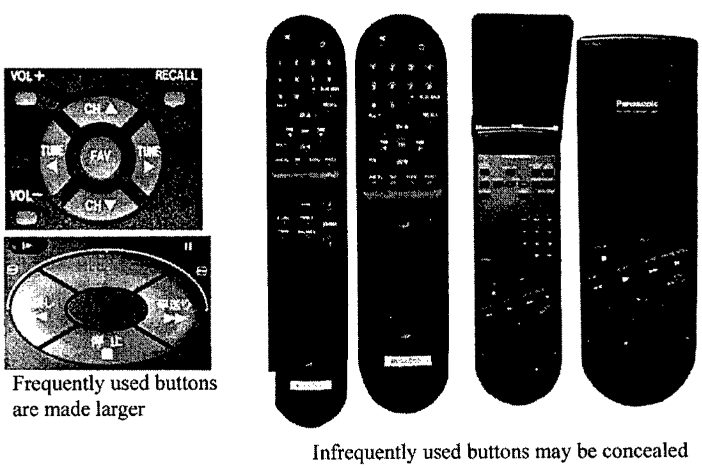


Figure 12. Examples of the application of importance and frequency-of-use principle to layout handset control buttons

7. Feedback - Some remote control handsets include a light emitting diode (LED) which lights up whenever a valid signal is transmitted, so that users know that the function is activated. Feedback can also be indicated tactilely by using buttons which depress to an extent detectible by a user. Other systems provide on-screen displays such as a Liquid Crystal Display (LCD) or Vacuum Florescent Display (VFD), to provide users with feedback and menus with step-by-step instructions especially for the operation of complex set-up functions.

4. CONCLUSION

Good user interface design of remote control handsets is vital for usability. In particular, as technology advances and products get more complex, more features and functions may be squeezed into a tiny remote control handset. The trend is thus to design graphical displays on the TV screen to reduce the number of buttons on the remote control. Care must be taken to ensure that the screen instructions and the required interactions are user-friendly. Notwithstanding these developments, designers of remote control handsets would still need to learn and understand the appropriate application of the established human factors principles illustrated in this paper.

REFERENCES

1. Baxter M., Product Design, Chapman and Hall, 1996.
2. Wickens C.D., Engineering Psychology and Human Performance, Charles Merrill Publishing Co., 1984.

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Developing a Comfortable Motorboat Seat

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To date, little emphasis has been placed on the comfort of motorboat seats. However, as manufacturers endeavor to make better products, considerations of ergonomics are rapidly gaining in importance. It should be noted, however, that motorboat seats differ in the way they are used from auto or motorcycle seats. The driver's seat on a motorboat has two roles. One is its function as a working seat for use during operation of the boat. The other is as a seat for relaxation, mainly when the boat is not moving. The design tendency so far has been to gear the seat more toward its function as a working seat during boat operation. However, the proportion of time spent using the seat for relaxation is also significant, so it is important to develop an ergonomically superior seat that gives the user a greater sense of satisfaction at either time. We therefore investigated which aspects of a seat are important to the user from the viewpoint of comfort, and, together with quantitative considerations of the distribution of seat pressure when the seat is occupied, identified points for improvement. We then incorporated these points in building a seat.

1. EXPERIMENTAL METHODS

1.1. Sensory evaluation of motorboat seats

1.1.1 Seats for evaluation

The following 5 types of seat were used for evaluation (A–C are test prototypes)

A: Prototype seat made using the RECARO seat line for reference
B: Seat A with reinforced support for the front portion of the thighs
C: Seat A with less support for the front portion of the thighs, and reinforced side support for the buttocks.
D: Current product
E: Current product

1.1.2 Evaluators

The evaluation was conducted by 22 people from our Engineering, Testing, Design, and Research Departments.

1.1.3 Terms used in evaluation

The following points were evaluated for the seat bottom and seat back.

Seat bottom (feeling): Sense of firmness, poor cushioning, too much cushioning, excessive springiness, impact attenuation, front-to-back fit, side-to-side fit, support pressure for thighs, feeling of crampedness from thigh side, feeling of crampedness from buttocks side, feeling of slipping in the buttocks.

Seat back (feeling): Sense of firmness, front-to-back fit, side-to-side fit, height of lumbar vertebrae support, pressure of lumbar vertebrae support, sense of being held, feeling of backward arch, feeling of forward hunch, feeling of pressure in the abdominal area, general evaluation.

1.1.4 Test methods

The 5 types of seat were lined up, and the evaluators sat in each one and rated it on a scale of 1 to 5 for each of the evaluation items.

1.2. Physical evaluation

The distribution of pressure on the seat when occupied was measured.

2. RESULTS AND DISCUSSION

2.1. Results of sensory evaluation

2.1.1 Features of evaluation

To understand where focus should be placed when evaluating a seat, a factor analysis was done from the results of the 5-step evaluation (Table 1). This table shows that the most important factors were sense of fit and of being held; the second was sense of firmness; the third, sense of crampedness; and the fourth, sense of impact attenuation.

Table 1. Factor loading

	Evaluation terms	FACT.1	FACT.2	FACT.3	FACT.4
Seat bottom	Sense of firmness	0.539	**0.655**	-0.023	0.189
	Poor cushioning	0.390	**-0.557**	-0.278	0.138
	Too much cushioning	-0.279	**-0.604**	-0.156	-0.432
	excessive springiness	-0.302	-0.084	0.140	-0.384
	Impact attenuation	-0.441	0.121	0.099	**0.530**
	Front-to-back fit	**-0.765**	0.100	0.174	0.030
	Side-to-side fit	**-0.727**	0.236	-0.061	-0.016
	Support pressure for thighs	-0.393	0.121	-0.004	-0.239
	Feeling of crampedness from thigh side	-0.123	0.142	**-0.756**	0.052
	Feeling of crampedness from buttocks side	-0.013	0.286	**-0.777**	-0.135
	Feeling of slipping in the buttocks	0.675	0.120	0.098	-0.249
Seat back	Sense of firmness	0.551	**0.568**	-0.095	0.092
	Front-to-back fit	-0.757	0.165	0.010	0.116
	Side-to-side fit	-0.667	-0.167	-0.112	-0.094
	Height of lumbar vertebrae support	0.087	0.004	-0.017	-0.403
	Pressure of lumbar vertebrae support	0.123	0.437	-0.022	-0.078
	Sense of being held	**-0.764**	0.032	-0.381	0.084
	Feeling of backward arch	0.514	0.143	-0.218	-0.396
	Feeling of forward hunch	0.302	-0.486	-0.313	0.423
	Feeling of pressure in the abdominal area	0.504	-0.588	-0.028	0.179
	Eigen value	5.081	2.495	1.663	1.384
	Proportion of variance	0.254	0.125	0.083	0.069

Table 2. Regression Coefficients

Explanatory variable	Parameter Estimate	Std. error	T	Prob > |T|
Constant	2.1858	0.3383	6.4602	0.0000
Sense of being held	0.2547	0.0699	3.6448	0.0005
Front-to-back fit	0.2448	0.0618	3.9588	0.0002
Feeling of backward arch	-0.2275	0.0586	-3.8832	0.0002
Feeling of pressure in the abdominal area	-0.1982	0.0556	-3.5639	0.0006
Side-to-side fit	0.1364	0.0662	2.0617	0.0422

From this, it is understood that when evaluating a seat, the strongest focus should be on the sense of fit and of being held when sitting, followed by whether or not the seat is firm and not too cushiony around the buttocks.

2.1.2 Evaluation items greatly affecting general evaluation

To understand which items greatly affect the general evaluation, a multiple regression analysis was done with the general evaluation as the criterion variable and the other evaluation terms as explanatory variables (Table 2).

The results show that a seat which will be rated more comfortable can be made by increasing the importance of the sense of being held by the seat back and sense of fit in the seat surface and back, and by eliminating any sense of backward arch and pressure in the abdominal area. Here, because the signs for backward arch and pressure in the abdomen are negative, the general evaluation can be improved to the extent that these items are eliminated so as not to be felt by the user.

2.2. Distribution of pressure on seat

From measurements of the distribution of pressure on the seat, it was found that the seats that received a high evaluation for the seat back were those which provided support in two places: the thoracic vertebrae and the upper pelvis-lumbar vertebrae. With such support, the spinal column is maintained in an "S" shape (Figure 1).

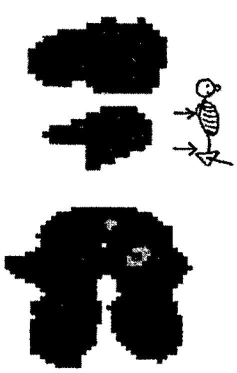

Figure 1. High evaluation seat

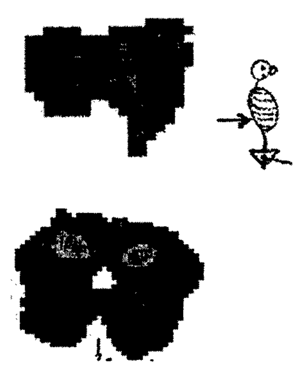

Figure 2. Low evaluation seat

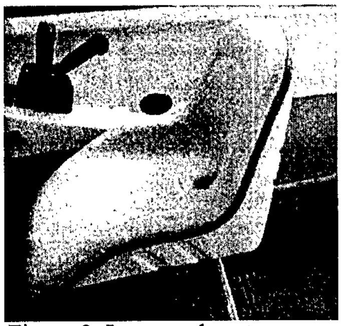
Figure 3. Improved seat

Seats which received a low evaluation, on the other hand, support the back in only one place—in this experiment the upper lumbar vertebrae—so that it becomes difficult to support the spinal column in an "S" shape. The surface pressure also increases, which means that vibrations and impacts more easily affect the internal organs (Figure 2).

The seat bottoms that were evaluated highly were those in which the pressure on the ischium was dispersed to the surrounding area, so that there were no locations of strong pressure other than the ischium itself.

The seat bottoms receiving a poor evaluation had several pressure peaks outside the area of the ischium or did not support the thighs, producing locations of strong pressure.

3. DEVELOPING AN IMPROVED SEAT

Based on the above experimental findings, an ergonomically improved seat was built (Figure 3).

3.1. Sensory evaluation

The general evaluation of the seat, based on the sensory evaluation, was 4.3 on a 5-point basis. Of the seats listed in 2.1.1, Seat B received the highest general evaluation at at 3.7.

The results from a *t*-test are shown in Table 3. The level of statistical significance was 1%.

3.2. Seat pressure distribution

From measurements of seat pressure distribution, it was seen that when the user is relaxing, the seat back supports the upper thoracic vertebrae (T7, T8), the thoracic vertebrae (T10, T11) corresponding to the center of the upper body mass, and the 4th and 5th lumbar vertebrae (L4, L5). During operation of the boat, when the user leans forward to grip the steering wheel, the seat supports the two areas of the T10 and T11 thoracic vertebrae and L4 and L5 lumbar vertebrae.

Table 3. The *t*-test for comparison of Seat B and Improved seat

SEAT	N	Mean	Std. Dev	Variances	t	DF	Pr>
B	23	3.70	1.00	Equal	-2.758	43	0.009
Improved seat	22	4.32	0.36	Unequal	-2.806	27.969	0.009

For H0: Variances are equal, F=9.113 DF=(22, 21) p=0.004

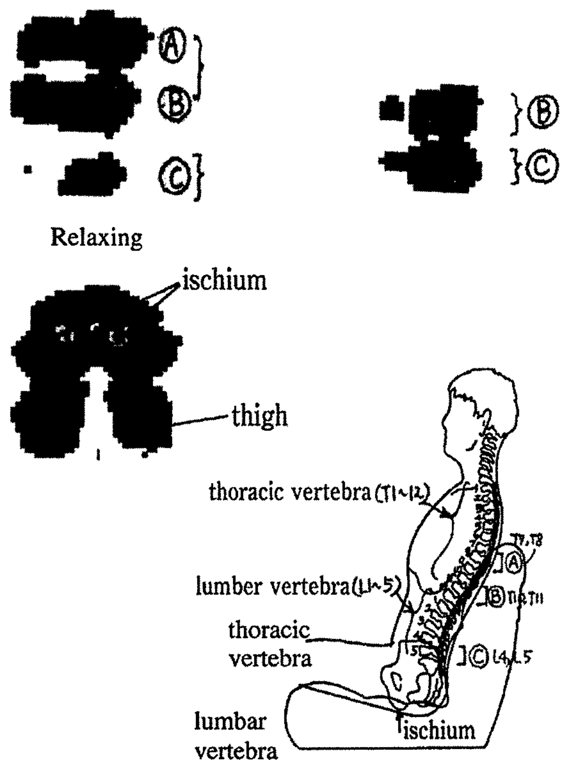

Figure 4. Pressure distribution of improved seat and seat back support points

Lumbar support has conventionally been provided in the area of the 3rd lumbar vertebra (L3) in order to maintain an "S" shape in the spine, but this places too great a burden on the lumbar vertebrae. Support of the upper pelvis (near L4 and L5) is effective in preventing this (Figure 4).

In the seat bottom, surface pressure on the coccyx is reduced, and the thigh area support is also improved.

3.3. Evaluation during actual operation

Evaluation of the seat during operation was done with the boat actually moving under power (N = 7).

From the result of sensory evaluation on a 5-step scale, a good overall evaluation of 4.5 was obtained. Good performance was also confirmed when hitting waves, in terms of upper body stability and impact absorption.

4. CONCLUSION

It was found that when evaluating motorboat seats, importance should be placed first on the sense of fit and being held, second on the sense of firmness, third on the feeling crampedness, and fourth on the sense of impact attenuation. Next, the key factors affecting the comfort of a motorboat seat are senses of fit, being held, and, negatively, backward arch and abdominal pressure.

From the distribution of seat pressure, it was determined that a comfortable motorboat seat, when used for relaxation, should support the upper thoracic vertebrae (T7, T8), thoracic vertebrae (T 10, T11), and the 4th and 5th lumbar vertebrae (L4, L5). When used during operation of the boat, the seat should support the thoracic area (T10, T11), and the 4th and 5th lumbar vertebrae. Effective lumbar support is provided when the upper pelvis in the area of L4 and L5 is also supported.

A new seat made in line with these findings received a high evaluation. This seat also provided good upper body stability and impact absorption against waves.

REFERENCE

1. Research Committee of Sensory Evaluation, Union of Japanese Scientists and Engineers. Sensory Evaluation Handbook (Japanese), JUSE Press Ltd., 1973

PART NINE

Ergonomics of Safety

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Organisational Accidents, Safety Programs and Management Participation: Some Notes on the Literature

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Literature on safety, organisational accidents and accident prevention was surveyed. It was found that a wide range of systems, methods and strategies are effective in the prevention of accidents and disasters. The variable that the majority of researchers identified as critical is day-to-day involvement of management in safety. It is argued that education of future managers is necessary for integrating Human Factors and safety concepts with mainstream business concepts.

1. INTRODUCTION

This article discusses a literature survey on organisational disasters and accident prevention. The survey was conducted on behalf of Brandforsk, the Swedish Fire Research Agency. The objectives of the survey were to identify assessment tools and prevention programs that industry safety officers and fire engineers can use when assessing, developing or managing prevention programs in industry settings. Prevention of organisational disasters is of interest to Brandforsk, in that occurrence means loss of lives, sizeable economic loss and long-term disruption of normal activities. Managing fire incidents is also of importance since the difference between a minor accident and a disaster is sometimes determined solely by speed of intervention (Toft & Reynolds, 1997). Prompt and accurate operator action might make the difference between a commonplace disturbance and a big disaster.

2. THE NATURE OF ORGANISATIONAL ACCIDENTS

Organisational accidents are rare but catastrophic events do occur within complex technological systems such as nuclear power plants, rail and air transport, chemical process plants and the like. Organisational accidents have typically multiple causes involving many people at different levels in the organisation. As an example, a mixture of decisions, deficient communication and abnormal climatic conditions precipitated the 1986 Challenger Space Shuttle disaster. Isolated, each of the factors was not in itself a cause; the combination precipitated the disaster where lives were lost and the otherwise successful program was called into question. Whereas the characteristics of individual accidents, that is accidents that happen to individuals have remained relatively unchanged over the years, the nature of organisational accidents can be regarded as a product of a more complex and sophisticated technology. This technology has profoundly altered the relation between systems and their human elements (Reason, 1997). The high level of automation in modern technology has made the information provided to the operators more abstract, rendering the system opaque. This has important consequences for the operator's ability to develop adequate mental models to guide him when making decisions. A paradox here is that automation has made the human factor more important. Bainbridge (1987) mentioned a number of "ironies of automation". One such irony is the fact that human beings are considered unreliable and inefficient and yet they are left to cope with those tasks that the designers have been unable to automate like restoring the system to a safe state after some unpredicted disturbance. Hollnagels' (1993) statement that 80 per cent of accident causes are due to the human factor seems to have become a common notion (Reason, 1987). Hollnagel (1989) has likened potentially fatal human errors in complex systems with earthquakes. Human errors, like earthquakes, are natural phenomena and thus seemingly inevitable; they come in different sizes, they are very hard to predict exactly and, most important here, they tell us something new every time they happen. There are ample references to dearly bought experiences from organisational disasters like *Three Mile Islands, Exxon Valdez, Bhopal*, etc. in the safety literature reviewed.

Research has generated considerable scientific literature about disaster prevention (Stubbs, Danielsson & Ohlsson, 1999). Prevailing thought in the scientific communities is that legislation gives an illusion of security rather than offering real protection. A key notion is that disasters are caused by decisions made well in advance, on a high level, that is by people in management positions. Typically, risks are unknown or ignored by the decision makers and the decisions oftentimes cause normal safety mechanisms ("defences") to be inadequate.

3. MANAGEMENT INVOLVEMENT AND SAFETY PROGRAMS

Throughout the literature direct or indirect reference is made to management's role in safety and disaster prevention. The role of management is described as a, if not the most important, factor contributing to an organisation's safety. Manager participation positively influences staff behaviour through developing a sense of participation in and "ownership" of a safety and prevention program. Manager commitment causes consistency in program design and implementation. Furthermore, managers become aware of how their decisions might affect an operation's safety. For instance, unrealistic completion timelines for projects can induce operator omission of steps of importance for safe procedures.

Expanding upon the role of management in guiding organisational behaviour, attitude and efficiency, Westrum (1993) and Weick (1987) discuss the concept of "organisational culture". Westrum describes organisational culture as "... those habits, folkways and norms that shape action...". Both authors, along with Pidgeon (1998) and Toft & Reynolds (1997) see management as having an important role in the shaping of an organisation's culture. In this case, the sub-set of an organisation's culture is its "safety culture". When translated into day-to-day work activities, willingness to following safe practices and yet thinking critically (e.g., being able to recognise when normal procedures/practices may cause accidents or disasters) is an organisation's safety culture.

In Sweden all employers are required to have a safety program with specific features. This has been a requirement since the previous turn of the century. The specific requirements have changed as a result of influences such as increased knowledge of hazards and events such as large-scale disasters or identification of an occupational disease. There are similar requirements in all countries in the world. Efficiency of enforcement varies with industrialised countries being the most active in the monitoring of employer compliance. For example, Sweden with its National Safety and Health Administration, Great Britain with its Health and Safety Administration work closely with employers in making certain that there are healthy work environments. Thus, governmental requirements establish general conditions within which organisations have the possibility to use programs adapted to the conditions in the work places and styles of operation.

Supporting employer efforts are research activities and informational reports that develop strategies and/or show how to comply with specific regulatory requirements (e.g. ,Kjellén, 1982; Swedish Work Environment Fund, 1994). Summaries of research activities describe a large number of studies and projects that offer a wide range of strategies for employers and/or regulators to draw upon when planning and operating safety programs (Menckel & Kullinger, 1996). Regulatory authorities are also able to draw upon studies assessing effectiveness and/or efficiencies and suggest ways to enhance operations (e.g., Harms-Ringdahl & Ohlsson, 1995). The broad range of approaches to safety and disaster prevention provides a range of choices that give managers the latitude to select a risk management strategy that most closely matches their organisation's particular needs.

Are the programs able to meet governmental requirements plus prevent accidents ranging up to major disasters? Researchers are generally positive or take a neutral position by recommending further research (e.g. Emmet, 1996). Descriptions of individual programs cite decreased accident/injury rates as evidence of the effectiveness of the programs being used (e.g., Ball & Proctor, 1993). These articles, among others, do establish that there are any number of risk management programs that have features necessary to reduce accident rates and prevent disasters.

Understanding and perceived value of safety is agreed upon among those working in the field of safety and disaster prevention. Management perception of the role of risk management in organisational operations is not as unanimous. For instance, Mintzberg, Quinn & Ghoshal (1998) in their book, *The Strategy Process: Revised European Edition*, do not include safety or disaster prevention strategies in their descriptions of corporate methods and techniques. In a sense, they are evoking the impression that risk management is not a core element of profitable business operations. Jackson & Muselman (1988) who describe industrial accident prevention as follows provide another representative example in a basic text on business:

> " *The factors found to contribute to industrial accident included the following:*
> 1. *Personal characteristics and attitudes of workers*
> 2. *Impersonal factors such as technical deficiencies in the work environment*
>
> *Personal deficiencies include lack of worker knowledge, improper attitudes, physical defects, and indifference to danger. Technical deficiencies include inadequate lighting and ventilation, poor design of equipment, improper materials-handling techniques, and ineffective safeguards on machinery. Four out of every five accidents are caused by personal rather than technical deficiencies.* " (Jackson & Muselman, 1984, p. 227)

Descriptions used in this text give the impression that causes of industrial accidents and disasters are due to factors beyond immediate control by management.

While managers may perceive that accidents are not readily controllable, this notion seems to be in sharp contrast with beliefs expressed by social psychologists. Elementary texts on social psychology that discuss leadership (management's actions) and conformity (what is expected by workers) can be used when considering risk management, safety and disaster prevention. Hogg & Vaughn (1998) describe conformity as a function of the individual's desire to follow the values of the group. In the work settings safe behaviours can be considered as following group values if the values of the group include thinking about safety and risk management when working. Deaux, Dane & Wrightsman (1993) describe leadership, the role of managers and supervisors, as the key dimensions of consideration and initiating structure. Consideration is characterised as the ability to communicate with group members. Initiating structure is defined as establishing organisation, communication and procedures. In research about establishing effective safety programs, Rundmo (1996) reported that employee safety attitudes were partially influenced by management commitment and involvement.

Considering the factors discussed, a difference between the two key groups involved (management authorities and safety experts) becomes readily apparent. Managers tend to view day-to-day risk management as beyond immediate control while experts/psychologists take the opposite view. Certainly, it is easy for people who have production goals and profit uppermost in their minds to lose sight of the risks involved. Safety is, like reliability or human factors, invisible in the sense that safe procedures are constant, which means there is nothing special to pay attention to. Very few people have direct experience of accidents, not to mention major disasters.

However, this difference in attitudes between managers and safety experts is not ubiquitous. Ball & Procter (1993) describe a successful safety program at a British steel company in terms implying that the managers of that organisation include the dimensions of consideration and initiating structure. Leadership is exercised in a manner that has caused the managers, supervisors and workers at all levels to view safety as being an integral part of operations. In more general terms, management's role in safety management is described as being crucial in eliciting behaviours needed to prevent accident and major disasters.

Helping managers to analyse causation through assessment of accidents and training is described De Joy (1994) as a strategy in disaster and accident management. Hallgren (1996), in writing about the prevention of industrial accidents, views Swedish labour laws as having a positive influence on organisational safety. He describes requirements for safety programs that involve workers in safety planning and assessment; features that encourage communication between all levels of an industrial operation.

Available to employers is a smorgasbord of safety programs and approaches, all having the potential to be effective. The key to safety success is as described by Reason (1990a, 1990b) in the control of "resident pathogens" that lie dormant until causing organisational accidents. The term "resident pathogens" includes decisions made at higher level in an organisation; for instance decisions creating the conditions that permit breaching of defences designed to prevent accident and disasters. Reason's conclusions have been identified and described in a number of ways by others (e.g., Cooper, 1998; Glendon & McKenna, 1995; Hoffman, Jacobs & Landy, 1995; International Atomic Energy Agency, 1996; Kirwan, 1994; Tallberg & Mattila, 1994). In his 1997 book on organisational disasters, Reason goes on to say that even the safest organisation is vulnerable to accidents and disasters. He describes an organisation's safety program as moving within a "safety space", where there is high-safety at one end and low-safety at another. Movements within the space are the results of changes through influential factors such as new technologies or procedures. The resident pathogens are growing or increasing in number with the changes and with the effort made to detect and remove these potential threats to safety. Reason's primary point is that just as an organisation must continually assess its business and marketing strategies to stay competitive it must do the same with its safety programs (Reason, 1997).

Although managers of modern organisations are facing innumerable demands upon their time it would also appear that one more demand is imposed, namely the demand that safety programs and systems be a regular part of their scheduled. Their investment of time will likely be repaid through time saved. Time that would have been required in the event of large-scale accidents.

4. CONCLUSION

The literature survey revealed that the variable that most often identified as having the greatest influence upon successful outcome of safety programs is active participation by management. Exercising leadership has the effect of positively influencing attitudes and behaviours at all lower level in an organisation. In some of the studies reviewed the failure in a program to reduce accidents was attributed to the lack of management knowledge, participation and/or ongoing commitment. We suggest an educational intervention designed to give future managers the knowledge needed to be involved on an ongoing basis. People starting as managers will be more likely to develop and maintain knowledgeable involvement in safety than those already working as managers. Development of a course in safety for business programs such as MBA programs is suggested, the strategy being that this group will be in the best position to integrate safety skills in with all other skills being acquired. A second approach will be to offer similar courses to current managers as part of business seminars that are currently offered. A case study could assess whether this results in changes in attitudes.

REFERENCES

1. Bainbridge, L. (1987). The Ironies of Automation. In J. Rasmussen, K. Duncan & J. Leplat (Eds). *New Technology and Human Error*. John Wiley & Sons.
2. Ball, J. & Procter, D. (1993). The Zero Accident Approach at British Steel, Teesside Works. *Loss Prevention Bulletin, 111,* 5-11.
3. Brehmer, B. (1987). Development of Mental Models for Decision in Technological Systems. In J. Rasmussen, K. Duncan & J. Leplat (Eds). *New Technology and Human Error*. John Wiley & Sons
4. Deaux, K., Dane, F. & Wrightsman, L. (1993). Social Psychology in the 90's. Pacific Grove, California, USA:Brooks/Cole.
5. Dejoy, D.M. (1994). Actions and attributions: Casual thinking and the management in safety. In G.Bradley & H. Hendricks (Eds). *Human Factors in Organizational Design and Management.* Amsterdam: Elsevier Science.
6. Emmet, E. (1996). Prevention of Major Accidents in Australia. *Journal of Occupational Safety and Health – Australia and New Zealand,* 12, 581-589.
7. Hallgren, L. (1996). The prevention of occupational accidents in industry. In E. Menckel & B. Kullinger (Eds). Fifteen years of occupational-accident research in Sweden. Stockholm, RALF
8. Harms-Ringdahl, L & Ohlsson, K. (1995). Approaches to accident prevention: A comparative study of eleven Swedish authorities. *Safety Science*, 21, 51-63.
9. Hogg, M. & Vaughn, G. (1998). *Social Psychology*. London: Prentice-Hall.
10. Hollnagel, E. (1989). Nordic Man-Machine Conference 1989: A summary of the main issues. *Proceedings of VIT Symposium. Människan i komplexa system.*
11. Hollnagel, E. (1993). *Human Reliability Analysis: Context and Control.* London: Academic Press.

12. Jackson, J.H., & Musselman, V.A. (1984). *Introduction to Modern Business* (9th ed.). Englewood Cliffs, New Jersey, USA: Prentice-Hall.
13. Kjellén, U. (1982). An evaluation of safety information systems at six medium-sized and large firms. *Journal of Occupational Accidents*, 3, 273-288.
14. Menckel, E. & Kullinger, B. (1996). Introduction: Twenty researchers summarise fifteen years of Swedish occupational-accident research. In E. Menckel & B. Kullinger (Eds). Fifteen years of occupational-accident research in Sweden. Stockholm: RALF.
15. Mintzberg, H., Quinn, J.B. & Ghosal, S. (1998). The Strategy Process: Revised European Edition. Prentice Hall: London.
16. Pidgeon, N. (1998). Safety culture: key theoretical issues. *Work & Stress*. 12, 202-216.
17. Reason, J. (1997). *Managing the Risks of Organisational Accidents*. Aldershot, UK; Aghgate.
18. Stubbs, J., Danielsson, M. & Ohlsson, K. (1999). *Safety Programs and Accident Prevention: Prevention of Organizational Disasters*. Luleå tekniska universitet. Research Report 1999:18.
19. Swedish Work Environment Fund (1994). *Accident Prevention*. Stockholm.
20. Toft, B. & Reynolds, S. (1997). Learning from disasters: a management approach. Leicester, UK:Perpetuity Press.
21. Weick, K. E. (1987). Organizational Culture as a Source of High Reliability. *California Management Review*, 29, 112-117.
22. Westrum, R. (1993). Cultures with Requisite Imagination: In J.A. Wise, V.D. Hopkin & P. Stager (Eds), *Verification and validation of complex systems: human factors issues*. Belin: Springer Verlag.

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Human Factors and Motor Vehicle Crashes: A Conceptual Framework for Ergonomic Research in South East Asia

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A methodology for analysing car accidents (based on a modified Haddon matrix) is proposed. Human factors with particular relevance to the study of traffic accidents in Southeast Asia are discussed. Three illustrations of the interaction of human factors with other elements associated with accident causation are provided.

1. INTRODUCTION

Although motor vehicle crashes have been the subject of ergonomic research for years, many questions still persist with respect to causative factors and accident prevention. This is particularly relevant to the Southeast Asian environment where both the number of vehicle registrations and the incidence of accidents and fatalities are high. It has been suggested that driver-related behaviour is often significant as a determinant of these high incidence rates (Swaddiwudhipong et. al., 1994).

The current paper illustrates a conceptual framework for the analysis of accident causation and identifies a number of cognitive and behavioural variables that may have particular significance within the ASEAN setting.

2. A CONCEPTUAL FRAMEWORK FOR STUDYING MOTOR VEHICLE ACCIDENTS

Traditional studies of human factors in road safety have tended to view the transportation system in terms of its major component elements: the human (H), the vehicle (V), the road (R) and the environment (E). Haddon (1970) proposed a framework in which each of these elements can be examined as part of an analytical matrix. This model has been instrumental in stimulating research designs and accident interventions (Williams, 1999).

November (1997), however, has argued that the Haddon matrix is limited by the way it considers each element independently, concealing the interactions that underlie the behaviour of real traffic systems. He has proposed expanding the matrix to provide for the analysis of inter-relationships between each of the four basic elements.

	PRE-CRASH	CRASH	POST-CRASH
BASIC ELEMENTS OF A HIGHWAY EVENT:			
Human (H)			
Vehicle (V)			
Road (R)			
Environment (E)			
THE *MODIFIED* MATRIX – INTERACTIONS BETWEEN ELEMENTS:			
Human-Vehicle (H*V)			
Human-Road (H*R)			
Human-Environment (H*E)			
… etc …			
Human-Vehicle-Road-Environment (H*V*R*E)			

Figure 1: Modified Haddon Matrix (after Noy, 1997)

Within this expanded framework, for instance, one would consider not only the human factors involved in a road accident (e.g., driver age, experience, fatigue, etc.) but also the interactions between each of those factors and the nature of the vehicle (e.g., model and type, roadworthiness, instrument configuration, etc.). Noy argued that studies of motor vehicle accidents could be strengthened if carried out within a model that emphasizes interactive relationships between Haddon's four basic elements of a highway event.

3. HUMAN (H) ATTRIBUTES AND TRAITS AS FACTORS IN ROAD ACCIDENTS

Na Ayuthya and Bohning (1997) reported that the highest risk of accident-related injuries in metropolitan Bangkok occurred among single male motorcyclists, aged 20 to 24, who were labourers or salespeople. Hauswald (1997) found that about 60% of Kuala Lumpur taxi drivers stopped for curbside inspections had failed to latch their seatbelts. Conrad et. al. (1996) reported that only 55% of sampled motorcyclists in urban Indonesia strapped on their protective headgear correctly. Lau et. al. (1998) reported that pedestrian behaviour contributed to about three-quarters of all pedestrian fatalities in Singapore from 1990 to 1994. All these findings raise questions that merit further investigation.

Left-handedness has been suggested by some North American researchers as a factor in the causation of road accidents and reduced longevity (Coren & Halpern, 1991). This hypothesis has been staunchly rejected by other authors (Lembessis & Fudin, 1994). Mixed-handedness may be a more important factor (Hicks et. al., 1998), an observation that could have implications for Asian cultural settings where the avoidance of sinistrality is encouraged (Hoosain, 1990). Research into the relationship between traffic accidents and the consistency of hand preference among Southeast Asian drivers is warranted.

Other research questions relate to the analysis of personality traits that may predispose individuals toward dangerous driving. Western studies have demonstrated that higher extraversion, impulsivity and aggression, and lower social adjustment correspond with increased risk of involvement in road accidents (Oborne, 1995). It would be valuable to examine the cross-cultural generalizability of these findings.

Locus of control – or an orientation toward fatalism – is a trait that may also be worthy of study. Drivers with an internal locus of control assume personal responsibility for their actions, while externalizers attribute outcomes to outside forces. Harrell (1995) sampled Canadian wheat farmers to show that those incurring injuries in the field were more likely to score high on a measure of risk-taking and to believe that their accidents had been caused by fate. Dixey (1999) found relationships between road accidents and fatalist attitudes in Nigeria. Attitudes toward fate have been shown to be instrumental in determining the level of risk that persons will take with regard to delaying treatment for illness (Chung et. al., 1999). An Asian cultural orientation to let destiny run its course may be a factor in the causation of road accidents.

4. HUMAN/VEHICLE (V*E) INTERACTIONS: MOTORCYCLE ACCIDENTS

The interaction of human characteristics with motorcycles illustrates the value of the modified Haddon matrix. In Malaysia, alone, approximately 68% of all traffic injuries involve motorcyclists and their overall relative risk is about 20 times higher than passenger cars (Radin et. al., 1998). Cubic capacity of the motorcycle is a significant factor in the risk of accident and in the severity of resulting injury (Wick et. al., 1998). At the same time, internal factors related to the experience, attitudes, values and motivations of the individual are critical, as well (Norghani et. al., 1998).

Reeder et. al. (1996) studied young motorcyclists in New Zealand and reported that their reasons for riding included excitement, economical and maneuverable transport, and freedom from supervision. Riders' perception of risk and their behaviour in traffic may be significantly shaped by the fact that they are interacting with a motorcycle, as opposed to another type of vehicle. These effects demand more intensive study, however, particularly in Southeast Asia where reasons for motorcycle use may well be influenced by more pragmatic occupational obligations and socioeconomic status.

5. HUMAN/ENVIRONMENT (H*E) INTERACTIONS: MALAYSIAN HOLIDAY TRAVEL

The revised Haddon matrix is helpful for recognizing interactions between the driver and the driving environment. Typically, the study of environmental factors in road accidents has included adverse weather, daylight or night-time conditions, roadway obstructions and other physical variables. The notion of the "driving environment", though, can also be broadened to include the social/societal milieu, the regulatory regime and the interpersonal circumstances under which motoring activity occurs (Radin, et. al., 1998).

The observance of several special holidays – notably Thaipusam, Hari Raya Aidilfitri and the Lunar New Year – within a four to six week span each year creates a unique driving environment on Malaysian highways. Roads become crowded with holiday travellers on their way to other locations and arrival times for family visitation or religious observances become more important. Hurrying becomes normative. Accident and road fatality rates soar.

Future research needs to focus on the way Malaysian drivers respond to the extra workload (Verwey, 2000) and special conditions created by this festive period. Papacostos & Synodinos (1988) identified four dimensions of driving behaviour in traffic: "usurpation of right-of-way"; "freeway urgency"; "externally-focused frustration"; and, "destination-activity orientation". Driving practices relative to each of these dimensions would be expected to vary according to the unusual traffic mix and speed differential that characterize the festive travel period. At the same time, driver personality traits, fatigue level, risk perception, locus of control (or fatalism) and other attributes would have effects, as well. The expansion of Haddon's matrix to provide for the interaction of human characteristics with environmental conditions strengthens the conceptual framework for research exploration in this area.

6. HUMAN/VEHICLE/ROAD/ENVIRONMENT INTERACTION (H*V*R*E): ITS TECHNOLOGY

Intelligent Transportation Systems (ITS) are a class of new technologies that include crash warning systems, automated travel management, video enforcement, automated toll collection, smart cards and advanced traffic management. ITS implementation serves a range of objectives, including the improvement of traffic network efficiency, reduced fuel consumption and vehicle emissions and, not the least, road safety (Van Aerde, 1995).

However, claims that ITS technologies will create immediate and significant safety improvements have not gone unchallenged. Little (1997) pointed out that a "smorgasboard" of uncoordinated and competing technologies could distract and overwhelm drivers, with a consequent reduction in safety. Noy (1997) noted that the evaluation of ITS devices has tended to focus on their technical capabilities rather than the manner in which they are incorporated within the vehicle and presented to the driver. Ultimately, the effect of ITS technology on safety, according to Noy, depends on the way it is engineered to co-interact with the driver and the vehicle, under a range of environmental conditions. This, again, is reflected in the expanded Haddon matrix.

This has significant importance for Southeast Asia, where ITS implementation has already been targeted by governments in Singapore, Malaysia and elsewhere. Standards for new technologies will need to be developed or adopted internationally. In both standards-setting and product certification testing, it will be important to consider human factors prior to product market release and installation.

7. CONCLUSION

Ergonomic research is an important component in the design of transportation systems suitable for Southeast Asia and for preventive efforts aimed at reducing traffic accidents. A number of driver-related variables can be identified, but it is essential to consider their interaction with road, vehicle and environmental conditions. It is concluded that this can be done best when methodology is based on a modified Haddon (1970) matrix.

REFERENCES

1. Chung, T.K., French, P., and Chan, S. (1999). Patient-related barriers to cancer pain management in a palliative care setting in Hong Kong. *Cancer Nursing, 22*(3):196-203.
2. Conrad, P., Bradshaw, Y.S., Lamsudin, R., Kasniyah, N. and Costello, C. (1996). Helmets, injuries and cultural definitions: motorcycle injury in urban Indonesia. *Accident Analysis and Prevention, 28*(2): 193-200.
3. Coren, S. and Halpern, D.F. (1991). Left-handedness: a marker for decreased survival fitness. *Psychological Bulletin, 109*(1):90-106.

4. Dixey, R.A. (1999). 'Fatalism', accident causation and prevention: issues for health promotion from an exploratory study in a Yoruba town, Nigeria. *Health Education Research 14*(2):197-208.
5. Haddon, W. Jr. (1970). A logical framework for categorizing highway safety phenomena and activity. Paper presented at the 10th International Study Week in Traffic and Safety Engineering, Rotterdam, 7-11 September.
6. Harrell, W.A. (1995). Factors influencing involvement in farm accidents. *Perceptual Motor Skills, 81*(2):592-594.
7. Hauswald, M. (1997). Seat belt use in a developing country: covert noncompliance with a primary enforcement law in Malaysia. *Accident Analysis and Prevention, 29*(5): 695-697.
8. Hicks, R.A., Inman, G., Ching, P., Bautista, J., Deharo, D., and Hicks G.J. (1998). Consistency of hand use and accidents with injury. *Perceptual Motor Skills 87*(3, Pt 1): 851-4.
9. Hoosain, R. (1990). Left-handedness and handedness switch amongst the Chinese. *Cortex 26*(3):451-454.
10. Lau, G., Seow, E. and Lim, E.S. (1998). A review of pedestrian fatalities in Singapore from 1990 to 1994. *Annals of the Academy of Medicine, Singapore, 27*(6): 830-837.
11. Lembessis, E. and Fudin, R. (1994). Sinistrality and reduced longevity: reply to Coren and Halpern's replay. *Perceptual Motor Skills, 78*(2):679-582.
12. Little, C. (1997). The intelligent vehicle initiative: advancing "human-centered" smart vehicles. *Public Roads, 61*(2):112-122.
13. Na Ayuthya, R.S. and Bohning, D. (1997). Risk factors for traffic accidents in Bangkok Metropolis: a case-reference study. *Southeast Asian Journal of Tropical Medicine, 28*(4): 881-885.
14. Norghani, M., Zainuddin, A., Radin Umar, R.S. Hussain, H. (1998). *Motorcycle Safety Program: Use of Exposure Control Methods to Tackle Motorcycle Accidents in Malaysia.* Research Report No. 3/98, Prepared for Ministry of Transport Malaysia, Kuala Lumpur.
15. Noy, Y.I. (1997) Human factors in modern traffic systems. *Ergonomics, 40*(10):1016-24.
16. Oborne, D.J. (1995). *Ergonomics at Work: Human Factors in Design and Development.* Chichester (West Sussex): John Wiley & Sons.
17. Papacostas, C.S. and Synodinos, N.E. (1988). Dimensions of driving behaviour and driver characteristics. *Applied Psychology: An International Review, 37*(1):3-13.
18. Radin Umar R.S., Norghani, M., Hussain, H., Shakoor, B., and Hamdan, M.M. (1998). *Short and Long Term Plan of Action on Motorcycle Safety Programs.* Research Report 1/98, Ministry of Transport Malaysia, Kuala Lumpur.
19. Reeder, A.I., Chalmers, D.J. and Langley, J.D. (1996). Rider training, reasons for riding, and the social context of riding among young on-road motorcyclists in New Zealand. *Australian and New Zealand Journal of Public Health 20*(4):369-374.
20. Swaddiwudhipong, W., Nguntra, P., Mahasakpan, P. Koonchote, S., and Tantiratna, G. (1994). Epidemiologic characteristics of drivers, vehicles, pedestrians and road environments involved in road traffic injuries in rural Thailand. *Southeast Asian Journal of Tropical Medicine and Public Health, 25*(1): 37-44.
21. Van Aerde, M. (1995). Estimating safety impacts of full deployment of an ITS. *Workshop Proceedings: Safety Evaluation of Intelligent Transportation Systems,* ITS America and Human Factors Committee and the National Highway Traffic Safety Administration. Reston, Virginia, May 1-2.
22. Verwey, W.B. (2000). On-line driver workload estimation. Effects of road situation and age on secondary task measures. *Ergonomics, 43*(2): 187-209.
23. Wick, M., Muller, E.J., Ekkernkamp, A. and Muhr, G. (1998). The motorcyclist: easy rider or easy victim? An analysis of motorcycle accidents in Germany. *American Journal of Emergency Medicine, 16*(3): 320-323.
24. Williams, A.F. (1999). The Haddon matrix: its contribution to injury prevention and control. Paper presented at the Third National Conference on Injury Prevention and Control, Queensland, Australia. Arlington, VA: Insurance Institute for Highway Safety.

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Ergonomic Guidelines for the Driver System Interface: Help for the Road Safety Design Process

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A set of ergonomics design guidelines for in-vehicle systems has been defined, based upon expert evaluations and experiments. They have been classified and structured in a handbook according to their content and for two applications: "Road and Traffic Information" and "Guidance/Navigation". These guidelines can be used by designers as a "check list", to verify that most of the key elements related to human-centred design have been taken into consideration.

1. INTRODUCTION

Nowadays, the vehicle is on the way to change deeply, due to the increasing part taken by the implementation of telematics technology, allowing to establish bi-directional communication between the driver and the external world. Indeed, an increase number of functions are going to be available inside the car. These functions will be more or less in connection with the driving activity itself: guidance and navigation, information on traffic and other road events in real time, collision avoidance and adaptive cruise control, internet and web sites access, communications on mobile phone, etc. [1, 2]. These technologies can also aim at enhancing driver's perception of the road environment in case of specific conditions such as night, fog, icy road, by sensors that give more precise information than the human perception itself. It has to be noted that the border between the various systems, in terms of functions, can be fuzzy. For example, the mobile phone, in addition to personal and professional phone communications, will soon offer other kind of services to the user, with some of them directly connected to the driving task, such as guidance and navigation, traffic information on real time, etc. [3].

Due of these technologies, the driver is less isolated inside the vehicle. He can be contacted and be informed about any kind of immediate or middle term events that are related to his route. He can also send emergency calls in case of problems. He can have enhanced vision of the road environment by sensors. He can also quickly react to unpredicted events by automatic control of his vehicle.

Obviously, this interactive communication between the driver and the external world for various aspects directly connected to the driving task can be a relevant support in terms of anticipation, orientation processes and decision making, with positive consequences in terms of road safety.

Nevertheless, the interference due to the display of untimely auditory or complex visual messages with the driving task has to be deeply investigated beforehand, to avoid making the new driving context worse than the original one, rather than better.

The purpose of this paper is to discuss, in the context of road safety issues, ergonomics of these in-vehicle systems interfaces, by proposing guidelines and recommendations related to the design process in order to help developers set up adequate interfaces, and to avoid misconception thereby inducing potential disturbances on the main activity of driving task.

2. GUIDELINES AND DESIGN PROCESS

The designer is working under time constraint, and has to resolve an important amount of crucial technical problems, in addition to the ergonomics specifications. Furthermore, the designer is aware of the responsibility he has concerning the system liability and safety in the context of the vehicle development. So, according to these constraints, supporting ergonomics data concerning the interface and the dialogue features, to make the process easier and more efficient, are usually welcome by designers.

This research aimed at setting up a set of ergonomic guidelines devoted to the system designer, in order to aid this activity from the ergonomic side. In this context, the ergonomic guidelines are defined as "recommendations and advice given to the designers in a form that can be directly applied to the product".

The interest of the guidelines is two-fold: firstly, as said, to support the design process, and secondly, to allow consistency among systems concerning the logic of their display and their use.

- These guidelines are proposed to the designers as potential resource in order to integrate a user-oriented approach in the early stages of their system development, with the final objective of ensuring system usability. The design process can then be quicker because, even if it requires more work to be integrated at the first step of the concept definition and prototyping, it allows making lighter the processes subsequent of mock-up or prototype evaluation. And, in the context of road safety, it can help to avoid misconception.
- If all the systems are developed according to the same set of main ergonomic principles, then, there will be design consistency among them. The drivers will be able to find landmarks and common logic of use, whatever the systems or the functions.

3. HANDBOOK OF ERGONOMIC GUIDELINES

3.1. Scope and definition

The work conducted was to define design guidelines for "Road and Traffic Information" system (system providing information to the driver regarding the features of the road network, particularly any potential hazards and congestion information), and for "Guidance and Navigation" system, supporting drivers' orientation processes after the selection of a precise destination (the Guidance system is a system which computes the best route to follow based on specific criteria, and gives to the driver guidance instructions in the course of the journey by displaying simple arrows before each manoeuvre; the Navigation system provides support to the driver by displaying an electronic map indicating vehicle position and destination point, with the route to follow underlined on the map, and the driver is expected to actively make navigation decisions at each intersection according to this information).

The gathering of these guidelines was based upon previous expert evaluations of various types of systems [4] and experimental approaches conducted on real road context and driving simulator (e.g. European project HARDIE [5, 6]; European project BERTIE [7], experimentation on the system CARMINAT [8] ; experiments on landmarks [9]).

These expertise and experimental approaches focused on some specific ergonomics aspects of the system interface and functions, such as the comparison between the use of simple arrows for guidance or complex road map for navigation.

The approach has been to gather data of these scattered origins to define the corresponding guidelines in a consistent format corresponding to each main result, structure the pool of guidelines in a usable way for readers, add explanation about the rationale of the guideline to increase its understanding, precise the references of scientific papers on the topic for additional reading and to produce a guideline handbook.

- Format of the guideline: clear and synthetic statement, to be usable quickly, illustrated with schema and drawings when necessary, showing examples of recommended and not recommended designs.
- Rationale of the guideline: additional information explaining the reason underneath the guideline, allowing to define the limits of its application, as there are no universal guidelines.
- References: the reader can refer to them if he needs more complete information.
- Cross guidelines: key words allowing to establish links between guidelines of close scopes, in order for the reader to have an overall view of the question and an easy navigation in the handbook.

From a general point of view, the guidelines were set out according to the following difficult compromise: to be precise enough to be usable by the designer, and to be general enough, so that they may apply to many different systems even in the future. Thus, most of the generally worded guidelines describe general principles, and can require to be translated into specific design rules adapted to the context to be applied. Some other precisely worded guidelines have been specifically set up for defined applications and context.

In the design process, it may be necessary to trade off the competing demands of different guidelines in terms of operational requirements. Indeed, not all the guidelines have the same priorities. That is to say, design guidelines are not " golden rules" and must be adapted to the design constraints and specific context; they can be considered alongside implementation requirements early in the design process, and have to be integrated in relation to a thorough understanding of the task requirements and the user characteristics.

Furthermore, the use of the guidelines does not prevent, replace or eliminate the need for a comprehensive evaluation process on the mock-up or the prototype among the final user population.

3.2. Structure and content

The guidelines have been classified according to the two main applications:

1) Road and Traffic Information, for critical road events allowing anticipation, and reorientation of the drivers, and
2) Guidance and Navigation, supporting orientation processes.

The headlines of these two parts are given in the table below, with one or several guidelines available for each topic.

Road and Traffic Information Design Guidelines
Information presentation types : Visual (pictogram, symbols, text, abbreviations, map), Auditory (tonal code, speech), Auditory versus Visual
System interaction : System state, RDS reception, R&T information selection
Information structure and content : Visual (general, association of pictogram and text, message vocabulary and structure, event location, traffic congestion), Auditory (vocabulary, length of message, availability, scheduling)
Harmonisation of vehicle and road information : Text, Pictogram, Association of pictogram and text
Integration with guidance and navigation applications : R & T information on navigation display, R & T information on guidance display.

Route Guidance and Navigation Design Guidelines
Navigation versus Guidance
Information content : General, Landmarks, Street names, Road layout, Distance, Location
Scheduling of information : Advance information, Timing of instruction, Stacking of instructions, Visual versus Auditory information
Maps : Information content and complexity, Colour coding, Text display, Scale, North-up versus Heading-up
Turn-by-turn information : Information content and complexity, Icons versus Arrows versus Text, North-up versus Heading-up, Text, Message structure, repeating messages
Linking to external information
Visual information : Physical characteristics, Information design aspects, System interaction
Auditory information : Physical characteristics, Information design aspects

4. INTEGRATION OF ELDERLY DRIVER CHARACTERISTICS

Concerning the definition of guidelines, a specific care has been devoted to the functional abilities of elderly drivers, when data were available concerning this point. So, many ergonomic criteria took into account the specificity of elderly drivers, in order to avoid overlooking the variability due to age in the design recommendations.

Indeed, the ratio of older drivers increases in the population. Therefore, telematics systems have to be designed carefully, to avoid to create critical conditions for this part of the population. Furthermore, these systems, if they are correctly designed for this purpose, can constitute a very useful compensation to some functional perceptive and cognitive deficiencies due to age.

So, it is important to take elderly functional abilities into consideration in the early development of the systems, especially knowing that recommendations necessary to satisfy elderly needs and requirements (improved legibility, easy navigation, clear instructions), are beneficial most of the time for the younger population of users [10].

5. CONCLUSION

Many studies from these last decades have been devoted to ergonomics of in-vehicle systems, stimulated by the road safety issue and by the potential benefit gained from these systems implementation. The set out of the main results into ergonomic guidelines, gathered and classified in a handbook, allowed, firstly to make this data easily available to designers, and secondly, to identify possible gaps in the knowledge in order to define further research priorities.

The use of guidelines allows more efficient design process, especially if they are taken into account at the early stages; it does not prevent, or replace, necessary evaluation of the specific product in its final context.

REFERENCES

1. T. Ross, K. Midtland, M. Fuchs, A. Pauzié, A. Engerts, B. Duncan, G. Vaughan, M. Vernet, H. Peters, G. Burnett and A. May, DRIVE II / HARDIE Design Guidelines Handbook, Human Factors Guidelines for Information Presentation by ATT Systems, 468 p., (1996).
2. A. Pauzié and C. Gabaude, Ergonomics of Telematics in Transport : Needs and Requirements of Elderly Travellers, ASEAN ERGO 1997, 5th SEAES Conference, Kuala Lumpour, Malaisia (1997).
3. A. Pauzié, The concept of the use of mock-ups for the design of multimodal information systems, Design of multimodal information systems, CODE project conference, Lisbon, (1999).
4. C. Nicolle, T. Ross, A. Pauzié and C. Eggerdiner, Expert evaluations of route guidance and navigation systems, DRIVE II / HARDIE Deliverable n° 8, 52 p., (1993).
5. A. Pauzié, Human factors design guidelines for information presentation by route guidance and navigation systems, DRIVE II / HARDIE Deliverable n° 19, Supplement Report, 19 p, (1996).
6. A. Pauzié and M. Vernet, Human factors design guidelines for traffic and road information presentation, DRIVE II / HARDIE Deliverable n° 24, Supplement Report, 21 p, (1996).
7. M.C. Ashby, S.H. Fairclough and A.M. Parkes, A comparison of two route information systems in an urban environment, DRIVE II / BERTIE Deliverable n°49, (1991).
8. A. Pauzié and J-F. Forzy, Ergonomic evaluation of guidance and traffic information in the CARMINAT program, III Annual World Congress on Intelligent Transport Systems, Orlando, (1996).
9. A. Pauzié, T. Daimon and M-P. Bruyas, How to design landmarks for guidance systems ?, IV World Congress on Intelligent Transport Systems, Berlin, (1997).
10. A. Pauzié, Elderly drivers faced with new technologies : consequences for the ergonomic design of driving aid systems, " Working with age ", Marquié, Paumes-Caubareille & Volkoff (eds), pp 285-294, Taylor & Francis, 1998.

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Safety Clothing: User-Oriented Product Development and Evaluation

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This paper outlines a user-oriented, systematic development and ergonomic evaluation of an innovative safety overall. Workplace safety has come to the fore recently after a series of accidents related to work. New Zealand's leading cause of injury in the workplace is by falls or a loss of balance (Accident Compensation Corporation Report, 1998). New Zealand has the third highest number of fall related fatalities in construction and the second highest fatality rate per 100,000 workers in the world (New Zealand Official Yearbook, 1998). This has prompted a demand for increased safety levels and equipment in the workplace. Legislation changes have introduced the compulsory use of Fall-Arrest Safety Harnesses when working at a height.

1. RESEARCH AND PRODUCT IDEAS

1.1. Aim: The research began in February 1999 and the aim was to design a safety harness integrated into a pair of work overalls, to form a modular, user-friendly safety harness system.

1.2. Main Objectives

- Identify the characteristics of a safety harness, and design an integrated system
- Investigate and confirm the materials to be used for the work overalls
- Create a prototype that meets ergonomic standards
- Test the prototype with users to ensure that it meets their needs

1.3. Project Constraints

- Time – approximately eight months from the start date.
- Legal – the product must comply with the Australia/New Zealand Safety Standard 1891.1:1995
- Patents on existing products
- Logistical – channels of supply, manufacture and distribution initially unknown

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1.4. Initial Market Research

1.4.1. Objectives

- Explore the range of designs, features that are used currently
- Determine market leaders/benchmarks
- Identify who the product users and buyers are
- Determine the size of the target market and their requirements
- Gauge the importance of characteristics of existing products from the product users and identify problems, if any.
- Determine attributes and characteristics that must be integrated into the proposed product by law and the standards associated with this product.

1.4.2. Brief Outcomes

- Problems with existing safety harnesses include: comfort, fit, difficulty to put on properly and easily and a less frequently mentioned reason - *"do not want to be seen to be wearing a safety harness as it goes against their macho image!"*
- Currently no product such as the modular combination of harness and overalls exists in the New Zealand market.
- There are two safety harnesses priced at NZ $490 and $230, made by Australian companies (names are omitted here in order to maintain confidentiality).
- There are two market leaders in the field of standard work-overalls - an Australian and a New Zealand company.
- The standard work overalls are sold separately from the safety harnesses and range in price from $50-$100. It can be seen that currently a safety harness plus overalls could cost approximately NZ$300 - $650.

1.5. User & Ergonomic Research Summary

Consumer Profile: Predominantly male, aged between 18 – 55 years

Target Markets: Construction workers, builders, painters, scaffolders, commercial and domestic cleaners, power company linesmen, oil rig workers, anyone working at a height.

Desired user & ergonomic requirements

- To fit a maximum number of New Zealand/Australian males aged 18-55 years
- Anthropometric guidelines (AUS/NZ 1891.1:1995; Dreyfuss, 1978; Murrel, 1979)
- Safe
- Lightweight
- Adjustable and modular
- Ease of movement
- More comfort while wearing the product

1.6. Idea Generation

Several sources for product ideas and idea-generation techniques were used:

- Competitor Analysis – retailer interviews, photographs/ brochures, patent search, qualitative user research, trade magazines

- Brainstorming with users, expert consultations (Ass.Prof Stephen Legg, certified ergonomist, Massey University), mind mapping and image boards.

2. PRODUCT DESIGN AND MANUFACTURE

2.1 Concept Generation

Concept Statement: The proposed product will consist of an adjustable and lightweight safety harness that can be integrated into a pair of work overalls. It will be easier to put on than existing products and will ensure that the harness is worn correctly. It will also offer ease of movement and comfort to the wearer while working, and provide safety to the wearer in the event of a fall.

A structured screening method was used to select the best and most viable model to take further into prototype development. A screening matrix based upon a range of technical and performance based assessment criteria (manufacturable, adjustable, simple, ease of movement, ease of integration, comfort, lightweight and thermal factors) were used to rate and select the best models.

- Several harness designs were produced and assessed. Discussions with manufacturers resulted in selecting a modified version of the Fall-Arrest Safety harness, for economical reasons and its apparent simplicity and ease of integration into overalls.
- The use of Velcro sleeves as opposed to a completely sewn in sleeve was chosen to help integrate and remove the Safety Harness from the overalls.

2.2 Material Considerations

For the work overalls, the polycotton blend material (65% polyester and 35% cotton) was preferred to the 100% cotton material because it is lighter, relatively longer lasting and costs less. There are strict limitations by law (AUS/NZ 1891.1:1995) on the materials that can be used for safety harnesses. The webbing and thread used on the harness must be made from high tenacity synthetic fibre. All the buckles will be made from strengthened steel, as they are readily available, strong and cost much less than other materials.

2.3 Manufacture

This stage included the finalisation of all components to be used in the product and their respective costs. End user's key attributes (easier to put on, more comfortable to wear, extra attachments, a front anchorage point for abseiling) were considered and incorporated into the harness design. The next stage was to integrate the harness into the overalls, so that the number of production processes involved are minimised. This stage was also used to try and maximise the comfort to the wearer and the product's ease of use. This involved detailed specifications and physical model making at the manufacturing factory in Manukau, Auckland on 14th July 1999.

3. PROTOTYPE AND USER EVALUATION

The initial prototype was tested with the target market to ensure that their requirements were met. Based on the feedback the model underwent more changes, reflecting the iterative development process based on user evaluation:

- The choice of bibbed, sleeve-less overalls instead of full-length overalls.
- The use of a modified Fall-Arrest Safety Harness
- The use of velcro flaps was discarded due to the high manufacturing time and cost and was replaced by the use of slits for the harness to feed through.

3.1. Ergonomic Evaluation

The modified Safety Harness-overalls should meet the requirements of the AUS/NZ safety Standard relating to Fall-Arrest Harnesses and Devices. This includes:

- Resistance of webbing to light
- Static loading test (Harness subject to constant 15kN force for 3minutes duration)
- Dynamic loading test (100 kg dummy is repeatedly dropped from a height so that only 2m of fall occurs before restrained)
- Proof loading of attachment hardware

3.2. Static and Accelerated Loading Test

Aim: To ensure that the safety and strength of the harness component and attachment have not been compromised due to its integration into the overalls.

Method: A volunteer human subject approximately 100 kgs was suspended from a height (at the 'City Rock' climbing gym, Palmerston North, New Zealand) for a short period of time. A 100 kgs dummy was suspended for a much longer time to test accelerated wear.

Results: It was found that there was no damage or deformation to the Safety Harness or the attachment on the safety Harness. No damage was incurred by the 'overalls' component. The harness-overalls combination remained together during both tests.

3.3. Dynamic Loading Test

Aim: To test the products performance and study the effects of a fall

Method: The same subject wore the proposed product and was connected to a belay line at the anchorage attachment on the rear of the harness system. The subject was then asked to climb up the wall to a safe height where possible injury would be minimised and then to let go. Enough line was let out so the maximum distance that the subject would fall would be approximately 2 feet.

Results: The subject was restrained in the fall by the product and was not injured. It was found that there was no damage done to the harness-overalls system from the fall.

3.4. User Trials – Simulated and Field Tests

3.4.1 Simulated Test

Aim: To gauge user satisfaction and test the product in a *simulated* environment.

Method: The insertion of the harness into the overalls was demonstrated to roofing and construction workers at Palmerston North, New Zealand, and they were requested to do the same. The workers were then asked to put on the harness/overall system and adjust it to fit their body and perform a number of different tasks, in order to test for restrictions in movement and comfort. Test subjects were then asked a series of questions to gauge their satisfaction of the product.

Results: Some of the users found the insertion of the Harness into the overalls confusing at first but with further instructions they were able to insert the harness on their own.

All users found the adjustment of the buckles to be easy and accessible, except for the chest buckles where the velcro sleeve integration method was used and it was found that the sleeves were too long and partially covered the buckles. While wearing the overall-harness system, movement was found to be easier and more comfortable than an ordinary Fall-Arrest Safety Harness, due to the fact that the webbing straps were tucked away inside of the velcro sleeves. This stopped any entanglements with clothing and held the harness away from the body somewhat.

It was found that the domes on the rear flap of the overalls where the harness is exposed sometimes popped open in some positions that placed a large strain on the overalls. All of the users expressed how excited they were about the new product and also expressed a willingness to purchase the product when released in the market.

3.4.2 Field Test

Aim: To test the product and gauge consumer satisfaction while being used over a longer period of time in the *natural* work environment.

Method: Construction workers at Able & Allan Ltd, Auckland, New Zealand wore the harness system for a week during work. At the end of the test period, problems and or benefits were reported back to the research team.

Results: Some minor problems were uncovered in this test including:

- the tunnels in the shoulders were too long
- the domes at the rear of the overalls kept getting caught up on things
- workers struggled to pull the overalls over their boots while they were wearing them.

3.5. Product Modifications Based On Testing

It can be concluded that the modified harness system functioned successfully. However, based on some of the problems identified in the above tests, a number of further modifications were made. These included:

- Shorter velcro tunnels were placed in the shoulders of the overalls to allow easier access to the safety harness adjustment buckles.
- Zips have been placed on the side of the legs of the overalls to allow the product to be put on over the work boots while the person is wearing them.

- Cargo pockets have been added to the side of the overall leg, above the knee, for extra storage to the user while working.
- Domes at the rear have been replaced with a permanently sewn strip that still allows the harness leg-loops to be fed through two slits.

4. COMMERCIALISATION

'Fraseon' overalls (Work overalls with a Fall-Arrest Safety Harness): A harness-overall system that is safer, more comfortable and easier to put on, plus overalls with zipped legs and cargo pockets for extra storage.

In New Zealand the market size is estimated to be approximately 10 000 people. The Australian market is estimated to be approximately 100 000 people. The product can be distributed through the existing network of 13 retail outlets throughout New Zealand. and will have distribution rights in New Zealand. The distribution of the proposed product in Australia is being negotiated at this stage. It is estimated that the product will enter both the New Zealand and Australian markets in 2000.

It is suggested to advertise in building trade journals, work-safety and Consumer magazines. The editor of 'Safeguard' magazine has expressed interest to publish an article on the product. This is the official journal for OSH (Occupational Safety and Health) and ACC (Accident Compensation Corporation, New Zealand).

It is planned to gain endorsements for the product from OSH and the New Zealand Master Builders Association. Along with the product's patent, this endorsement could be outlined in promotional materials. In addition, large construction companies in NZ could be approached using a sales representative. The 'Fraseon" product could be displayed at Safety Trade shows (held in Auckland and Australia each year). *'Fraseon'* has been registered as a trademark in New Zealand.

4.1. Financial Assessment

The Net Present Value (NPV) for the New Zealand firm has been calculated at NZ $150,008 and for the Australian firm at NZ $492,683 (detailed calculations are excluded here to maintain confidentiality, but can be provided confidentially, if required). The project will be able to cover all of its costs and be profitable. The Internal Rate of Return (IRR) for the New Zealand firm has been calculated at 519.8 % and for the Australian firm at 432.5 %. The payback period for the investment is approximately 3 months. Some points to consider:

- Competition from new products that may be introduced in the future
- Aggressive marketing strategies from existing manufacturers
- Changing interest or inflation rates could increase the risk

5. CONCLUSIONS

The applied product development methodology, starting from the initial user research, right through to the development, evaluation and commercialisation strategies demonstrates a successful user-oriented approach. The systematic research resulted in a patentable, commercial product that meets end user needs. It achieved the objectives of incorporating user requirements to produce a safer, more comfortable and easy-to-use harness system.

In future, if the target market expands to include females, then female anthropometric data should be considered and a product designed specifically to suit them.

REFERENCES

1. Accident Compensation Corporation Report, New Zealand, 1998.
2. New Zealand Official Yearbook, 1998.
3. Australia/New Zealand Standards 1891.1:1995
4. H. Dreyfuss, The Measure Of Man - Human Factors In Design, Whitney, 1978.
5. K.F.H. Murrel, Ergonomics: Man In His Working Environment, Chapman and Hall, 1979.

PART TEN

Human Factors of E-Commerce

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Evaluation of A Virtual Conference: CybErg 1999

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CybErg 1999 was a virtual conference held entirely on the World Wide Web. This paper presents an evaluation of the success of the conference when compared to its predecessor: CybErg 1996. The evaluation shows that CybErg 1999 was perceived to be easier to use and created more specific discussion than CybErg 1996.

1. INTRODUCTION

It was recently estimated that 242 million people from around the world are connected together through their personal computers on the World Wide Web (Commercenet, 2000). This source of easy communication has led to professional and academic institutions utilising the web for the purpose of discussion and expansion of ties amongst colleagues (Ransdell & Anderson, 1995). One such form of this communication is to stage a virtual, or cyber conference.

Virtual conferences attempt to replicate the structure and format of a traditional academic conference on the web. They consist of a web site where participants can view papers (usually in text format, with some graphics) and then submit their written questions about the paper for the authors or anyone else who may care to respond. Virtual conferences may also feature 'chat bars' for discussion on non-technical matters, information boards for the posting of notices during the conference and exhibitions of commercial products.

Unlike at a traditional conference, the existence of a number of 'parallel' sessions at a virtual conference does not preclude 'attendance' at any paper, as all papers can be accessed at any time during the conference. A virtual conference is usually active for a limited period of time, so that it is possible for participants to monitor the discussions of interest, unlike virtual journals, which tend to be limited to publishing papers, without the attached discussion.

The existence of such conferences has the potential to greatly increase the accessibility to academic discussion for those people who are unable to travel to traditional conferences. Factors limiting traditional conference attendance are likely to include time (people may not be able to dedicate the number of days required to travel to and attend a conference) and money (for travel, accommodation and registration costs). Both these factors are reduced substantially with virtual conferences. If an academic has access to a computer linked to the web, financial costs are minimal and the time required to participate, whilst potentially no different overall, can be structured to fit in with the participant's other commitments.

The potential downside of virtual conferences is that the lack of financial and time resources required to participate may reduce commitment to participate. Participants may be distracted from the issues being discussed at the conference by other events going on in their 'real' world. In addition, the issues of interacting with the computer itself may interfere with the ability to participate - people may be motivated to participate, but prevented from doing so by poor interaction requirements.

The purpose of this paper is to compare a recent virtual conference (CybErg 1999) with a similar conference held in 1996 (CybErg 1996).

1.1 CybErg 1996

CybErg 1996 was a virtual conference on ergonomics that was held on the web from 1-30 September 1996. During that period 56 papers covering a range of ergonomics issues were presented and discussed. The papers were in text and graphic form, but did not include sound or video formats. Authors and other attendees were able to comment on, question or provide answers regarding each paper and on general ergonomic issues. In addition to complete papers, the paper's abstracts could be accessed separately, as could biographies and, in most cases, photographs of the authors. Also available at the conference was a Chat Bar for social interaction with other participants, a Virtual Tour of Western Australia (the location of the conference convenors), a community noticeboard and links to other ergonomics information on the Internet. Attendance was free, simply requiring registration. A more detailed description of the conference is provided in the conference opening address (Straker, Pollock, Case and Kemp). The web site for the conference can still be viewed (http://www.curtin.edu.au/conference/cyberg/centre/), although active discussion at the conference finished at the end of the conference period.

After CybErg 1996 an evaluation (Pollock, Straker and Forgione, 1999) identified a general positive impression from the conference plus some suggestions for changes. Good aspects identified included the nature of the discussions:

- opportunity to read a paper in full before commenting,
- greater time to compose one's question or answer,
- good for those with lesser English or public speaking skills, and
- the opportunity to ask questions on any paper at any time.

Aspects participants suggested changing included:

- the discussion software (there was no indication of the amount and newness of discussion on any paper),
- speed of response (slowness did appear to impede interaction for some),
- navigation structure ('flatter' hierarchy of menus to access papers and a complete lists of papers rather than conference 'streams' suggested),
- difficulty with 'frames' (which divide the screen into two windows).

Based on the evaluation of CybErg 1996, several changes were made for CybErg 1999.

1.2 CybErg 1999

CybErg 1999 was active from 15 September to 15 October 1999. It featured 62 papers (7 invited, 55 selected from submitted abstracts) that were presented in text form with some graphics. One critical difference between the two conferences was that participants were asked to pay a registration fee of Aus$110 to participate in CybErg 1999 (registration had been free in 1996 as all costs were covered by the sponsors). Other changes made for CybErg 1999 were aimed at increasing quality interactions and making interaction easier and faster.

The conference site can still be accessed at http://cyberg.curtin.edu.au/members/

More quality discussion: CybErg 1999 introduced special symposia on controversial topics to stimulate discussion and hopefully increase incentive to look at other areas of the conference. Authors were approached and asked to write specific 'position papers' on the symposia topics. In total seven invited papers in three symposia were included in CybErg 1999. Sponsorship was obtained to provide prizes for the top three papers of the conference and the best three contributors to the discussion at the conference (as voted by the scientific committee). 'Live' discussion sessions were held each Friday during the conference when people were encouraged to log on at the same time and participate in some 'real-time' discussion.

Easier interactions: CybErg 1999 used a flatter navigational structure with just two or three levels. Greater use was made of a menu bar at the top of every page to lead directly to the main parts of the conference, rather than having to navigate via the structure in the left-hand frame that had been used in CybErg 1996. New bulletin board software was used to manage the interactions. Besides its ease of use, it highlighted where most activity was taking place, monitored which comments were yet to be read and informed authors by email when a question had been asked about their paper.

Faster interactions: CybErg 1999 had its main site at Perth, Australia, but also had a 'mirror' site in the USA. This should have made access times quicker for people with faster links to USA than to Perth. In addition, both html and pdf versions of all papers were distributed to registrants before the conference so that people need not log into the CybErg site to access the papers, but could read them off-line and then just log on to the Perth site to participate in the discussion. It was hoped that accessing the data intensive parts of CybErg (the papers with figures) would therefore be much quicker.

Transmission speed is limited by a user's computer, modem and connection lines, as well as the content of the conference. Whilst increased use of video and audio might have added interest to the conference, current transmission times made these inadvisable for many users. CybErg 1999 was therefore kept very simple and lean to make interaction as fast as possible for all participants. For participants with slow connection links advice was given to download without images. The following evaluation looks at the extent to which the aims outlined above for CybErg 1999 were achieved.

2. METHOD

2.1 Procedure

The evaluation compares logged interaction data for the two CybErg conferences, as well as subjective evaluations by the participants. Data logs of the interactions with both the CybErg 1996 and CybErg 1999 were available. In addition, conference web-based evaluation forms were distributed to all participants by email at the conclusion of each of the conferences.

2.2 Measures

Data Logs: The participants interactions with the two CybErg conferences were logged by the web software. In addition, the content of the discussions were available for inspection. The variables extracted for this evaluation were:

- number of papers
- number of registrants
- countries represented by registrants
- number of discussion postings (ie questions and answers)
- number of discussion postings on papers versus general discussion

Evaluation forms: The CybErg evaluation forms asked subjects to indicate:

- the level of their interaction with the conference (Number of times conference accessed, number of papers read, etc),
- their perception of the quality of the conference (quality of papers relative to 'flesh' conference), and
- satisfaction with interface/interaction (navigation ease, speed of response)

3. RESULTS

3.1 Data Logs

CybErg 1996 had 1078 participants, compared with just 149 participants at CybErg 1999. Whilst the dramatic reduction in participants might have indicated a less successful conference in 1999, the data relating to interactions in the discussion contradict this.

The total number of comments made by participants in the 1996 and 1999 conferences were similar (1996: 592 comments on185 topics; 1999: 566 comments on 218 topics). Thus indicating that whilst there were far fewer participants at the 1999 conference, those who were there were far more active (on average) than those at the 1996 conference. Indeed, it is likely that the free registration at the 1996 conference attracted a very large number of people who may not have had any direct interest in contributing to the conference, but just wanted to look out of curiosity.

Comments at the two conferences were divided into those that were related to one of the specific papers, and those that were related to a more general discussion topic (social comments, or general comments about the profession or virtual conferences). A higher proportion of comments at the 1999 conference was related to specific papers than to more general discussion (CybErg1999: 76% of comments, 83% of topics on specific papers; CybErg 1996: 64% of comments, 77% of topics on specific papers). The seven invited papers in the three symposia attracted a good amount of discussion with 75 comments (19 topics).

The number of comments per topic was greater for the symposia papers than for the other papers (mean of 3.9 comments per topic vs 2.2). In 1996 there were 2.7 comments per topic for the paper-related discussion. Note that the general discussion tended to create longer discussion 'strings'. The mean number of comments per general/social topic was 3.7 in 1999 and 5.0 in 1996 (although the 1996 data was skewed by one topic with 25 comments - it was the topic "What about a beer?"!). It would appear that the symposia created discussion that was more like that which took place about more general/social issues and that might reflect greater involvement by the participants.

The chairs of the sessions at both CybErg conferences made sure that at least one question was asked of every paper, prompting at least one reply from the authors. In 1996, 12 of the 56 papers had only one question and no more than 1 reply, compared with just 1 paper in 1999. The live Friday discussion periods were not as successful as had been hoped. Whilst there were 56 comments (21 topics) raised over the five Fridays, many people did not interact with the live discussions.

Thus overall the discussion at CybErg 1999 was greatly increased, given the number of participants, was more specific and covered more papers than in 1996. This interpretation is supported by the data from the evaluation forms.

3.2 Evaluation forms

136 of the 1078 participants at CybErg 1996 responded to the request to submit an evaluation (response rate:12.6%), compared with 32 of the 149 participants at CybErg 1999 (response rate: 32.3%). A higher percentage of respondents were authors in the 1999 sample (1996: 25% authors; 1999: 45% authors). The questionnaire asked for responses on ordinal scales (eg never, once, 2-5 times, 5-10 times, etc), thus modal responses are given in the following section.

Activity : In 1996, respondents indicated that they had accessed the conference on average 2-5 times, compared with the modal response of "more than 20 times" for the 1999 respondents. The 1999 respondents were clearly more active in the conference. Both groups reported reading about the same number of papers at the two conferences (mode: 2-5 papers), but the 1999 participants participated in more discussion sessions (1996: 0; 1999: 1-9). Subjective comments indicated that participants had difficulty identifying the correct time to log on for a live discussion. This, together with the low numbers of people available to participate in the discussion meant that these sessions were not the 'community market place' that had been envisaged.

Quality : Whilst 38% of 1996 respondents indicated that the quality of the papers was better than at a 'flesh' conference, only 20% believed this to be the case in 1999. However, this was counterbalanced by just 7% thinking that the papers were worse than at a 'flesh' conference in 1999, compared with 13% in 1996. Perception of the quality of the discussion was better at the 1999 conference than the 1996 conference. In 1996 only 36% thought the quality of discussion better than at a flesh conference, and 30% thought it was worse. In 1999 62% thought the quality was better than a flesh conference and only 10% thought it was worse.

Interaction : In terms of speed of response, acceptability of speed of response and navigational ease, CybErg 1999 was rated more highly than CybErg 1996. (Speed of response: "Very Fast + Quite Fast" 1999 65% , 1996 58%; Acceptable speed of response? "Yes +OK, but like a bit quicker" 1999 91%, 1996 82%; Ease of navigation: "Very Easy + Quite Easy" 1999 62.5%, 1996 50%).

Open ended comments : 60% of respondents to the 1996 questionnaire and 72% of the respondents to the 1999 questionnaire added further comments at the end of the questionnaire. Most of these comments enlarged upon the issues raised in the questionnaire. Of interest to this analysis was the fact that only 2 people in 1999 indicated that they had been attendees in 1996 and commented upon the differences. The comments indicated that these two participants thought that 1999 was an improvement on 1996. For example one respondent wrote "The concept is excellent and the improvements since '96 made it very much better to operate once the initial learning curve settled!"

4. DISCUSSION

As outlined in the Introduction, CybErg 1999 aimed to improve on the success of the 1996 conference by increasing quality discussion and making interaction easier and faster.

The evidence from the amount of discussion per registrant, the fact that there was more paper-specific discussion (as opposed to 'chat') and that more papers were discussed in 1999 indicates that the first aim was achieved. The increase in rating of the quality of discussion between 1996 and 1999 also attests to this fact. It appears that the symposia were particularly successful in generating involvement in discussion.

The subjective reports indicated that people found the 1999 conference easier and faster to use, thus supporting the second aim. Of course there have also been developments in people's familiarity with web interaction, as well as improvements in technology in that time, both of which could have contributed to the improved perception of the interaction. It was interesting to note that some participants still reported significant problems with the speed of response of the conference. Whilst the organisers had done everything they could to reduce the 'size' of the conference and thus the possible transmission problems, organisers of other virtual conferences should keep this issue in mind when considering more advanced features such as the use of video that could further reduce transmission speed.

Comments during and after the conference indicate that there is still room for improvement in CybErg. Suggestions for improvements include:

- issuing the CD-ROM earlier (due to very long postal delays, some participants only received the CD after the conference had commenced.)
- playing a more active role in moderating the discussions (several participants found the comments made by one person at the conference inappropriate)
- increasing the role of the symposia (these generated the most discussion)
- improving the role of 'real-time' discussion sessions.

The use of a registration fee is supported. Whilst it appears to have dramatically reduced the number of participants, the people who did participate may have felt a greater commitment to the conference, as reflected in their increased contribution to the discussion.

In summary, CybErg 1999 showed an improvement over CybErg 1996 in terms of scientific discussion and perception of the ease of interaction with the conference. Whilst virtual conferences are never likely to replace 'flesh' conferences, they do provide a viable alternative for sharing scientific discussion with others around the world.

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REFERENCES

1. Commercenet (2000). Survey of world wide web usage. http://www.commerce.net/research/stats/wwstats.html
2. Pollock, C.M.; Straker, L.M. & Forgione, L. (1999) Evaluation of the CybErg 1996 Virtual Conference. Manuscript submitted for publication.
3. Ransdell, S.E. & Anderson, M.D. 91995). Establishing a SciP list for year-round discussion: Keeping the information ball rolling. *Behavior Research Methods, Instruments and Computers*, *27*, 116-119.
4. Straker, L.M.; Pollock, C.M.; Case, I. & Kemp, R. (1996). Opening address by the CybErg convenors. In L.M. Straker and C.M. Pollock (Eds) *Virtual Proceedings of CybErg 1996: The First International Virtual Conference on Ergonomics*. http://www.curtin.edu.au/confernce/cyberg : Curtin University.

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Cultural Considerations and Applicability of Western Usability Guidelines in the Design of Chinese E-Commerce Websites

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The key to the success of e-businesses is to understand what entice people to buy things online and to provide them with the means to carry out these shopping transactions. E-business Web page designers must also have a sound understanding of the consumer behaviors in the targeted markets. Research to understand the psychology and expectations of online shoppers will not only help consumers and e-businesses but also the manufacturers of the equipment and telecommunication infrastructure which support these businesses. This paper discusses some of the issues in our research to i) understand what motivates Chinese consumers to buy online and ii) whether the Web usability guidelines derived in the West are appropriate for Chinese consumers.

1. INTRODUCTION

Online commerce is growing at an extremely rapid pace and it has been estimated that new e-commerce sites make their way onto the Web almost hourly [1]. E-commerce is expected to account for about 5 percent of the gross domestic product in the world's top 25 economies in a few short years [2]. Traditional retailers are going online in droves and the growth in e-business is not confined to the West. In China for instance, e-commerce transactions are expected to increase as the number of Internet users increases from its current estimate of 10 million to 60 million in 2005 [3]. Adding to the potential pool of Chinese e-shoppers are the owners Wireless Application Protocol (WAP) mobile phones. The number of WAP equipped phones in China is expected to grow from between two and five million units at the end of 2000 to 250 million units by 2004 [4, 5].

Other data paint a more sobering picture of e-business. Analyses by GartnerGroup predict that 75 percent of all e-business startups will fail [6]. Recent study conducted by Zona Research found that about 30 percent of the Internet-savvy users in their survey experienced difficulty finding the product they want on the Internet; twenty percent have abandoned their purchases at least three different times when shopping on the Web; and thirty-nine percent of the users in this survey also decided either not to buy online or take their shopping elsewhere [1]. Other studies have found that up to 60-75 percent of e-shopping transactions were discontinued, and e-tailers were having difficulty building loyal customer bases as online customers turned back to traditional brick-and-mortar stores or print catalogues to make their purchases [1, 7, 8, 9]. Similar observations were made in Asian cities. For instance, all the participants in an online "survival test" staged by the Chinese government in three major Chinese cities in the latter half of 1999 expressed negative views of the adequacy of China's e-commerce industry [10]. It also appears that Asian e-businesses are having a harder time than their western counterparts. Of every $7 spent on e-commerce in Asia, $6 goes to non-Asian companies [11].

1.1 Online shopping in China

China is one of the fastest growing and potentially the largest consumer market in the world. To ensure that we are ready with solutions to the problems which e-shoppers and e-businesses are likely to encounter when e-retail becomes mainstream in China, a research program at the Institute of Psychology in Beijing has been initiated to study the experiences and responses of Chinese consumers in their early and subsequent encounters with e-shopping. In parallel with this, effort is also being made to determine whether i) Web usability guidelines derived in the West are appropriate for Chinese consumers and, ii) the extent to which usability guidelines derived from e-shopping studies conducted on desktop computers are applicable to handheld devices. The goal of our research is to obtain an understanding of what motivates Chinese consumers to buy online, and how to enhance the quality of their online shopping experience. The result of this series of studies will benefit not only the consumers but also the development of the equipment and infrastructure to support online business in China. Some of the issues we are addressing are highlighted in this paper.

2. ONLINE SHOPPING BEHAVIOR – IS THERE A CULTURAL UNDERPINNING?

The problems encountered by e-shoppers and the situation facing e-businesses have resulted in a proliferation of books and articles on topics ranging from Web page design to marketing strategies to help e-businesses stay viable. A subject frequently discussed in these literature is website design and measures to promote web usability (see Nielsen's website: www.useit.com for a sampling of these). *Consumer Behavior*, and *Human Computer Interaction* (HCI) research has helped practitioners become aware of the need to be sensitive to the different purchasing and behavioral patterns of consumers and software users across different cultures. However, the World Wide Web is widely accepted to be a world without borders and in which the physical location where business is conducted is of little importance. As Schwartz observes, the Web resembles a parallel universe that mirrors the physical world in some ways but exhibits entirely unique properties in others. Consumers' behavior changes dramatically when they enter this Web space and have different expectations when interacting with a company on the Web [1, 2]. The consequence of this is that the conventional metrics for measuring the usability of a software could not be used to evaluate the usability of a website [12]. Other observations show that the manner in which visitors traverse the Web are very different from their interaction with software [6]. Differences are also manifested in how people scan but rarely reading word-by-word the contents in Web pages [9] and their information retrieval and navigation strategies vary greatly depending on the task they are performing on the Web [2, 12, 13].

2.1 Evolution of Web culture and influence on consumers' behavior

The evidence above leads us to ask if a unique and universal Web culture will evolve over time and whether the behavior of online shoppers in China will eventually resemble those of their western counterparts in this cyber-world. Our work would be cut out for us if this premise holds true because the behavior of online shoppers in the West could then be used to predict the behavior of e-shoppers in Asia. But then again, it is unlikely that this would be the case. If consumers in countries like the US who are familiar with catalogue shopping are having bad experiences with online shopping, then it would be all the more difficult for Chinese consumers to take to e-shopping when they are only beginning to have access to the Internet and exposure to online services. In other words, Western and Chinese e-shoppers (and e-businesses) are on very different learning curves.

2.2 Local consumer cultures – resistance to change

The other side of the argument is that cultural differences are so deeply rooted that they are reflected even in e-shoppers' behavior on the Web. Research in consumer behavior reveals very different motivational factors for purchase and consumption patterns between consumers in Asia and the rest of the world markets. Social recognition is important in a collectivist society and Asian consumers tend to be motivated by externally focused, social needs such as affiliation, admiration and status. However, Sch tte and Ciarlante note that even within Asia, there are striking differences in consumer preferences across cultures. For instance, Japanese consumers place strong emphasis on service rather than price. Because of their generally lower income, Chinese consumers on the other hand, are more price conscious in their purchase decisions. Because of their cultural characteristics, it also takes far longer to establish brand loyalty with a Chinese consumer than it does with a Western consumer. The curiosity Chinese consumers have for brands leads to a high level of variety-seeking brand switching. If a product fails to deliver on important product attributes, Chinese consumers' pragmatism and relative lack of emotional ties with the specific products or brands allows them to try without hesitation another brand, provided that such a move does not conflict with group norms [14].

Against this backdrop, it is difficult to ignore the sociocultural underpinnings of traditional retail consumer behavior even though online shopping is the focus of our research. This being the case, then the e-business website usability guidelines developed in western countries must be examined for cross-cultural transposability. It is not because these guidelines are cross-culturally invalid; indeed there is much in common. For instance, Web usability guidelines to facilitate users' navigating through Websites, proper use of colors and background, text formatting, etc., are equally appropriate to users of all cultures [15; 16; 17]. But consumer's decision to buy, or not buy is not determined by usability considerations alone. We also need to develop an understanding of what brings an e-shopper online, and the factors necessary to transform a visitor to an e-business site into a buyer. And, an understanding of the attitude and culture of the potential users can help us provide the usability and add to the quality of their online shopping experience. Our approach then is to use studies conducted in countries with more matured e-business enterprises as frameworks to guide us in this series of studies in China. This allows us -- without reinventing the wheel -- to adopt the best practices and formulate new guidelines where the existing ones are inadequate. Our initial work in this area is centered on cross-cultural comparisons of findings pertaining to e-shoppers decision making and purchasing behavior in the east and west.

3. USABILITY GUIDELINES FOR WEB BROWSERS IN PORTABLE DEVICES

The design principles applied to e-commerce websites today are based on lessons learned from the development of e-information Websites; these in turn, were built on a foundation of HCI research in other application domains. Studies of website usability have however found that users have different modes of information seeking behaviors depending on the tasks performed. Navigation through Web sites is very different from navigation through the user interface of software and hardware products. Designing for the Web is different from traditional software user interface and as Spool points out, navigation and content of the Website are intricately linked [12, 13, 18]. At the same time, people respond differently to the same information presented on different medium [2]. In designing for the Web, the designer surrenders full control and has to share responsibility for the user interface with users and their client hardware/software [18]. Given that consumers can now access the Web wirelessly via WAP capable cellular phones and pocket PCs, these observations have important implications not only on the design of websites but also the design of the devices which enable wireless access to the Web.

3.1 Problem displaying high information content webpages in pocket PCs

Usability guidelines for software applications in PCs and Personal Digital Assistants (PDA) are often inapplicable to cellular phones even though much effort has gone into making cellphone interfaces emulate that of PCs and PDAs'. This is because devices like pocket PCs and cellphones typically have small displays, the size of which ranges from half, to an area slightly bigger than a business card. It is obvious that current Web design guidelines for large display like desktop monitors are inappropriate for handheld devices like cellphones. Furthermore, a display big enough to display a given amount of information in English (without scrolling) is not sufficient to display the same information in Chinese. This is due to the nature of Chinese font construction on electronic displays -- Chinese fonts take up almost twice as much space as alphanumeric fonts to provide the same degree of readability on small displays.

In conjunction with the study on e-shoppers behavior in China, we are also studying different approaches to displaying high information content Chinese Web pages in the next generation of wireless Internet access devices. Preliminary simulation studies in our laboratories have shown that a display size one and a half times the area of business card could provide a reasonable degree of maneuverability on a scaled down graphic browser. Our assumptions in this series of study are that future WML would support this display format and that the e-shopper would be in operating in a "goal-directed" mode, i.e., the buyer already has in mind what he wants to purchase and is unlikely to adopt a browsing or "window shopping" strategy as he would on the PC. A series of simulations studies are being carried out in our laboratories in Singapore and Beijing to determine the extent to which these assumptions hold true.

4. CONCLUSION

The key to the success of e-businesses is to understand what entice people to buy things online and to provide them with the means to carry out these shopping transactions. The limiting factor to online buying is not international boundaries but culture. In developing the user interface to cater to e-shoppers around the world, merely using the right metaphors and colloquial terms is no longer adequate to guarantee usability or user acceptance. E-business Web page designers must have a sound understanding of the consumer behaviors in the targeted markets. Further research to understand the psychology and expectations of online shoppers in China will not only help consumers and e-businesses but also the manufacturers of the equipment and telecommunication infrastructure which support these businesses.

REFERENCES

1. Zona Research. (1999) Shop Until You Drop? A Glimpse in Internet Shopping Success.
2. E. Schwartz. (1997) Webonomics. NY: Broadway Books
3. Reuters. (2000) Nokia Strengthens China Presence With WAP Deal. April 26, 2000.
4. Agence France Press. (2000) Ericsson Links With GWcom to Provide Wireless Internet Service. April 21, 2000.
5. Reuters (2000) Intrinsic Eyes Early Start in China WAP Market. April 21, 2000.
6. E-Commerce Times. (1999) 75 Percent of E-Business Destined to Fail. November 12, 1999.
7. ZDNET. (2000) Shoppers of the Web Unite: User Experience and Ecommerce. February 24, 2000
8. E-Commerce Times. (1999) Message to E-Tailers: Deliver Better Service or Become E-Toast. September 13, 1999.
9. E-Commerce Times. (1999) E-Tailers Waking Up to Customer Service Needs. October 19, 1999.
10. Agence France Press. (2000) China's E-Commerce Fails Test – And Brave Volunteers. September 7, 1999.
11. USA Today. (1999) Asia's Culture Hampers Net commerce. February 16, 1999.
12. J. Spool. (1998) Web Site Usability: A Designer's Guide. NY: Morgan Kaufmann Publishers
13. C. W. Choo, B. Detlor and D. Turnbull. (2000) Information Seeking on the Web: An Integrated Model of Browsing and Searching. First Monday, Volume 5, No 2.
14. H. Sch tte and D. Ciarlante. (1998) Consumer Behavior in Asia. London: Macmillan Press.
15. J. Nielsen. (1996) Top Ten Mistakes in Web Design. Alertbox May, 1996.
16. J. Nielsen. (1997) Changes in Web Usability Since 1994. Alertbox December, 1997.
17. J. Nielsen. (1999) The Top Ten New Mistakes of Web Design. Alertbox May, 1999.
18. J. Nielsen. (1997) The Difference Between Web Design and GUI Design. Alertbox May, 1997.

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Formative Evaluation of a Browser Add-On Search Tool

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This paper presents a formative evaluation of information retrieval tool for Internet search. The user interface and retrieval performances are the two identified criteria for user-oriented evaluation. The framework of methodology and presentation of test findings are presented in the paper. Comparison of results from both qualitative and quantitative analysis provides a more complete picture for the usability of information retrieval tool. It can help the developer and design development to improve their interface and retrieval performance.

1. INTRODUCTION

Extensive research's had been carried out to measure each information retrieval performance and their interface design [1,2]. In most cases, researchers rather than users make relevance judgments on the information retrieval tools. Bosch and Beaulieu (1995) suggested that performing evaluation involving real users were expected to be relevant for evaluating information retrieval tool. Observing how users interact with existing products may starting point but more formal, laboratory type testing and diagnostics will be required to establish objective evaluation criteria.

The purpose of this study is to examine the usability of browser add-on search tool from end-user perspectives. Rappoport (2000) discussed on the two important issues of site search design that were search interface and search quality. She discussed on the differences of search interface available currently and how the search quality will affect on the user search performance. In our study, we proposed a set of criteria (Table 1) based on Rappoport issues that can be used by end-user to evaluate the usability of information retrieval tool. The following are the criteria (i) user interface, the objective is to know what type of problems would be face by users using the search tool; (ii) retrieval performance, the objective is to find how well the current search result retrieved based on user judgment. The user interface criteria was classified using the "8 golden rules" for interface design [6] and measured using the simplified version of Questionnaire for User Interface Satisfaction (QUIS) [7]. Cronbach's alpha was consistently in the .89 to .94 range over a series of studies. Thus, the overall reliability of the QUIS is quite high. The retrieval performance criteria was measured using the modified version of performance measurement used by Su and Chen (1999). This paper will use the findings from the evaluation to illustrate issues of practice and methodology in the context of qualitative and quantitative investigations in order to give a comprehensive understanding of the Internet user, search interface and retrieval performance.

Table 1
Usability Criteria for User-Oriented Evaluation

Usability Criteria	User	
	Qualitative	Quantitative
1. RETRIEVAL PERFORMANCE		
Relevant Links		X
Time taken		X
Precision 1 & 2		X
Coverage		X
2. USER INTERFACE		
Strive for consistency	X	
Provide shortcuts for skilled users	X	
Offer informative feedback	X	
Design for closure	X	
Offer simple error handling	X	
Permit easy reversal of actions	X	
Reduce short-term memory load	X	
Support user control	X	
Overall user satisfaction		X

2. METHODOLOGY

This section describes the method we performed to evaluate our case study prototype, called Sigma. However, our findings were based on the availability and functionality of Sigma. Sigma is a Java-based stand-alone application and it runs on 7 parallel search engines. It allows users to filter linkrots (dead links and error pages) and to download the search results onto the local hard disk for off-line browsing. It keeps a list of history queries created and does not require users to learn any syntax. It uses a natural language processor in order to provide relevancy ranking in the result. Since Sigma is still under development process, a small sample of experienced Internet user is good for formative evaluation [8]. 11 subjects were selected for the interface evaluation except 8 subjects for retrieval performance evaluation. They were paid in order to have good cooperation. A small usability lab was created and equipped with video and audio recording. The evaluation was carried out on a PC desktop with a 200 MHz Pentium processor and MMX technology, 32-MB memory. The computer was connected to Internet service provider, Jaring through local network. The following are the two evaluations carried out for this study.

2.1. User interface evaluation

Experimenter gave instructions to subjects after they signed consent form. Subjects were basically allowed to explore Sigma on their own for 10 minutes. After that, 2 search task were given and they were require to use Sigma as their search tool only. They were strictly prohibited to use other search tools. The search tasks given to them were (i) Find the person(s) who is/are doing research in affective interface in Massachusetts Institute of Technology and save the file (well defined); (ii) Find out whether there is/are meta-search engine research being done and save the file (ill defined). Subjects were also encouraged to voice any feature they like or any difficulties they were having while using the Sigma. These verbalizations and their actions were recorded and were later analyzed. In the end of evaluation, subjects were asked to comment on Sigma and to fill in a post-questionnaire.

2.2. Retrieval performance evaluation

Subjects were asked to submit their query and evaluate the results processed by Sigma. First, subjects filled in their query and explained briefly what they want to search. Experimenter ran their queries on Sigma because Sigma processing was taking nearly an hour for a query. All results retrieved were time-stamped and duplicate links were recorded. Subjects were asked to evaluate the top 10 links in the search result list. They were asked to view the full page of document to determine the relevancy. For each link, subjects rated either relevant or not relevant. For the relevant links, subjects were asked to indicate their satisfaction range from lowest value 1 to highest value 7. At the end of evaluation, they were asked to fill in a post-questionnaire. The following are the definition of measurement used (i) rank value = value given by the information retrieval system; (ii) result retrieved = total of document founds and duplicate links; (iii) precision 1 = ratio of relevant document (value range from 1 to 7) found in the 10 result; (iv) precision 2 = ratio of relevant document (value range from 4 to 7) found in the 10 result; (v) linksrot = number of links did not works; (vi) duplicate pages = number of links that are referring to same page.

3. RESULT

Subjects were collected from the University Science Malaysia graduate student. All subjects are 20-29 years old and 9 subjects (82%) are male. 6 subjects (55%) used Internet Explorer and 45% used Netscape Navigator. 2 subjects (18%) use Internet less than 14 hours per week. 7 subjects (64%) use Internet from 15 to 40 hours per week. Only 18% use Internet for more than 40 hours per week. 9 subjects (82%) search specific information most of the time. 5 subjects (45%) used only one search tool while others (55%) used more than one search tools. All subjects had experienced using browser add-on search tool before this. All of them had used Web Ferret (11 subjects), Copernic (5 subjects) and Beeline (1 subject).

3.1. Findings for user interface evaluation

We presented our findings into two different sections that are strengths and opportunities enhancement. These findings can provide designers and developers with general guidelines for effective user interfaces for information retrieval. The strengths of Sigma were: (i) looks simple and easy to learn and use; (ii) filter all linkrots; (iii) keep history of query submitted; (iv) save function to download documents. We rephrased the "8 golden rules" using our findings for opportunities enhancements. Verbal data analyses are presented in italic forms. The following are the golden rule:

1. Provide shortcuts for skilled users. Most subjects had familiarity with standard keyboard function key. Therefore any input from the keyboard and the mouse should be supported. *"This system should respond from any input device I use, not the mouse all the time."*
2. Support user control. Sigma should allow subjects to stop the search process. Subjects felt rigid and restricted with the whole session and could not do anything but had to wait for the process to end. *"It should provide a stop button!"*

3. Offer simple error handling. Some of the term and language used in the dialogue message were not suitable and inappropriate. Messages should informed what went wrong and indicate how to solve it. *"What is repository? I never heard this word before."*
4. Reduce short-term memory load. The search result layouts were not complete and it left subjects wondering what is the result refers to. The indication of visited links was not clear because subjects try to look for which links they had visited. *"Is this the link? Or this one?"*
5. Strive for consistency. The "Default" button act as saving the current changes as default after subjects modified the search engine. However, 1 subject had different means on "Default" button. *"I thought that default will reset the changes I made to the original value."*
6. Design for closure. Sigma should let subjects choose whether to have auto filter linkrots or dictionary processing in the search processing. This would make subjects felt relief and reduce memory burden than waiting for hours of processing.
7. Permit easy reversal of actions. When subjects ran their query, a message box informed them that the query existed in the repository. Subjects had to find the query in the history by themselves. Others need a fresh new list of results with the same query.
8. Offer informative feedback. Subjects did not know whether the Sigma was still processing or there was no result at all. An indication on how many results found by Sigma should be provided to the subjects. *"Is Sigma still processing?"*

The overall user reactions on Sigma interface were collected from the simplified version of QUIS questionnaire. Most of the subjects (54.5%) found that Sigma were somewhat easy to learn to use. Average ratings were given for flexibility (36.3%), attitude (63.6%) and effectiveness (54.5%).

3.2. Findings for retrieval performance evaluation

A comparison study was done between two ranking systems that were direct matching (DM) and dictionary (NLP). Ranking system based on NLP ($\pm$2.1 hours) was taking longer time than DM ($\pm$3.8 minutes) to process especially for 50 results per engine. The rank value based on DM could goes up to 25%. This shows that Sigma need to be redesigned for the DM ranking. The result retrieved by the Sigma did not achieve the number of retrieval expected especially for fifty results per engine. The reason was 7 individual search engines used by Sigma were returning more than fifty documents. Remark was that Sigma lost thread in the middle of processing. For each query submitted, there were links duplications occur in the result retrieved. Ranking system based on NLP was performed well on retrieving relevant documents (satisfaction range from 4 to 7). There are no significant differences among the means of precision 1 ($F=0.59$, $p=0.57$) and precision 2 ($F=0.35$, $p=0.71$). Even though, Sigma capable of removing all duplication links but another problem is page duplication appears on the top 10 results. 7 subjects (64%) said that maybe sometimes they will use Sigma in the future and maybe sometimes they recommend Sigma to others.

However, from the statistical analysis, it does not really show how well Sigma performs for certain cases. Sigma retrieved badly in the first 10 results by retrieving most documents from plants and machinery for query 4. Sigma performs better for query 6 because there were 7 page duplication occurred on the top 10 results. Duplication pages occur frequently in almost subject query performed. This indicates that the current information retrieval tool needs to solve this problem in order to have a better retrieval performance. Most subjects said that they had seen the web page when they encountered a new web page that similar. *"I think I have been here before."* Most of them fall on the wrong conclusion when they saw consistency of the web page structure and layout.

4. DISCUSSION

From this case study, we found that we can know how well Sigma performs especially from the end-user point of view. We also have statistical measurement to determine overall usability performance in term of interface and retrieval performance. By considering both results found in Sigma interface and Sigma retrieval performance, we conclude that user satisfactions on Sigma usability are average and there is improvement needs to be done on Sigma. This is a better way to indicate the current status of efficiency and effectiveness of Sigma for developer and end-user.

Do users perceive interface design to be important when using information retrieval product?

In the case study, subjects were active in giving comments on Sigma interface. It included good and bad as well. From the survey, we found that 8 subjects (73%) felt there were too many feature, advertisement and links in the search engine. Subjects seem to be very frightened off when they were using browser add-ons with a lot of feature in it. For instance, they were surprised when Copernic 2000 launch on the screen display and they do not even know where to start. *"Whoa, it has a lot features... Where should I start?", "It too complex. For me, WebFerret is fine. It has a query textbox and results at the bottom. Just like Windows find dialog box."* Therefore, the users do perceive interface design importantly for information retrieval tool.

What kinds of interfaces for search engines or outputs provide maximum interaction between the system and the user?

6 subjects (55.5%) had the same mental model that the search engine was like a library catalog card system. Even though, most of the search engines provide title, URL, summary, size, date modified and other feature as well, subjects could not tell exactly whether the links are relevant or not. Therefore, the important output informations are search result and current status. The search result should include title, URL, summary and labels. From the survey, 8 subjects agreed that titles were the most important feature, followed by keywords highlight (7 subjects), summary or first sentence (6 subjects) and URL (5 subjects). Even though ranking is an indication for accuracy, user can be given the customization on the search result layout. *"I do not really count on the rank. Its' not helpful. I usually scan the first 10 and if nothing found, I'll use another query"* Summary in a balloon tip form is a very good way of conveying large information.

Every browser add-on should display the current status of search clearly. This includes the number of result found and current search query (Figure 1). Browser add-on should provide a clear feedback on it successful or unsuccessful search. It will not let the users wondering whether the browser add-on does not found anything or system is not working or the Internet connection is down. If Internet connection is down, then the browser add-ons should inform the user that there is a problem in making connection to the Internet. If browser add-on does not find anything, then the browser add-on should tell the user by indicating "0 documents found". *"It's nothing there or not working? Maybe I should run the query again?"*

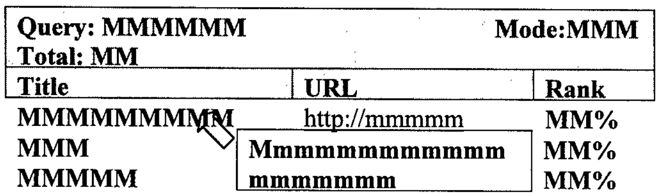

Figure 1. Recommendation for Output Display

5. CONCLUSION

The advantage for each evaluation is that it provides promising results without having bias or personal judgment on the prototype. We can evaluate the effectiveness and efficiency of Sigma from real end-users testing. It provides feedback to maintain the good feature and suggestion on improving the current Sigma. The evaluation was carried out in differently setting to test each criteria. It would take a lot of time and resources to prepare the whole evaluation process. Further research on information retrieval tool is suggested to involve novice user to evaluate the information retrieval tool. An understanding of individual difference on searching information is also necessary to further our understanding of user-search tool interaction.

REFERENCES

1. A.L. Baker Datastar Web: A Comparison with "Classic" Datastar Command Language Searching. Online & Cdrom Review, 22(3) (1998).
2. H.T. Chu and M. Rosenthal, Search Engines for the World Wide Web: A Comparative Study and Evaluation Methodology. Proceeding of the American Society for Information Science (1996).
3. V.M. Bosch and M.H. Beaulieu, CDROM User Interface Evaluation: The Appropriateness of GUI's, Online and CDROM Review, 19(5) (1995).
4. A. Rappoport, Website Searching and the User Experience, http://www.searchtools.com/info/ui/search-HI-1.html (4/9/2000).
5. L.T. Su and H.L. Chen, User Evaluation of Web Search Engines As Prototype Digital Library Retrieval Tools, Proceeding of the 3rd International Conference on Conceptions of Library and Information Science (1999).
6. B. Shneiderman, Designing the User Interface: Strategies for Effective Human-Computer Interaction (2nd eds), Addison-Wesley Publishing Company, USA (1992).
7. J.P. Chin, V.A. Diehl and K.L. Norman, Development of an Instrument Measuring User Satisfaction of the Human-Computer Interface. ACM CHI'88 Proceedings, 213-218 (1988).
8. J. Nielsen, Usability Engineering, Academic Press, Inc, London (1993).

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Justifying a Usability Engineering Method for Web Advertising

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Advertising plays an important role for industries to promote their products and services to their customers. The variety of advertising techniques have been changing over the years from traditional medium such as print, radio, television, and cinema to digital form as the World Wide Web (WWW). There are Web sites appearing on the Internet everyday and the Web has grown almost 20 fold over the past five years. As such, advertisers are finding the Internet as a vast medium with endless opportunities in promoting their products and services. Companies are setting up their dot-com Internet Presence Site (IPS) to join the Information Super Highway. However, the presence of Internet advertising, especially banner ads on the Web, gather little attention from the users; users may easily leave host IPSs if the content does not promise a value-added information to look for. As such, heuristic evaluation, one of the usability engineering methods (Nielsen, 1994), is highlighted as a practical approach to determine the level of usability for Internet advertising models.

1. INTRODUCTION

Since early 1990's, the rapid growth of Internet capacity has created an alternative opportunity for traditional advertising. Hence, using Internet as a medium to promote companies' IPSs and selling products has become an essential advertising tool in marketing strategy.

In terms of Internet advertising expenses, the Internet Advertising Bureau pointed that US$906.5 million was spent on Internet advertising in the US in 1997. The figure is expected to rise to US$7.7 billion by 2002 and the revenue is predicted to reach US$24 billion by the year 2010 (Jupiter Communications; Murphy, 1996). Meanwhile, the worldwide Internet economy will grow six fold in four years. According to IDC, the Internet economy which is worth about US$500 billion last year, will pass the US$ 1 trillion mark by 2003. The Internet economy in Asia-Pacific itself, being driven primarily by businesses going online, will grow twice as fast as the global rate, or 12 times as much as from US$10 billion in 1999 to US$123 billion in 2003 (Asohan, 2000).

Doubtless to say, the list of published figures goes on to highlight the emerging importance of e-commerce and business transactions being carried out on the Internet. This highlights that WWW has become a *significant agent* for industry to present their image and as an alternative means to promote and sell their products and services.

Though the marketers are excited about the emergence of e-commerce, there is also an increase in Internet advertising models appearing on the WWW. The role and nature of Internet advertising is changing, but there is little documentation and study to show the effectiveness of the method(s) in attracting and retaining the virtual visitors to the company's IPS. As such, this paper highlights the usability engineering heuristic evaluation method as a means to help in determining and enhancing the effectiveness of existing Web advertising models.

2. INTERNET ADVERTISING MODELS

Zeff and Aronson (1997) categorized the Internet advertising model based on two categories, which are Internet advertising via e-mail and Internet advertising via the Web (Figure 1). This paper shall focus on IPSs and banner ads models.

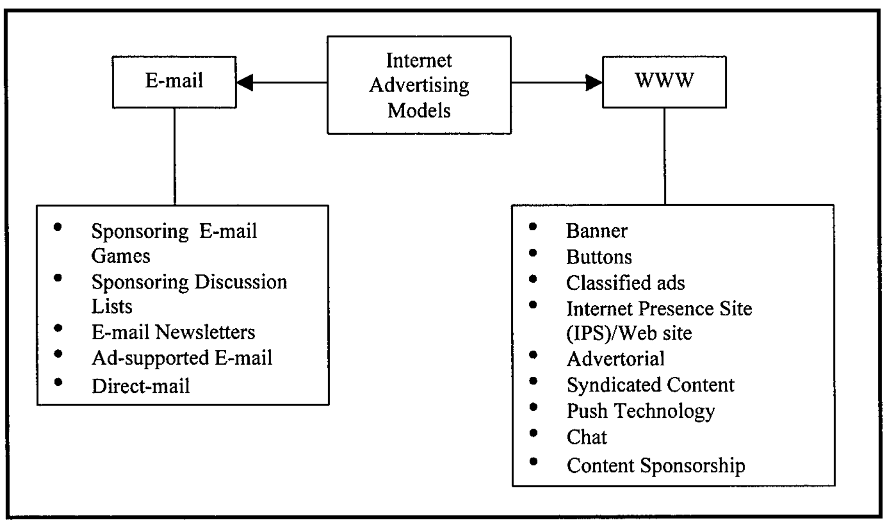

Figure 1 Internet Advertising Models

3. DILEMMA ON THE NET

The principle of banner ads is to capture users' attention via an animated and hyperlinked Graphic Interchange Format (GIF) image that, on clicking, leads users to the hyperlinked site. According to Barrett (1997), banner advertisements have an effect that is directly and precisely measurable: users click on the banner can easily counted. However, the dilemma is that banner ads on the WWW may be viewed by hundreds of Internet users, but none of them may be the IPSs' targeted audience in the niche market. Therefore, the resulting reach of the ads is "zero" and its effectiveness is deemed negligible. Furthermore, the persuasiveness of such advertising models in contrast to the non-advertising content appearing on Web pages is questionable. On the other hand, Chatterjee (1996) considers banner ads to be a form of *passive exposure,* in that the consumer does not consciously decide to view the banner ads.

The portal of IPS is the virtual storefront of a corporate, which it represents the image, and branding of the company. Lack of persuasive and value-added content, poor design, complicated navigation links with unorganized multimedia elements will 'scare' the users away from revisiting the company's IPS. A study done by Gartner Group (1995) found that 90 percent of Web sites were developed without asking existing customers what they wanted. In their rush to have an Internet presence, many firms that ordinarily employ sound research practices abandon their logic and develop ineffective Web sites. In short, how well the WWW as an effective medium to retain the audience and pay the repetition of revisiting the Web site is still in query.

4. JUSTIFYING USABILITY AS AN APPROACH

The key interest is to attract people to visit the company's Web site, and this causes large sums of money being invested in the advertising budget (Nielsen, 1999). Unfortunately, the amount of investment on Web advertising, whether it is worth to generate revenues to company, is still doubtful and questionable. To date, only the top 0.01% of Web sites can generate sufficient revenues from advertising: in the larger picture, advertising is almost irrelevant for the success of the Web (Nielsen, 1997). In fact, the term "user friendly" has no significant meaning unless it can be defined in real terms (Mandel, 1998). Anderson and Norman (1989) also mention that "user friendly" has become so lacking in content as to be virtually meaningless.

Hence, the author highly recommends usability as an effective and reasonable approach to enhance the current Web advertising approach and content. Nielsen (1999) states that it is necessary for all new Web sites to encompass high levels of usability if they wanted to succeed.

The author recognises that many product planners and marketing people tend to ignore user interface issues and neglect the usability issue during the implementation of marketing strategies. In addition, Nielsen (1999) stressed that Internet start-ups typically spend 300 times as much money on advertising as they spend on usability. As a result, many of these new sites will fail to keep their users and will not grow into long-term success. Anywhere from an average of 48% to a maximum of nearly 100% of the code for an interactive system is now used to support the user interface (Myers & Rosson, 1992). As a result, ensuring usability is the real issue to tackle the current Web advertising problem to generate the higher revenue for advertisers and companies.

The International Standards Organization (ISO) defines usability as "....the effectiveness, efficiency, and satisfaction with which specified users can achieve specified goals in particular environment" (Jordan, 1998; Mandel, 1998). The author defines usability of Web advertising as "a usable Web advertising should ensure the effectiveness of click-through and efficiency to navigate and draw attention of users in order to maximize the user satisfaction through implementing user-centered design process."

In order to overcome the Web advertising dilemma, heuristic evaluation (Nielsen, 1994) is strongly recommended as a fundamental method of enquiry towards usability problems in user interface design so that they may be accounted for as part of an iterative Web advertising design process. Heuristic evaluation is explicitly intended as a "discount usability engineering" method. Independent research (Jefferies et. al., 1991) has indeed confirmed that heuristic evaluation is a very efficient usability engineering method. One project case study found a benefit-cost ratio for a heuristic evaluation project of 48: The cost of using the method was about $10,500 and the expected benefits were about $500,000 (Nielsen, 1994).

This benefit-cost ratio showed that it is worth to invest on usability carrying out with heuristic evaluation on Web advertising for the benefit of the return on investment (ROI).

5. USABILITY HEURISTICS ADOPTED FOR WEB ADVERTISING MODELS

10 usability heuristics, as listed by Neilsen (1994), shall be applied in context of the study. The following exhibit the 10 usability heuristics and its context of application and consideration :

1. Visibility of system status
   "The system should always keep users informed about what is going on, through appropriate feedback within reasonable time". The banner ads should clearly define where the de tour will lead the user to the destination by showing the surfing status at the navigation bar. Meanwhile, the IPS should ensure that there is a marked system on each page at the bottom of the Web page or a branded logo to keep the user informed of the navigation experience.
2. Match between system and the real world
   "The system should speak the user's language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order". Since the online audience is from varied backgrounds, the language used will be diverse. As a result, the advertisers need to identify the geographical and demographical aspects of potential target users in order to support specific needs and preferences.
3. User control and freedom
   "Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo". The WWW is the user-driven medium (Nielsen, 1999). Even though the advertisers intend to impose Web advertising tactics, such as sending unsolicited e-mails to newsgroups subscribers, using unnecessary number of colours on Web pages and applying high resolution animations, they should be aware of the reactions from their virtual customers. The advertisers should provide them "emergency exits" to support user control and freedom.
4. Consistency and standard
   "Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions". Even though a banner ads can be designed in different languages to cater for a variety of regional audience, but the design and content should be maintained to ensure the consistency of the corporate image. Consistency is one of the important elements in the interface design process. When designing a corporate IPS, the colour and style of every page on a title menu should be consistent in order to highlight the various Web page content.
5. Error prevention
   "Even better than good error messages is a careful design which prevents a problem from occurring in the first place". Bandwidth configuration is the main problem for banner ads in which a banner ads usually will not exceed 12kbs. It will be difficult if the advertisers like to integrate all the multimedia elements in the banner ads. Thus, precautions in the

banner ads size and bandwidth configuration should come first. For the IPS, JavaScript is used to prevent some errors before users submit the data for fill-up form.

6. Recognition rather than recall
"Make objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate". The effectiveness of online branding to arouse recall and cognition of users is still in query. Advertisers should understand that a lot of online companies still implement traditional advertising as the slave media to supplement their advertising campaign. As such, online advertising or branding should integrate with offline stores in enhancing its services since the security of online payment is still in doubt worldwide.
7. Flexibility and efficiency of use
"Accelerators - unseen by the novice user - may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions". Banner ads composed of simple GIF animations can be enhanced to add more functionality and interactivity. For example, banner ads can perform online purchases and sending requests without leaving the banner ads WWW site. Users are only looking for information which they need and that attracts their interest. A well-organized and structured information resource will retain the user to revisit the site. However, it does not mean the user will find the necessary information in the linked Web page. Thus, the link site sought by users should contain a "feedback" link where users can prompt the Webmaster if in doubt.
8. Aesthetic and minimalist design
"Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility". Banner ads have limited screen space i.e., content, to convey the advertising message. Hence, good copywriting and design should carry precise information to the users. Good copywriting of banner ads immediately inform users the kind of content the destination link is providing.
9. Help users recognize, diagnose, and recover from errors
"Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution". An error message should be available as a substitute for broken or disabled hyperlink. Commonly, a "404 Bad Request" or "No such Link" dialogue appears from the link server but no input from the specific IPS.
10. Help and documentation
"Even though it is better is the system be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large". Banner ads does not need much documentation, unless it involves interactivity and feature enhancements. Somehow, the information-rich content IPS should emphasize on the information design and flow, and the hierarchy of content to invoke user's task and interaction. Users easily get frustrated when they are unable to find the information they require. Intelligent agents should be improvised as the "personal butler" during navigation.

6. CONCLUSION

This study hopes to provide a broader view in enhancing Web advertising models in terms of its effective reach to its intended niche market. In so doing, this study also aims to involve the following areas:

a) the changing trends on Web advertising philosophies,
b) role of Web advertising and the emergence of E-commerce,
c) consumer behaviour and Web advertising,
d) culturability on Web advertising.

Currently, work is being conducted at the Faculty of Creative Multimedia to involve certain areas of expertise and industry, and to look into the issues, practice and enhancement of E-commerce.

REFERENCES

1. Anderson, R.H.; Norman, S.. Beyond User Friendly. EDUCOM Review, Fall; 1989; p50-54.
2. Asohan, A. The dot-gone danger. The Star In-tech, 18 April 2000, p3.
3. Barrett, N.. Advertising On The Internet: how to get your message across on the World Wide Web. London: Kogan Page, 1997.
4. Chatterjee, P. Modeling Consumer Network in World Wide Web sites: Implication for Advertising. Dissertation Proposal, Owen Graduate School of Management, Vanderbilt University, 1996.
5. Gartner Group Reserch. Web Sites: What Customers Want and Do Not Want. Gartner Group Research, November 9, 1995.
6. Jefferies, R; Miller, J.R.; Wharton, C.; Uyeda, K.M.. User Interface Evaluation In The Real World: a comparison of four techniques. Proceedings ACM CHI'91 Conference. New Orleans, LA., April 28-May 2, 1991, p119-124.
7. Jordan, P.W.. An Introduction to Usability. London: Taylor & Francis Ltd., 1998.
8. Jupiter Communications. Online. Available: http://www.jup.com September 1998.
9. Mandel, T.. The Elements of User Interface Design. New York: John Wiley & Sons, 1998.
10. Murphy, I.P.. On-line ads effective? Who knows for sure?. Marketing News, v30,20; 23 Sept. 1996; p1, 38.
11. Myers, B. A.; Rosson, M. B. eds.. Survey on User Interface Programming. Proceedings of CHI Conference on Human Factors in Computing System. ACM, 1992, p195-202
12. Nielsen, J. (1997). Why Advertising Doesn't Work on the Web. Online. Available: http://www.useit.com/alertbox/9709a.html. 1st September 1997.
13. Nielsen, J. (1999). Usability as Barrier to Entry. Online. Available: http://www.useit.com/alertbox/991128.html 28th November 1999.
14. Zeff, R.; Aronson, B.. Advertising on the Internet. NY: John Wiley & Sons, Inc., 1997.

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A Cooperative Technique for Usability Evaluation of a Three-Dimensional Web-Based Marketing System

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The integration of three-dimensional (3D) virtual environments on the web page or better known as 3D Page has been made possible due to the availability of desktop computer with high processing power, 3D graphics accelerators and improved bandwidth. However, usability evaluation on the applications created using such technology is still very rare. Recognising the importance of creating a more user-centred application, this study takes the move to perform continuous usability evaluation on a 3D page using the co-operative evaluation technique. A 3D web-based marketing system, which is meant to market toys via the web, has been chosen. This paper reports on the co-operative evaluation process and the design principles revealed from the process. It also shows the suitability, practicality and usefulness of the evaluation technique for assessing the usability of 3D Page and thus, produces a more user-centred application.

1. INTRODUCTION

Desktop virtual environment is gaining its popularity over the recent years. This technology is advancing so rapidly due to the development of desktop computers that are of ever-increasing amount of computing power and the widespread availability of three-dimensional (3D) graphics accelerators to handle most of the graphics rendering 'pipeline'. Consequently, this has enabled the creation of visually rich and perceptually realistic virtual environment applications at relatively low cost.

The rapid increase in the bandwidth available to end-users has also made possible the integration of virtual environments on the web pages. '3D Page' is the term coined for a web page which includes a virtual world, an interactive 3D environment that can be explored at will in real time. This web page will usually also include standard HTML text and graphics. Advanced 3D Pages will also allow interaction between the virtual world and the HTML (Supercape®, 1997). Thus, this advancement enables the simultaneous utilisation of the benefits offered by both web and virtual environment technology.

2. THREE-DIMENSIONAL WEB-BASED MARKETING SYSTEM

3D pages are now used in various kinds of application, such as entertainment, education, training, architecture, marketing, and so on. This paper will however only focus on the use of this kind of web page for electronic marketing or better known as Electronic Commerce (e-commerce). Electronic commerce over the Internet is a new way of conducting business. It is growing rapidly because of its impact on business costs and productivity. According to a source in U.S. (Organisation for Economic Co-operation and Development, 1999), e-commerce is predicted to approach a trillion dollars by the year 2003-05.

There are indeed a number of reasons for using 3D pages in e-commerce. By applying one of the most advanced technologies, a company is believed to be able to improve its profile through the association with leading edge technology. Users are also allowed to freely navigate the three-dimensional virtual environments, manipulate and interact with the virtual objects or products, and observe their intelligent behaviour. Thus, this definitely improves the realism of the marketing process.

Research has also proved the motivating factor of the desktop virtual environments technology (Chen & Teh, 1998; Johnson et al., 1998; Pantelidis, 1996). Exploring and interacting with 3D pages is a compelling and absorbing experience that could lead to longer visits. For instance, according to the news released by Superscape® (1999), the Westin Tokyo Hotel's web site has reported a 45% increase in traffic to the site after incorporating an interactive three-dimensional virtual hotel into the web page. The performance of virtual environments on the web has also been tremendously improved with the invention of new processor and improved bandwidth. Consequently, larger and more complex virtual worlds can be downloaded and larger amount of 3D animation data can be streamed over the Internet to bring these virtual worlds to life (Roehl, 1999).

3. PROBLEM

At the early introduction of the conventional 2D page, many usability problems were introduced. However, to date, usability assessment of such web pages has gained well-deserved attention. As a result, many design guidelines that help to alleviate the identified problems have been produced. The integration of virtual environments on the web page is somehow a rather new technology and as with any other new technologies, it is anticipated that there still exist many unidentified cognitive usability problems. In fact, usability evaluation of virtual environment on its own has rarely been conducted despite its increasing popularity. Most of the virtual environment research and development efforts are overwhelmed with the technical hardware and software issues, thus, paying least attention to create more user-centred applications. (Gabbard et al., 1999; Hix et al., 1999). Thus, it is definitely important and useful to investigate the usability issues of virtual environments, particularly when the virtual environments are integrated into web pages.

4. AIMS

As human-computer interface is one of the most important parts of any software product, this study takes the move to perform usability evaluation on a 3D page, which is specially designed to market toys via the web. A usability evaluation technique, known as cooperative evaluation, will be employed to assess the usability aspect of this three-dimensional web-based marketing system. It is anticipated that the outcomes of the evaluation, which is a set of design principles, could benefit many parties that intend to venture into electronic commerce.

5. METHODOLOGY

5.1. Subjects

Although worldwide audience could browse the 3D page, the target customers are those who possess purchasing capability. Based on a result obtained by the First International Altavista Asiawide User Survey (1997), it was found that more than 50% of Asia Internet users are from the age ranging from 20-29 years old. About half of the Asia Internet user population is tertiary educated. This survey result seems to be applicable to the Malaysian Internet user profile as currently, educated young adults are most widely exposed to the use of computer. Therefore, this group will be the most potential customers as they are the computer literate group and most likely to shop on the web.

In this project, four final year undergraduate students from various faculties of Universiti Malaysia Sarawak were recruited as the representative users. All of them are computer literate but has never experience a 3D page. They were purposely selected from different faculties to represent the target customer population, which comprises people from diverse career.

5.2. Apparatus and procedure

The first version of the prototype system was designed based on a number of usability principles for conventional web pages revealed by different research and the field of cognitive psychology. Generally, it was designed to incorporate three-dimensional virtual world (see Figure 1) in order to mimic a real marketing environment. Unlike the two-dimensional pages where only the photograph or images of the products are shown, products in this prototype could be displayed and manipulated in three dimensions and the user could freely explore the virtual world. To improve the realism of the virtual environments, most of the virtual toys were incorporated with behaviour or characteristics that mimic the real toys. For instance, a car that can be maneuvered, musical instruments that produce sound when activated, a ball that bounces or rolls, a radio that sings and so on.

Frame-based design that separates the web page into three sections (virtual environments, dynamic links and information, menu) was employed. However, the virtual environment occupies a larger portion of the window to attract more attention to this virtual environment. Talking and/or animating agents have also been incorporated into the system. These agents functioned at providing verbal explanation, instruction and help to the user.

The usability of the prototype system was evaluated based on the cooperative evaluation approach. Monk et al. (1993) described cooperative evaluation as a technique to improve a user interface specification by detecting possible usability problems in an early prototype. One or more representative users are required to participate in the evaluation. It is seen as a technique for participatory design, that is, a way of getting users and designers to communicate effectively about a design.

During evaluation process, subjects will collaborate with designers to evaluate the system together. Designers who are also the evaluators will first specify the representative tasks that the subjects need to work through. A task sheet written in a presentable form will be prepared. This task sheet will keep the subjects focus on the parts of the prototype that the evaluators are interested in at that moment. Example of the tasks given during the first and second iteration of the evaluation process is shown in Table 1.

Two evaluators present in the session where one plays the role to interact with the subject while the other one takes notes. As each subject works, the subject explains to the designer what he or she is doing and asks questions. The subject is encouraged to think aloud while using the system. This is achieved by asking them to give a running commentary of what they are doing and what is going on, or simply by asking them to tell you what they are thinking. Audio and video recording are used to record what the subjects say and do. The main function of these recordings is to act as a backup if there are important details of the session that the evaluators cannot remember and provide concrete demonstrations of user problems. The evaluators then will summarise their observations. Unexpected behaviour and comments about the interface are viewed as symptoms of potential usability problems.

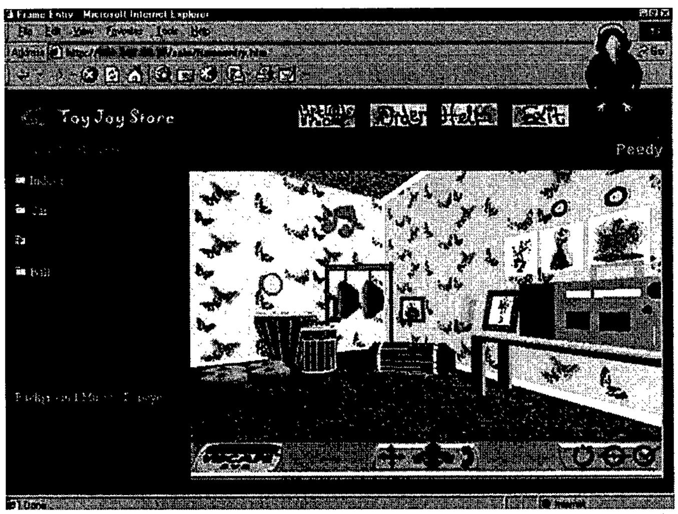

Figure 1: A screen shot of the three-dimensional web-based marketing system

Table 1.
Example of the tasks given during the first and second iteration of the evaluation process

	First iteration	Second iteration
Task 1	• Type the URL • Switch on the background music • Explore the main page	• Type the URL • Explore the main page
Task 2	• Explore the main virtual room • Navigate to one of the doors • Try to open the door • Explore the room • Return to the main room again	• Explore all the 4 virtual rooms • Interact and manipulate any of the toys available in each room
Task 3	• Go to the 'BALL ROOM' • Explore the room • Interact and manipulate any of the toys • Find the soccer and try to interact with it • Repeat for other balls	• Place your order via the online ordering form
: :	: :	: :

6. RESULTS AND DISCUSSIONS

6.1. First iteration of the cooperative evaluation

The following will describe some of the major flaws or dissatisfactions identified through this evaluation and the improvements that have been made to produce the second version of the system.

6.2. Design of the 3D web-based marketing system - Second prototype

Navigation

Subjects were found to face difficulties in the navigation. Firstly, they did not know how to navigate and secondly, the navigation is not as smooth as what they have expected. Although the help icon is provided, only two of the subjects utilised it. A few modifications were performed on the system to improve this situation. Instead of having the user to find the assistance on their own by activating the help icon, a talking and animating agent will be popped up when the user enters a virtual world for the first time. This agent will inform the user to refer to the help icon if they encountered problem in navigation.

One way to enable the user to experience smoother navigation is to provide dynamic link between HTML and the virtual world. In the original prototype system, the user will have to explore the whole main room in order to link to the other toy rooms. This could be time consuming, especially when the navigation is not smooth either due to the low mastery level of the user or the complexity of the virtual environment. By providing dynamic link, the 'scannability' of the web page content could be improved. Scannability, according to Ramsay et al. (1998), refers to the ease with which the user could 'parse' the page. A left frame of the page which shows a list of toys available in virtual room enables the user to know all the toys available and more importantly, to access it instantly.

Once a toy is selected from the hypertext link on the web page, a new virtual world that only consists of the selected toy will be loaded. This will enable the user to concentrate on this particular toy. For those who use the prepared hypertext link for the first time, an animating and talking agent will inform the user of the additional information available on the left frame. The size of the virtual room and objects has also been increased proportionately to facilitate user's navigation. A bigger virtual environment could also assist the user to have a more detail view of the toys in the virtual room.

Interaction with virtual toys

The subjects also commented on the slow response given by the virtual toys. This delay occurred due to the processing time of the personal computer used. One of the solutions to this problem is to remove all replicated virtual toys in room in order to remove the complexity of the virtual room that will definitely takes up the computational time.

Not all of the virtual toys were incorporated with behaviour that will enable them to provide response when interacted. This surprises a few of the subjects. Subjects also dissatisfied with the amount of information provided for each virtual toy (product code, type, price, and a brief description of the toy). They demanded additional useful information. Thus, in the second prototype, all virtual toys will be incorporated with their relevant or realistic behaviour. Additional information, for instance, choices of colour, exact dimensions of the toy, and instructions for interacting with the virtual toys were included.

Talking and/or animating agent

The evaluation has also revealed that the agent has talked too long, too fast, and difficult to be understood. Certain actions, e.g. yawning and snoring while the agent is not giving explanation or inactive, were also found to be annoying and according to the subjects such actions made them felt unappreciated. Therefore, in the second prototype, the agent will only provide brief explanation and will disappear when inactive. However, the agent could be reactivated on request by clicking on the help graphical icon.

6.3. Second iteration of the cooperative evaluation

The revised prototype system is then evaluated for the second time using similar cooperative evaluation approach. Unlike the first evaluation, the number of negative feedback received during this evaluation is much lesser than the initial evaluation. Generally, subjects were satisfied with this revised prototype.

6.4. Design of the 3D web-based marketing system - Third prototype

The only problem that can still be observed is the inability of the subjects to notice the connectivity between the left frame and the frame containing the virtual environments. To alleviate this problem, animating and talking agent is used to reveal the connectivity explicitly using both verbal and visual cues. The agent will firstly animate to the left frame and point at the location where relevant additional information could be retrieved and simultaneously it will give verbal explanation of the information.

7. CONCLUSIONS

Although the cooperative evaluation technique was applied to a 3D virtual environment web-based marketing system, it certainly could be extended to assess and improve the user interaction design of any other 3D pages. In general, this study has revealed a number of aspects that must be taken into consideration when designing a 3D Web-based electronic marketing system. Most of the recommendations on improving the design, as described below, could also be applied to any other 3D pages.

This study has shown that it is important to provide user with easier navigation of the system. Subjects were found to have difficulty to map two-dimensional input to three-dimensional navigation. In general, they were more comfortable with the conventional 'point and click' kind of interaction rather than the 'point, click and drag' interaction. Dynamic link is a new, useful and interesting feature provided by this 3D page as it enables the interaction between HTML and the 3D virtual environment. It was found that utilising dynamic link could actually alleviate the navigation problem ('point, click and drag' operation) because user could access the desired virtual products with minimal navigation through the virtual environment. However, the user has to be informed of this connectivity. In this case, talking and/or animating agent is found to be useful. Spacious and uncluttered virtual environments were also found useful to ease navigation.

Responsiveness measures the rate of communication between the system and the user. Response time is generally defined as the duration of time needed by the system to express state changes to the user. In general, short duration and instantaneous response times are desirable. To achieve fast response time when interacting with virtual objects, the designer will have to consider the trade-off between the complexity and realism of the virtual world with the response time.

This study has also shown that the usage of talking and animating agent is effective in attracting user's attention. It also functions to provide verbal explanation, instruction and assistance to the user. However, care must be taken as it could produce negative effect on the user if it used too frequently.

The ability to acquire sufficient information is demanded by every potential customer in real marketing environment. This study has shown that providing sufficient information about the products to the potential customer is also essential in a virtual marketing environment. The added dimension provided by the 3D page, when compared to the 2D page, has undoubtedly improved the realism of the marketing environment. Besides, the incorporation of intelligent behaviour to the 3D virtual products also plays role to create entertaining and engaging environment.

In summary, this study has pointed out a few principles for improving the usability of a 3D web-based marketing system, specifically, or 3D page, generally. It also shows the practicality and usefulness of cooperative evaluation approach to produce a user-centred application and its suitability for assessing the usability of 3D pages. Further work concerning the employment of this evaluation technique on 3D pages of other applications can further verify and generalise the identified principles.

REFERENCES

1. Supercape®, 3D Webmaster – User Guide, England (1997).
2. Organisation for Economic Co-operation and Development, The Economic and Social Impacts of Electronic Commerce: Preliminary Findings and Research Agenda. [Online]. Available: http://www.oecd.org/subject/e-commerce/summary.htm (1999).
3. Chen, C.J. & Teh, C.S., Desktop virtual reality as a new learning tool: A study of its technical dimensions, Proceedings of National Conference on Cognitive Science, UNIMAS, Sarawak (1998) 221-229.
4. Johnson, A., Roussos, M., Leigh, J., Vasilakis, C., Barnes, C., & Moher, T., The NICE project: Learning together in virtual world, Proceedings of IEEE Virtual Reality Annual International Symposium, IEEE Computer Society, California (1998) 176-183.
5. Pantelidis, V., Suggestions on when to use and when not to use virtual reality in education. VR in the Schools,2, 1, [Online]. Available: http:// eastnet.educ.ecu.edu/vr /vrits/2-1pante.htm (1996).
6. Superscape®, Superscape News, [Online]. Available: http://vwww.com (1999).
7. Roehl, B., Shared worlds, VR News, 8, 10, (1999) 10-11.
8. Gabbard, J.L., Swartz, K., Richey, K. & Hix, D., Usability evaluation techniques: A novel method for assessing the usability of an immersive medical visualization VE, VWSIM'99 Proceeding, California, (1999) 165-170.
9. Hix, D., Swan E., Gabbard, J., McGee, M., Durbin, J. & King, T., User-centered design and evaluation of a real-time battlefield visualization virtual environment, Proceedings of IEEE Virtual Reality '99, IEEE Computer Society Press, (1999) 96-103.
10. Survey Result: 1st International AltaVista Asiawide User Survey, [Online]. Available: http://www.skali.com.my/our_services/survey/av1/av_1.html (1997).
11. Monk, A., Wright, P., Haber, J. & Davenport, L., Improving your human-computer interface – A practical technique, Prentice Hall, N.J. (1993).
12. Ramsay, J., Barbesi, A. & Preece, J., A psychological investigation of long retrieval times on the World Wide Web. Interacting with Computers. 10, 1, (1998) 77-86.

PART ELEVEN

Ergonomics in Action: The Case of Indonesia

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Application of Integrated Ergonomics and SHIP - Approaches in Resolving Sustainable Development Problems in Bali, Indonesia

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Bali for years has to face various sustainable development problems namely competing demand of limited resources (especially water and land), environmental stresses, inequity of economic gains distribution, cultural dislocation, weak management and shortage of development fund, which created various adversely negative impacts to the island. The root causes are due to in-holistic approach in development planning as well as weak law enforcement, which must be seriously taken into consideration in overcoming the problems.

To anticipate, several workshops with integrated ergonomics and SHIP approaches have been organized since 1999 by Bali Human Ecology Study Group(Bali-HESG), covering various significant relevant issues to the problems. The goals of the workshops are to collect action plans that must be carried out to solve the problems as well as to empower and to enhance the participants' capacity to think and act holistically. To work in a team and approaching the problem interdisciplinary as well as to develop collaboration has been encouraged through working in a small group. Ergonomics approach was also gave color to the process of the workshops in term of work and rest pauses designed as well as in providing appropriate and adequate breaks and lunches. In short, organizational development and management of the workshop processes have been creatively conducted and wisely innovated from one workshop to another workshop to fit the need and demand emerged. Changes as global trademark is consciously done from time to time.

The results showed that the participants were practically felt that they had given their full participation and fully satisfied in following the whole programs, which could be seen from their active contribution during the workshops and also from the quantity and quality of the outcome in form of relevant action plans which are really promising.

1. INTRODUCTION

Bali, a small province island of Indonesia, which has for years to fight continuously to be survived and kept sustainable from various adversely development and environmental impacts, is recently also has to face the global free market as well as the monetary crisis which has been faced since 1997 by Indonesia. And within this situation, political reformation and democracy is also has to be considered, among others how to be ready to conduct the new democracy sound act on autonomy, which is sometime created euphoria but in other hand not seldom created also discourage about Bali's sustainability. As Bali is just a small island, and practically depended upon its economic potentials like tourism, agriculture and small scale industry, and in fact, is having only limited natural resources which are now competitively demanded by the development of the above various sectors. In addition, various interrelated problems and issues must also be faced like environmental pressures, inequity in economic gains distribution, social cultural dislocation, inappropriate/ weak management and shortage of development fund. This condition shall consequently course to a wise and rational choice that Bali must be developed as one island, one environment and one management. But it was really a difficult decision to conduct for example within the implementation of the new act on autonomy which gave authority mostly to the regencies. As a technology of democracy, this act must be managed as such that it is actually could enhance the quality of life of the people and must also be fit to the efforts of sustainable development of Bali and global demand as well.

This paper tries to illustrate efforts of community empowerment and participation which have been done so far to anticipate and implement effective and efficient ways to overcome the sustainable development problems in Bali in order to achieve humane and sustainable development of Bali and also fit to global demand.

2. MATERIAL AND METHODS

Knowledge, Attitude and Practice on integrated ergonomics and SHIP-approaches have been exercised and developed through sequence workshops with similar methods and different attractive up to date stimulating topics related to sustainable development problems occurring in Bali. In each workshop every participant must take active involvement, contribution and responsibility. No papers were presented, but guidance how to conduct the workshop was given. The results in form of action plans are primarily the outcome of full participants contribution who were as such selected representing the stake holders of Bali, like the government official, member of parliament, NGO, industry, academician, and so called Bali lovers. For each workshop different relevant participants were invited, and covered more or less of 150 persons who were divided into small groups of ten to twelve with different background. Each participant has similar right, and assisted by a facilitator in carrying out the discussion fit to the instruction given by the moderator (the author of this paper).

The workshop in general following such a mechanism: problems identification, reverse them into positive statements, SWOT/SWBL/SWBR analysis, vision, mission and work plan statement, and ended by writing complete action plans.

3. RESULTS AND DISCUSSION

Five workshops and shall be followed up with others, under the umbrella of Resolving the Sustainable Development Problems in Bali have been carried out just recently with different topics namely :
1) Resolving the Sustainable Development Problems in Bali through participatory and empowerment of the Community. Enhancing the ability to think and act holistically (14-16 September 1999); 2) Effective and Efficient Anticipation and Implementation of Autonomy is a Must to Attain Sustainable Development of Bali. Think and Act with SHIP-approach in facing the Acts No 22/1999 and No25/1999 (3-4 March 2000); 3) Resolving the Sustainable Development Problems in Bali. Effective and Efficient utilization of Limited Water Resources (28 March 2000). 4) Resolving the Sustainable Development Problems in Bali. Effective and Efficient Effort to Manage Nutrition Need and Demand in Bali (3 May 2000) . 5) Resolving the Sustainable Development Problems in Bali. Effective and Efficient

utilization of Public Transport, Individual Cars and Road Capacity in Denpasar. Empowerment and Participation of the Community (11-12 May 2000)..

Bali-Human Ecology Study Group (Bali-HESG), Department of Physiology, School of Medicine, University of Udayana was the organizer with the help of the students of the Postgraduate Study Program on Ergonomic and on Sport Physiology, supported by the Research Institute of University of Udayana and the Regional Development Planning Board of Bali Province. It depends on the topic, various relevant government technical departments also supported the events. In case of the workshop number 4) about Nutrition, this was done as a cooperative work between Antioch University and Udayana University, in this case between Department of Whole System Design and Bali-HESG, which was founded in 1986 as a coach for ergonomists to learn and working in an integrated way with other disciplines to solve sustainable development problems occurring in the community.

The ergonomic approach in organizing the workshops in term of time distribution of works and rest pauses, the quality and quantity of breaks and lunch and its timing to be served, the size of each table group and its excellent trained facilitator, the aerobic exercises to maintain their endurance and to be physically fit, and the attractive workshop guidance and its effective time allocation, and last but not least the AC-meeting room, as a whole created a conducive atmosphere for the participant as well as becoming a good example for the participants how to conduct such a workshop later in their own environment. As the workshop took usually 1-3 days, and some of the participants were present mostly in one or two of the workshops, it is a good conditioning exercise also for them to implement the idea afterward. How attractive was the topics as well as how high the endurance of the participants could be seen from their continuous and active participation during the days of the workshops. This indirectly showed how ergonomics could be effectively and efficiently influenced the process of the workshop, and of course also its results. And the answer of course in form of feeling of healthy, efficient and comfort of the participants in carrying out the workshops.

Appropriate Technology approach, where a comprehensive approach to select a technology must be done from various existing aspects consist of economic, technique, ergonomic and social cultural, energy saving and environmental preservation, were exercised in these workshops within various steps like changing problems into visioning (from negative into positive statement), analyzing those positive statements through SWOT (Strength-Weaknesses-Opportunity-Threat) or SWB/SWBR (Strength-Weaknesses-Benefit-Losses/Risk), then writing the strategic planning specially the vision, mission and work plan and finally the action plans, through team work, collaboration, empathy, and other human relation activities. Each concept, idea, technique, method, tool, etc., must be assessed through this process. Like it or not, the participants through all those processes, get used with comprehensive thinking and act particularly in writing the positive statement, analyzing through SWOT/SWBL/SWBR, and in electing the best action plan.

SHIP-approach (systemically, holistically, interdisciplinary and participatory) has been exercised through the whole process, especially when best decision must be elected. For example, in anticipating and implementing the autonomy acts, Bali as a small island with limited natural resources, which must be developed through its three economic potentials, agriculture, tourism and small scale industry, sustainable development become a must. So every development or intervention must be considered highly to this objective condition. That is why Bali must be considered as one island, one environment and one management. And this concept must always be taken into consideration for every development step.

Empowerment of individuals in participating these workshop to be able to think and act holistically, has been conditioned from the beginning of the workshop through different processes. Start with introduction phase where everybody must introduce oneself background to his group members and telling one successful story faced during his life. By so doing barrier between members of the group could be broken down and feeling of brotherhood could be developed. Then through brainstorming mechanism, everybody must stated problems that he had faced within the theme of the workshop. From the list of problems which have been collected the group has to reverse the negative sentence into a positive one, which meant that we have to bury what has happened and try to look forward. Through this process, each participant was taught how to appreciate others ideas and how to look forward in this global decade. Then from all those positive sentences, the group must choose only 3-5 sentences that they thought to be the most crucial and essential to be worked out through the workshop. Here again each participant has to be tolerance, empathy, and in arrogance. Monopoly was prohibited and work together in a team has been developed intensively. The 3-5 sentences being chosen have now to be analyzed through SWOT or SWBL/R criteria in term of sustainable Bali. Each participant had an opportunity to sharpen his/her analytical capacity and widen his/her horizon through this process. Brainstorming mechanism was also used during the process. Again no monopoly and arrogance in using the time provided. The role of facilitator in each group defined the success of time utilization.

Through all those learning processes, which in reality to enhance the individual capacity both their behavior as well as the substance of the problems, now each group was asked to state a vision which is significantly related to the theme of the workshop as well as the umbrella itself. Then writing the mission to achieve the vision and the work plan how to attain. Vision as feasible dreaming must be thought and approved by the whole group members. While mission could be stated in several significant statements. Then work plan as general action statements follows.

The last process in term of action plans must be written in detail and precisely by the group which covers " who is doing what, when, where, why, whom , why , how and how much budget needed and last but not least is there any supported act or law in existence"

If not, an appeal must go to the parliament to make it. By so doing, we don't want that the output or outcome of the workshop is still just like a list of want, but is really an action that could be implemented. Here again the empathy, feeling in a team, in arrogance behavior, etc., was developed.

Through all those processes, individual capacity was really being developed through a conditioning mechanism.

4. CONCLUSION

Bali as a small island is facing various sustainable development problems like competitive demands of limited resources (water and land), environmental pressures, inequity in economic gains distribution, cultural dislocation, poor management and shortage of development fund so that very often too depended upon investor. Efforts in resolving these problems were done through several workshops with the application of integrated ergonomics and SHIP approaches, in which empowerment and participation of the community were highly encouraged. The results showed that both the output in term of action plans as well as the process itself were really successful as it was planned. More of the participants are now becoming more holistic in act and thinking, and more aware how ergonomics could gave conducive atmosphere to carry out a task.

REFERENCES

1. A. Manuaba. Appropriate technology choice and transfer is a must for sustainable development in Asia, with special reference to Indonesia. Asian Studies Association Annual Conference, Perth, Australia, 1994.
2. A. Manuaba. Total approach is a must to attain sustainable improvement of working conditions and environment in small scale and cottage industry. International Conference on Occupational Health in informal sectors, Denpasar, Indonesia, 1997.
3. A. Manuaba. Appropriate technology approach with its "built-in" ergonomics aspect is a must in technology transfer to attain sustainable development to industrially developing countries. Global Ergonomics. Elsevier. Amsterdam-Lausanne-New York-Oxford-Shannon-Singapore-Tokyo,1998.
4. A. Manuaba. Bali: Enhancing the image through more effective planning. In Bali, Balancing Environment, Economy and Culture, edited by Sugeng Martopo and Bruce Mitchell. Department of Geography Publication Series Number 44, University of Waterloo, Canada, 1995: 29-42
5. A. Manuaba. Enhancing the Culture. As above number 4, page 521-534

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Ergonomics Intervention in Small-Scale Industry in Bali

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Tourism development in Bali gives a positive effect on small-scale industry. The growth of small-scale industry opens the job opportunities. Even though, from the ergonomics point of view, many thing has to be done in order to make the work more humane. Walk-through surveys had been done to small-scale industries in Denpasar and surrounding. Methods applied were interview, observation, and measurement. The results found are as follows: 1) the home industries visited were handicrafts, Balinese orchestra/gamelan, and woodcarver/wood statue factories; 2) working conditions were very poor in terms of ventilation, lighting, sanitation and hygiene, working spaces, water supply, locker, no canteen, no personal protective devices, no training and course, and low wages; 3) working environment was mostly hot-moisture climate; 4) based on that, the demoplots as ergonomics interventions were conducted in some factories; 5) the interventions carried out resulted an increased productivity, decreased muscular complaints, reduced the working heart rate, and improved the subjective feeling to their tasks. It is conclude that ergonomics intervention, event benefiting the industry but it is still need to be encouraged to employer. It is recommended that an awareness program should precede every ergonomics intervention in industry for employer, employees and government as well.

1. INTRODUCTION

In Bali, the growth of small-scale industry is quiet amazing. In every village, there is at least one industry in producing small goods for souvenir. The activities are managed in every house such as handicraft industry or in a factory with a better management such as garment, blacksmith, gold and silver craft and jewellery. That is resulted from the development of tourism of the country (Manuaba, 1998a, 1998b).

Unfortunately, it is not associated by the mechanism that protecting and preventing the workers from the occupational health diseases or hazards. The working condition and environment still poorly managed, as reported by Rafei (1997), Achmadi (1997) and Manuaba (1998a). It is due to the fact that management, labour union still lacking of knowledge on the importance of safety and healthy working condition (Manuaba, 1998a, 1998b). On the other hand the government still facing with the shortages, and limited quality personal on the matter. Some studies have been conducted in identified the existing problems in workplaces (Djestawana, 1999; Sutajaya, 1998; Sutjana et. al, 1998; Paula, 1999). Based on that, ergonomics interventions were carried out. The results found out are reported in this article.

2. MATERIALS AND METHOD

2.1. Subject

Working conditions and environments of small-scale industry were selected as subject of study. The small-scale industries selected were handicraft, balinese orchestra, and woodcarver industries, which are located in Denpasar, and surroundings were chosen.

2.2. Methods

Observation on the working postures and working conditions were conducted. Measurement also performed on the working environments such as lighting, climate, and noise; working heart rate, and the work productivity were also measured. Interview has also carried out using Nordic Body Map to find out the muscular complaints before and after work. Then, after a discussion with managers had been carried out, ergonomics interventions to overcome the existing problems were carried out, as demoplots accordingly.

2.3. Analyses

The data found then analysed using SPSS as described.

3. RESULTS AND DISCUSSION

The industry visited is presented in Table 1 involving a number of workers, male and female, totally about 92 person.

The physical characteristics of subject are presented in Table 1 showing that the workers are belongs to an ideal body weight. There are no overweight or under weight's cases were observed. That could be due to a balance caloric input and output. The existing health and safety problems found are presented in Table 2 with the main problems are as follows:

Table 1
The physical characteristics of workers in some small industry visited in Bali

No. Industry	n	Age (yr)	Weight (kg)	Height (cm)
1. Handicrafts	20	23.1 +/- 5.75	48.9 +/- 5.26	154.1 +/- 6.56
2. Balinese Orchestra	20	35.5 +/- 11.3	58.6 +/- 6.28	162.0 +/- 6.62
3. Woodcarver Ind.	20	19.5 +/- 2.1	56.0 +/- 7.80	164.7 +/- 3.50
4. Wood statue Fact.	32	24.3 +/- 4.55	62.5 +/- 6.30	165.5 +/- 5.04

The findings are conform the results reported by Manuaba (1998a;1998b), and as reported by Rafei (1997), Salter (1997), and Mikheev (1997). It is a feature of workers in developing countries work with poor working environments.

Based on that, some ergonomics interventions were carried out. Interventions conducted in every workplace are presented in Table 3 which was preceded by an awareness step, to discuss the benefits of program with employers, as recommended by Manuaba (1998a;

1998b). The interventions were carried out using the principles of low-cost improvement (Kogi, 1997; 1998), the appropriate technology and participatory ergonomics (Manuaba, 1998a; 1998b; Gilad, 1998) by making use of the existing materials and the local skills. Results found are as follows: In handicraft by giving an ergonomics chairs and tables the workers do their tasks more comfort; there were no more unergonomics working body positions observed. The working heart rate was significantly decreased ($p<0.05$), the subjective feelings were also decreased ($p<0.05$), the musculo-skeletal complaints reduced significantly ($p<0.05$) and the productivity was increased significantly ($p<0.05$), from 0.47 to 0.78 (Paula, 1999). In Balinese orchestra factory with 20 subjects measured, giving the same results. The working heart rate reduced, ranging from 9.03% to 14.95%; the musculoskeletal complaints also decreased; and the subjective rating scale also showing an improvement. All results found statistically were significant ($p<0.05$) compared with the mean values of before treatment (Djestawana, 1999). In woodcarving industry also gave a positive result. An improvement on working body postures associated by a decreasing the working heart rate, reduced the musculoskeletal complaints, and workers felt a better working position (Sutjana et al, 1998). In wood statue factory, the similar result was found. It was associated by an increased on productivity about 25.5 %, which is statistically significant ($p<0.05$) (Sutajaya, 1998). The intervention result an improvement on working body posture means no more unnatural postures while working. The muscles work more efficient without additional workload as well (Grandjean, 1988). The working rest and fatigue was minimised as indicated by result of individual assessment. All those were supported for the work productivity as also reported by other researchers (Kogi et. al, 1998; Gilad, 1998). In doing the above interventions, appropriate technology and low-cost principle must be considered (Kogi, 1997; 1998; Manuaba, 1998a, b) by the ergonomists, employees and employer as well.

Table 2
The problems existing in the small-scale industry visited

No.	Health and safety and ergonomics problems identified
1.	Poor working environments: lighting, ventilation, temperature, spaces
2.	Working body postures: stooping posture, spinning positions, bending
3.	Poor working conditions: work layout, work process, material handling, non-ergonomics tools, heavy workload, no protective devices
4.	Insufficient quality manpower: lower physical working capacity, low level of education, without training and course, carelessness, lower motivation, without considering the factory vision, no manpower planning, wrong management system,
5.	Lack of evaluation and monitoring:

Table 3
The ergonomics intervention carried out in small-scale industry in Bali

No. Industry	Intervention conducted
1. Handicraft in Tabanan Regency.	Ergonomics chairs and tables for workers
2. Balinese Orchestra factory.	Working body posture, and environment
3. Woodcarving industry.	Working body posture
4. Wood statue factory.	Working layout, work process, body posture

4. CONCLUSION

Conclusions could be drawn are: In small scale industry the workers are still facing with the poor working conditions and environments; ergonomics intervention informs of demoplots resulted a decreased working heart rate, musculoskeletal complaints, subjective complaints, and an increased on work productivity.

Therefore, it is recommended that ergonomics intervention in small-scale industry is still needed; in order to achieve the sustainable improvement it must build on the local technology and the economically low-cost.

REFERENCES

1. Achmadi, U.F. 1997. The PHC based , occupational Health care delivery system (Experience from Indonesia). Paper presented at ICOHIS 97 at Denpasar, 21-24 October 1997.
2. Djestawana, I G.G. 1999. Improvement of working posture in "manggur process" of Balinese Orchestra Factory decreases the working heart rate, musculoskeletal disorders of workers at Balinese Orchestra Factory at Tihingan, Banjarangkan, Kelungkung Regency. Master Thesis. Postgraduate School on Ergonomics. Udayana University.
3. Gilad, I. 1998. Ergonomic participatory plan in the diamond industry. In: P.A. Scott, R.S. Bridger, J. Charteris (Ed's). *Global Ergonomics*. Elsevier. Amsterdam:919-924.
4. Grandjean, E. 1988. Fitting the Task to the Man. An Ergonomics Approach. Taylor and Francis.
5. Kogi, K.; Kawakami, T., Itani, T. and Batino, J.M. 1998. Impact on productivity of low- cost work improvement in small enterprises in a developing country. In: P.A. Scott, R.S. Bridger, J. Charteris (Ed's). *Global Ergonomics*. Elsevier.Amsterdam:23-26.
6. Kogi, K. 1995. Participatory ergonomics that builds on local solutions. j Human Ergo 24:37-45.
7. Manuaba, A. 1998a. Appropriate technology approach with its "built-in" ergonomics aspect is a must in technology transfer to attain sustainable development in industrially developing countries. In: P.A. Scott, R.S. Bridger, J. Charteris (Ed's). *Global Ergonomics*. Elsevier. Amsterdam: 57-62.
8. Manuaba, A. 1998b. Widen the horizon is still needed in ergonomic approach and application in Indonesia. Paper presented at: One-Day Seminar on Ergonomics and Sports Physiology at School of Medicine, Udayana University Denpasar, at November 18, 1997.
9. Mikheev, M. 1997. Occupational Health for all feasible and cost effective efforts. Paper presented at: ICOHIS 97, at Denpasar, 21-24 October 1997.
10. Paula, J.A. 1999. Improvement of working posture by implementing chair and working table based on anthropometric data of workers increases work productivity and decreases the musculoskeletal disorders. Master Thesis. Postgraduate School on Ergonomics. Udayana University, Denpasar, Bali.

11. Rafei, U.M. 1997. Occupational health and safety in the informal sector: a challenge for the 21st century. Paper presented at ICOHIS 97 at Denpasar, 21-24 October 1997.
12. Salter, W. D. 1997. Occupational Health and safety in the informal sector, an ILO perspective. Paper presented at ICOHIS 97, at Denpasar, 21-24 October 1997.
13. Sutajaya, I M. 1998. Improvement of working condition reduce musculoskeletal complaints and working heart rate as well as increased productivity among wood carvers at Peliatan, Ubud, Bali. In: P.A. Scott, R.S. Bridger, J. Charteris (Ed's). *Global Ergonomics*. Elsevier. Amsterdam: 505-510.
14. Sutjana, D.P., Suwetra, K., Widana, K., Tirtayasa, K. and Adiputra, N. 1998. An improvement of working posture decreasing subjective complaints of woodcarving. Paper presented at: One-Day Seminar on Ergonomics and Sports Physiology, at School of Medicine, Udayana University Denpasar, November 18, 1998.

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Ergonomic Design Evaluation of a Hand-Tractor: Value Analysis and Cumulative Trauma Disorders (CTDs) at a Sugar Factory in Jatiwangi, Majalengka

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Indonesia as one of the agricultural country in the world, produces rice, palm oil, cane sugar, canned fruit and many other produces. These produces are all intended to serve the Indonesians people to increase social welfare in creating just and prosperity society. One of the most important produce is cane sugar, produced by cane sugar factory Jatiwangi, Majalengka, West Java, Indonesia. The Factory uses Hand-Tractors to substitute man or animal power in cane- field hoping that other productivity or quality of cane sugar can be ideally increased. Unfortunately, the Hand-Tractors cannot be maximally used because of human factors problems, for example, the unskilled operators of the hand tractors complained about feeling hurt at certain part of their body. The writer studied Hand-Tractors Yanmar YZC-105L type used at cane sugar-field Jatiwangi, Majalengka through ergonomics analysis and studies of cumulative trauma disorder (CTDS). The result of study shows:

1. The tractors are difficult to operate because they are too heavy to drive. This is because if hand tractor handle is too short, some operators need bamboo to make the tractors easier to drive. Furthermore, the tractor causes pain on biceps, triceps and back part of the body of an operator.
2. The hand-brake handle is difficult to operate because of the spacing between the brake and handle does not match with Indonesian fingers. Extra power is needed to operate them and consequently they hurt fingers muscles.
3. The hand-tractor is very often used driving backwards for some work to be done. When it is operated on uneven field, the operator feels pain at his shoulder and waist.

1. INTRODUCTION

1.1 Background

National development in Indonesia is moving very fast. In the year 2003 the government and the people of Indonesia have to be ready to welcome and implement the APEC (Asia Pacific Economics Commitment) Agreement in ASEAN Countries.

To anticipate the effect of the free trade policy, the national instability, the government has launched some policies to solve especially social problems following the free trade policy. One of the solutions is to produce cane sugar which is needed mostly by the people of Indonesia. It is produced by cane sugar factory under PTP-6 Rajawali II under controlled of the Department of Finance, Republic of Indonesia.

Cane sugar factory Jatiwangi PT Rajawali II tries hard to think about how to increase the income of the company to solve the national instability. The solution is done through management policy, including productivity development, quality and quantity of sugar cane.

To fulfill the purpose, PT Rajawali II operates hand tractors. The focus of the study is on probing Hand-Tractors Yanmar YZC-105L Type to observe the strengths and the weaknesses of the machines through ergonomical approach.

1.2 The Purpose of Study

1). To evaluate the use of hand tractors at cane-field with ergonomical aspect approach and to know what factors hinder the tractor seen from design and other technological attributes

2). From the results of the evaluation of ergonomics design, it is hope to contribute to an increase in the quality and quantity of cane sugar at the factory.

2. THE APPROACH TO PROBLEM SOLUTION

The hand tractor Yanmar YZC-105L type, used by Jatiwangi sugar tractor to process the cane it is needed to evaluate ergonomically through the aspect of anthropometry, value analysis, and cumulative trauma disorders (CTDs)

2.1 The Aspect of Anthropometry

Table 1 shows the dimension of hand-tractor YZC-105L type, with respect to anthropometry. The evaluation of hand-tractor is on the width of shoulder standing height shoulder, length of palm, arms reaching, fingers length, length of foot step and body weight.

Table 1. The dimension of hand-tractor YZC-105L

No.	Attribute dimension	size
1.	Height of handle bar	95.5 cm
2.	Width of handle bar	102 cm
3.	Handle bar clutch diameter	3.4 cm
4.	Brake clutch space	10 cm
5.	Length of brake leg	15 cm
6.	Gear handle reaching	55 cm
7.	Length of handle bar	31 cm
8.	Weight of tractor	190 kg

Table 2 Anthropometrical data analysis result

No	Human body size	Percentile 5	Percentile 95	Modus
1.	Width of shoulder (LBH)	38.56	65.25	51.15
2.	Standing Shoulders height (TBB)	124.44	164.11	143.64
3.	Length of Palm (PTT)	16.283	22.276	17.848
4.	Arm reaching (JT)	65.603	87.654	78.108
5.	Length of fore finger (PJ2)	6.505	9.715	9.187
6.	Length of middle finger (PJ3)	7.745	11.138	9.299
7.	Length of ring finger (PJ4)	6.625	10.153	9.026
8.	Length of little finger (PJ5)	5.412	8.495	7.221
9.	Length of footstep (PLK)	43.53	71.22	56.96
10.	Body weight.	50.25	71.45	61.55

Resource : Result of Observation by 30 hand tractor drivers at cane sugar factory, Jatiwangi

The result of statistical processing shows:

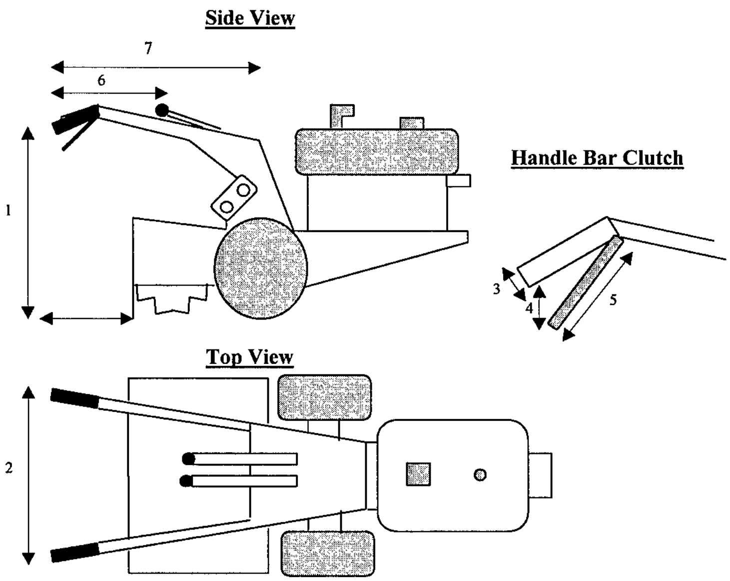

Figure 1. The Hand Tractor

2.2 Cumulative Trauma Disorders (CTDs)

CTDs are traumas experienced by hand tractor operators resulting from abnormal working situation which is created by uneven fields or even by failure of the function of part of the body. The result of the study shows there are 3 kinds of cumulative trauma disorders (CTDs) on the hand-tractor:

1. The length of the handle bar is too short, so the body moves forward because of unbalanced weight of diesel machine and the operator. The trauma felt by the operator is pain on biceps, triceps, shoulders and back.
2. The hand –tractors some time is used on bumpy cane field. The operator must drive backward. The situation makes the tractor difficult to control. Because of backward driving, the implement (knife processing) flatten the land to make the tractor stability. This causes pains on the shoulders, joint, and waist of the operators.
3. Hand brake handle is difficult to reach it is because too tight. The space between handle bar and brake do not match with Indonesian fingers. The brake is too strong to restrain and the operator must use the extra energy

2.3 Design Evaluation of Hand-Tractor

The result of CTDs and Anthropometrical analysis an ergonomical hand-tractor are:

1. The width of handle bar

To determine the width of handle bar:

The width of handle bar = LBH + 2(½ √2 (JT – PTT) ...(1).

The formula refers to the assumption, if the hand stand forward = O^{o}, and stand aside = 90^{o}, the hand position result optimal power is 45^{o}.

$$\sin 45^{o} = \frac{a}{(JT - PTT)}$$

Width of handle bar = 51.15 + 2 (½ √2 (78.11 – 17.85) = 93.76 cm

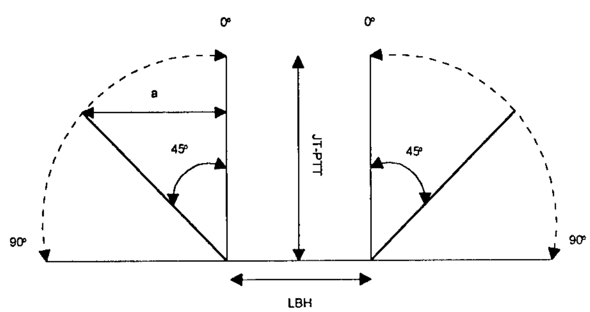

Figure 2. The width of Handle bar size

2. The height of handle bar

To determine the height of handle bar from land level:

The height of handle bar = TBB – ½ √2 (JT-PTT) ...(2)

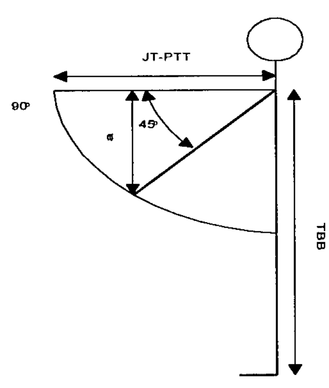

Figure 3. Handle bar height size

3. Handle bar Clutch

   To determine ergonomical handle bar clutch done with percentile 5 from the palm length. The position of palm is round to cover the handle bar clutch circle. The space between fingers and waist is 7 cm.

   The size of handle bar clutch circumference is :

$$D = \frac{circumference}{TI} = \frac{16.283 - TI}{3.14} = 2.95\ cm \qquad \ldots(3)$$

4. Brake Clutch

   To know the space between brake and handle bar, is used the length of fore finger (PJ2), middle finger (PJ3), ring finger (PJ4) and little finger (PJ5. The result according percentile 5:

   Length of fore finger = 6.50 cm
   Length of middle finger = 7.75 cm
   Length of ring finger = 6.63 cm
   Length of little finger = 5.41 cm

   The space between brake and handle bar $\pm$ 5 cm. The length of brake leg calculated from width of palm Percentile 95 = 11.18 cm

5. Gear Handle Reach

   The determined reaching space gear-handle is used percentile 5 (JT – PTT). The score is 65. 60 - 16.28 = 319.32 cm
6. Space between operator and implement

   Determined by percentile 95 from toot steps = 71.22 cm
7. Length of handle bar

   Determined by balanced principle of lever

$$M_1X_1 = M_2X_2$$

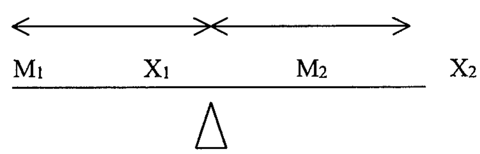

Figure 4. Level balancing principle

Weight of tractor = M_2 = 190 kg
Length of diesel Machine = X_2 = 86 cm
Operator weight (percentile 5) = M_1 = 50,25
Length of handle bar $x_1 = M_2X_2/M_1$ = 190(86)/50.25 = 325. 17 cm

The calculation (table 3) proves the complain exist through the CTDs analysis are less length of handle bar, space of brake clutch, and length of brake leg.

Table 3
The comparison between Hand-tractor dimension and calculation

No.	Dimension evaluated	Tractor dimension (cm)	Result of calculation (cm)
1.	Width of handle bar	102	93.78
2.	Height of handle bar	95.6	101.03
3.	Length of handle bar	131	325.17
4.	Handle bar diameter clutch	3.4	3.95
5.	Length of brake leg	15	11.18
6.	Space of brake clutch	10	5
7.	Handle-gear reach	55	49.32

2.4 Value Analysis

To complete hand tractor evaluation with anthropometry and CTDs aspect, there is a need to study further consumers' needs of the tractor. The analysis includes function need (identification of the tractor relevant to consumers), need analysis (to know the attributes which need to resist and develop as performance repairing)

The attributes need to rise up performance as follow:

1. Simplicity of performing maneuver
2. The weight of the tractor (too heavy)
3. Machine duration (reliability of machine, durability)
4. The simplicity of regular maintenance

The attributes have to be resisted in performance as follow:

1. The function land processor
2. The practical and simple operation
3. Corrosion resistance
4. The alternative vehicle

3. CONCLUSION

Through the analysis on anthropometrical CTDs and value aspect, to the tractor, the result shows:

1. The operators have difficulty in controlling the tractors because the length of handle bar is not optimal. The tractor is too heavy so the operators feel pain on their muscles.
2. Hand brake is not ergonomically designed. The space of brake clutch is too far so the operators have to use extra energy to pull the brake and experience pain in their finger muscles.
3. The result of need analysis shows that the priorities to develop performance functions are, simple maneuver attributes and the weight of hand tractor.

REFERENCES

1. Barnes , R.M. ,"*Motion and Time Study*", John Wiley & Sons, New York., 1985
2. Barry H, Kantowitz ,"*Human Factor Understanding People-System Relationship*", John Wiley & Sons, New York., 1983
3. Bridger, R. S. ,"*Introduction to Ergonomic*", McGraw Hill, Singapore., 1995
4. Mc Cormick,Ernest J, "*Human Factor in Engineering and Design*", Mc Graw Hill Book Co., New Delhi., 1976
5. Niebel, W. Benjamin,"*Motion and Time Study*",Irwin Inc.,Illinois. 1988

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Effects of Vibration on the Operator of a Tamping Rammer Machine

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Vibration is a mechanical oscillation which is produced by regular and irregular periodic movements on its standstill point. Vibration which occurs on motor-handle machine such as tamping rammer, grinder, rock-perforator, sawing-machine, and so on, is transmitted from the hand to the body, especially on the upper-body, that cause quivering on the body it self. Vibration on the hand will produce some effects on blood vessel and hand-nerves. Blood-transmission to the hands and fingers will be decreased for where it will create clumsy and suspended animation on the hand, and will slowly diminish hand-control. The employee, therefore, has difficulty in handling, grasping and moving the hand or fingers. The character of this problem is reversible if it has been detected early. For a long period, this will cause a permanent trouble, the so-called hand-arm vibration syndrome. To understanding the problem on hands and fingers movement, an early study of hand time-reaction on the employee who uses tamping rammer machine has been done by using pre and post tests. The result showed significant changes of hand time-reaction.

1. INTRODUCTION

The use of motor-handle machine has been widely applied, for instance, tamping rammer, hand-tractor, grinder, rock-perforator, concrete vibrator, sawing machine, and so on. The use of these motor handle machines aims to improve efficiency and productivity of the work. On the other hand, these machines cause some vibration and noise effects. Vibration which appears on motor-handle machines is transmitted from the hand to the body especially on the upper body and cause quivering on the body it self. Dul and Weerdmeester [1] described that there are three important variables that determine this vibration such as intensity, frequency and exposure duration. Grandjean [2] and Bridger [3] reported that strong vibration and a long period of exposure time did affect visual acuity, performance in various psychomotor, muscle work, blood vessel and respiration, where it will increase casualty.

Tamping rammer is one of the motor-handle machines that use to condense the soil. This machine is operated by grasping its handle with two hands but the body is on standing position, and control on forward and backward directions. This machine converts rotation movement of motor into translation movement that produce knocking. Periodically of this impact generates vibration and noise. Vibration on the hand during operation will reduce blood transmission on the hands and fingers due to constriction of blood vessel. Helander [4] and Pheasant [5] explained that decreasing of blood transmission created clumsy and suspended animation on the fingers, consequently, the employee has difficulty to handle, grasping and moving the hand or fingers. Bridger [3] described that the character of this problem was reversible if it has been detected early. For a prolonged period, this will cause a permanent trouble, the so-called hand-arm vibration syndrome.

According to the preparation described above, the main problem is the effect of vibration on the hand-time reaction of the employee who are using tamping rammer machine. This research aims to understand the influence of vibration on hand-time reaction and pulsation of the artery of the operator.

2. MATERIAL AND METHOD

2.1. Subject

Five subjects who were randomly selected were engaged in the experiment. Subjects' mean age between 22-25 years old and they have not yet used this tamping rammer machine, in order to avoid the effects of this machine to their body on the past time. This research is designed with one group pre and post tests design. Measurement was carried out on the pulse of artery and hand time reaction, before and after work. The mean results before work will be compared to the mean results after work. Analyses were accomplished by using t-test on one tail test with significance level 5 % ($\alpha = 0,05$).

2.2. Device

This tamping rammer machine has an impact availability of about 570-600 times per minute or on frequency of about 10 Hz, Jumping stroke 45-55 mm or on acceleration of about 77g and weight 80 kg. Helander [4] described that the fainter of rubber reduced the amplitude by 70 %, and the acceleration was about 5.4 g on the motor handle. For fully operated, tamping rammer machine can be operated on 40 minute nonstop. The instruments to measure are stopwatch, to measure time, and ruler, to measure the time reaction, with 60 cm length, 3.5 cm width, 0.4 cm thickness and 110 gram of weight.

2.3. Procedure

Before test, pulse of the artery (on relax condition and with palpation of ten pulsation) was measured by using a stopwatch, continued by measuring pulse of the artery per minute. After three times of measurement (with one minute interval), the mean pulse of the artery for pre test was completed. Pulse of the artery for post test was achieved by three times exercises during 30 minutes. All pulse measurements were observed on standing position. Hand-time reaction test has been accomplished by release the ruler and clip it between thumb and forefinger. The distance between thumb and forefinger has been fixed on 3.5 cm (width of the ruler). Time reaction is similar with the length of the ruler, the shorter the length the shorter time reaction is. Those tests were observed three times, for left and right hands and for pre and post exercises, continued by calculating the mean values. Beside these measurements, subject conditions such as age, height and weight were also measured.

3. RESULT

Result of the measurement can be seen in Tables 1, 2, 3, in order to understanding the difference between time-reaction of pre-test and post-test.

Table 1. Data of the samples

Variable	Mean	Standard Deviation	Minimum	Maximum
Age (years)	22.80	0.84	22	24
Height (cm)	166.20	4.60	161	172
Weight (kg	55.60	5.02	51	63.5

Table 2. Heart Rate

Variable	Mean	SD	Min	Max
Resting pulse (beat/minute)	84.97	6.80	77.93	94.76
Working pulse (beat/minute)	130.13	11.47	116.14	140.49

Table 3. Hand time reaction and t-test

a. Time reaction

Variable	Mean	SD	Min	Max
Right hand				
Before work (cm)	19.43	1.36	17.67	21.33
After work (cm)	21.73	3.54	18	25.67
Left hand				
Before work (cm)	17.00	1.13	15.67	18.33
After work (cm)	23.03	3.43	19.67	27.00

b. "t" test for hand time reaction

Variable	Mean	SD	"t"	P
Right hand	2.30	3.89	1.32	> 0.05
Left hand	6.07	3.14	4.32	< 0.05

4. DISCUSSION

The results of the artery pulse before working have the mean value of 84.97± 6.8 beats per minute, with the minimum of about 77.93 beats per minute and the maximum of about 94.76 beats per minute. Grandjean [2] categorized the results as a light working, where it affected by the movement from home to the job location. Results of heart rate after working have the mean value of 130.13± 11.47 beats per minute, with the minimum of about 116.14 beats per minute and the maximum of about 140.49 beats per minute. Grandjean [2] categorized the results as a heavy working, where it differs of about 45.16 pulses per minute, or an increase of 53.14 % from resting pulse. Grandjean [2] described that the increasing of working pulse should not exceed 30 pulses per minute on standing position. The results indicate that the job will not achieved the optimal periodically working.

Results of right hand time reaction test for pre test have the mean value 19.43 ± 1.36 cm, with the minimum of about 17.67 cm and the maximum of about 21.33 cm. After working, the mean value was 21.73 ± 3.54 cm, with the minimum of about 18.00 cm and the maximum of about 25.67 cm. By using t-test, it can be obtained that the time-reaction was decreased but insignificantly with $p>0.05$.

Results of left hand time reaction test for pre test have the mean value of 17.00 ± 1.13 cm, with minimum of about 15.67 cm and the maximum of about 18.33 cm. After working the mean value was 23.07 ± 3.43 cm, with the minimum of about 19.67 cm and the maximum of about 27.00 cm. By using t-test, it can be obtained that the time-reaction was decreased significantly with $p<0.05$. Right hand indicates an insignificantly different, but left hand indicates a significantly different. This difference causes since the subjects were not left-handed and always use right-hand on their proper jobs.

The measurement has been conducted into the machine it self. Stationary height is 76 cm, handle diameter 2.7 cm. Nurmianto [6] explained that the average height of Indonesian people of about 163 cm, elbow height of about 100 cm and handgrip diameter of about 4.5 cm. Grandjean [2] suggested that for heavy work on standing position, height of working plane should be 15 cm under the elbow or about 85 cm. Therefore, the operator's posture seems to be distorted during activity which generate weariness. Handle diameter with smaller than hand-tool requirement, affects fingers ability when handling and grasping.

5. CONCLUSION

1. Generally, the results indicate that job of the operator of tamping rammer can be categorized into heavy condition and should not be operated periodically on 8 hours.
2. Results of right hand-time reaction before and after working show insignificant difference of $p > 0.05$. Results of left hand-time reaction before and after working show significantly difference of $p <0.05$.

6. SUGGESTIONS

1. Tamping rammer was operated on frequency of about 10 Hz and acceleration of about 5.4 g. Since the results indicate that the work is categorized as heavy job, then time exposure should be reduced.
2. Wearing gloves for the operator is suggested in order to avoid hotness and to faint the vibration effects.

REFERENCES

1. Dul,J. & Weerdmeester, B. 1993. Ergonomics for Beginners : A quick Reference Guide,Taylor & Francis Ltd.
2. Grandjean, E. 1988. Fitting the Task to the Man, A Textbook of Occupational Ergonomics 4th, London : Taylor & Francis Ltd.
3. Bridger, R.S. 1995. Introduction to Ergonomics, McGraw-Hill Inc.
4. Helander, M. 1995. A Guide to the Ergonomics of Manufacturing, Taylor & Francis.
5. Pheasant, S. 1991. Ergonomics, Work and Health, Macmillan Press Scientific & Medical.
6. Nurmianto, E. 1996. Ergonomi, Konsep Dasar dan Aplikasinya, Penerbit PT. Guna Widya, Jakarta.

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Work Posture and Musculoskeletal Discomfort of Stone Carvers

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The aspect of worker posture and musculoskeletal discomfort were assessed among sixteen stone carvers in Duda village, Karangasem Regency, Bali. Descriptive analysis, with the help of Mannequin software was used to evaluate the relationship between work posture and musculoskeletal discomfort. From the data recorded through on the spot observation and questionnaire distribution was found that static working posture for a long time caused low back discomfort, buttock, neck, back, shoulder, elbow, hand, arm, wrist, and leg discomfort. From this survey it can be concluded that musculoskeletal discomfort were closely related to the working posture. It is suggested to use table and bench based on anthropometric data of the workers.

1. INTRODUCTION

Duda village in Karangasem regency is one of central stone carver industries. The raw material used for this small industry is a kind of volcanic stone which is grayish black in colour. The biggest temple in Bali, Besakih temple are now renovated by using this stone because of its natural good looking, hard and long life.

Photo 1 *Bale agung*

From photo 1, the volcanic stone is used as a base of the *bale agung* building (building found in the temple area). Most of the workers found in this village are still using traditional handtools to finish their work and the awkward working posture are sitting, kneeling and squatting on the ground. The daily working time from 08.00 in the morning till 16.00 in the afternoon including one hour of lunchtime, 12.00 – 13.00. All of these ergonomically unsound (awkward) working postures resulted in musculoskeletal discomfort (see photo 2-4).

Photo 2 working posture 1

Photo 3 working posture 2

Photo 4 working posture 3

Activities which cause awkward working posture for long period of time will produce musculoskeletal discomfort (Pheasant 1991; Granjean 1988; Li and Haslegrave 1999).

In order to find out the relation between working posture and musculoskeletal discomfort this survey is done and furthermore the use of ergonomics table and bench are advised to meet the healthy, safety, comfort and efficient environment.

2. MATERIAL AND METHOD

2.1. Subject

In this survey 16 stone carvers (male) in Duda village were selected randomly as sample.

2.2. Method

This survey was carried out on 21 and 22 of April 2000. The methods used were:

- On the spot observation from 09.00 - 11.00 and from 14.00 - 16.00.
- Interview and filling questionnaire before lunch time and before the end of working time.

The working posture during observation were photographed (photo 2-4) and the data collected were analyzed descriptively

3. RESULT AND DISCUSSION

The sample physical characteristics presented in Table 1.

Table 1
The sample physical characteristics

No	Variables (N=16)	Mean	SD	Range
1	Age	29.5 years	5.75	22 - 37
2	Experience	12.5 years	5.75	4 - 20
3	Body height	165.56 cm	4.07	158 -172
4	Body weight	63.0 kg	3.83	55 - 69

The above data show that the stone carvers were in productive period of age and have enough working experience. Body height and body weight were in normal range. The deeper questioning found that most of them starting their work when they were teenage.

The static working position will cause musculoskeletal discomfort as presented in Table 2 more than 50% of the workers complaining discomfort around the muscle at low back, buttock, neck, back, shoulder, hand, and leg. Mannequin simulation of working position (figure 1) related to the table of torque (figure 2). By changing the working position the torque resulted was also change. Figure 2 illustrate the highest torque supported by muscles around the vertebral muscles. Research done by Liao and Drury(2000) showed that working posture-comfort-performance was interrelated. The effects of ergonomic factors on musculoskeletal discomfort were clearly evident in the analysis of research carried out by Sauter et. al (1991); Starr et. al (1985); Wiker et. al (1989).

Table 2.
Musculoskeletal discomfort of stone carvers (N=16 person), 2000

NO	LOCATION OF DISCOMFORT	%
0	Upper part of neck	81.25
1	Lower part of neck	75.0
2	Left shoulder	43.75
3	Right shoulder	68.75
4	Upper part of right arm	43,75
5	Back	75.0
6	Low back	93.75
7	Buttock	93.75
8	Right elbow	62.50
9	Left lower arm	31.25
10	Right lower arm	43.75
11	Right wrist	43.75
12	Right hand	56.25
13	Left thigh	43.75
14	Right thigh	43.75
15	Left knee	37.50
16	Right knee	37.50
17	Left leg	56.25
18	Right leg	56.25
19	Left ankle	18.75
20	Right ankle	18.75
21	Left foot	12.50
22	Right foot	12.50

Mannequin software simulation

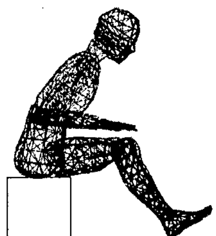

Figure 1 posture simulation

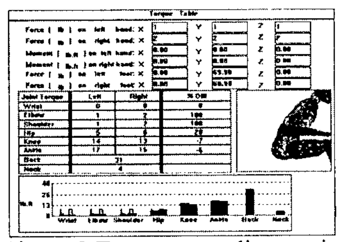

Figure 2 Torque according to simulation

Questionnaire evaluation of musculoskeletal discomfort presented in Table 2.

4. CONCLUSION

It is concluded, awkward working posture for hours during the day for years caused musculoskeletal discomfort among stone carvers. Most stone carvers complaining low back discomfort, buttock, neck, back, shoulder, elbow, hand, arm, wrist, and leg discomfort. By using mannequin software the working posture can be simulated and the torque resulted can be evaluated from the following table. Based on the study which have been done (Sutjana et. al 1994; Sutajaya 1997; Suyasning 2000; Swanson et. al 1997) the propose of ergonomics table and bench according to the anthropometric of the workers are highly recommended to reduce the musculoskeletal discomfort.

REFERENCES

1. Granjean, E. Fitting the task to the Man. A textbook of occupational Ergonomics. 4th edition. New York: Taylor & Francis. 1988.
2. Li G, Haslegrave CM.(Abstract).Seated work postures manual, visual and combined task. Ergonomics (E-Journal)1999 Aug;49(8):1060-86.
3. Liao MH, Drury CG.(Abstract). Posture, discomfort and performance in a VDT task. Ergonomics 2000 Mar;43(3):345-59.
4. Pheasant S. Ergonomics Work and Health. London: Macmillan Press.1991
5. Sauter SL, Schleifer LM, Knutson SJ. (Abstract). Work posture, work station design, and musculoskeletal discomfort in a VDT data entry task. Hum Factors 1991 Apr;33(2):151-67.
6. Starr S. J., Shute S.J., Thomson CR.(Abstract). Relating posture to discomfort in VDT use. J Occup Med 1985 Apr;27(4):269-71.
7. Sutjana, D. P. et. al. Improvement of Working Posture Increases Productivity of Roof Tile Home Industries Workers at Darmasaba Village, Badung Regency. In Proceeding of the Conference of SEAES. November 21-23,Bangkok. 1994.
8. Sutajaya, I M. 1997. Muskuloskeletal Disorder and Working Heart Rate Among "Batako" Workers at Gianyar Regency. International Conference on Occupational Health in Informal Sector. Bali. 21 - 24 October 1997.
9. Suyasning HI. Low cost implementation decreases neck and shoulder complaints among the male silversmiths at Lod Tunduh village, Ubud. Department of Physiology. 2000
10. Swanson NG, Galinsky TL, Cole LL, Pan CS, Sauter SL.(Abstract). The impact of keyboard design on comfort and productivity in a text-entry task. App Ergon 1997 Feb;28(1)9-16.
11. Wiker SF, Chaffin DB, Langolf GD.(Abstract). Shoulder posture and localized muscle fatigue and discomfort. Ergonomics 1989 Feb;32(2):211-37.

Investigation of Sitting Work Posture of Cagcag Weaver at Desa Gelgel, Klungkung, Bali

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The improvement of sitting work posture of *cagcag* weaver was investigated among three groups of different sitting style : sitting work posture on the floor (control), sitting work posture on the sloped chair (treatment I) and sitting work posture on the *balai* chair (treatment II). Using 30 items self rating questionnaires, subjective feeling complaints was assesed on 30 women of *cagcag* weavers in Desa Gelgel, Klungkung, Bali. Principal components analysis was to find 3 substantial dimensions : weaken activity, weaken motivation and weaken physical fatigue by general conditions. The result showed that both treatments mean scores were significantly difference decrease the weaken activity and weaken physical fatigue by general conditions than the control group.

1. INTRODUCTION

The *cagcag* is traditionally weaving loom of *songket* Bali textiles. The processing of Bali's *songket* by hand woven in small scale industry because it's ethnic variety motive. The *songket* is also hidden art, tradition, and simplicity (Manuaba, 1983). The weaving inclusive of sedentary working, where the present working style the weaver long sitting on the floor covered by mats. It is hereditary from generation and according to the traditional manner of weaving work posture.

The problems of sitting work posture of the weaver are: 1) the angle of the body between trunk with thigh is 90°; 2) the angle of the thread between bowel with thigh less than 30°, where is likely tilt the head and neck downward and maximum forward reaching in order to get the task; 3) the rectangle of the foot with ankle, which is predetermined by the foot rest to support of the leg. So was repetitive and monotonous movements, which the foot, leg, arm, back and neck area becomes uncomfortable (Grandjean, 1993, Pheasant, 1988, Kroemer, et al, 1994). There are also indications slower of work processing and feelings of fatigue occur during or after work. Although they had been the average working heart rate 83.75 beat per minute or other standard developed for light work (Rodahl, 1989).

Based on the problems ergonomics intervention distinguised of sitting work posture between conventional style and compromise- participatory style, were: 1) improving of the long sitting work posture on the floor to the long sitting work posture on the sloped chair; 2) improving of the long sitting work posture on the floor to the normal sitting on the *balai* chair. This research to find out the impact of sitting work posture to subjective feeling complaints of *cagcag* weaver at Desa Gelgel, Klungkung, Bali,

Table 1. Physical characteristics of the subject

Variable	Control Group (n = 10)		Treatment I Group (n = 10)		Treatment II Group (n = 10)		Anova	
	Mean	SD	Mean	SD	Mean	SD	F	p
Age (year)	26,50	4,06	26,60	4,80	27,10	3,51	0,06	0,93
Body Weigth (kg)	48,05	4,92	48,56	4,47	49,45	3,83	0,31	0,73
Body Heigth (cm)	154,73	4,58	155,72	4,89	155,30	4,35	0,11	0,89
Length of Employment (year)	11,00	3,19	11,20	3,71	10,20	2,57	0,27	0,76
Blood Pressure (mmHg)	71,50	7,84	71,50	9,73	71,50	7,09	0,00	1,00
Diastolik	102,50	7,91	104,00	6,99	108,50	10,0	1,38	0,26
Sistolik								

From table 1, it can be seen that the average subject age is optimize physical performance (Nala, 1986b), stature is ideal (Tjokronegoro, 1981), length of employment is appeared to have similar capable (Hagglund,1998), status of health is within normal limit, and physical fitness categories is average upward.

The working heart rate of the subject both treatments group between pretest and posttest improvement is significantly different, but all of these were categories into light work (Rodahl,1989). Climate factors are dry temperature (26,5° – 32°C), wet temperature (24,5° – 32°C) and relative humidity (70-83%) that's comfortable for Indonesian people (Manuaba, 1983).

Statistical analysis result of subjective feeling complaint by "t" paired comparison showed as follow :

1. weaken activity : control group is not significantly different, increase by 0.23%; treatment I group is significantly different, decrease by 30.98%; treatment II group significantly different, decrease by 20.62%;
2. weaken motivation : control group is not significantly different, constant by 0%; treatment I group is significantly different, decrease by 14.23%; treatment II group significantly different, decrease by 17.07%;
3. weaken physical fatigue by general condition : control group is not significantly different, decrease by 0.99%; treatment I group is significantly different, decrease by 26.36%; treatment II group significantly different, decrease by 20.62%;

Analysis result between treatment groups by one way analysis of variance showed that treatments significantly difference ($p<0.05$), influence their weaken activity and physical fatigue by general condition. It means the subject sustained work activity without becoming fatigue due to sitting work posture as well as comfort and healthy. This result is similar to Paileeklee, et al (1995) study result on female mats weaver in Thailand; and also confirm the study result of Helander and Zhang (1997) on seated workplace design in China. Statistically there is no significant difference ($p>0.05$), but decrease weaken motivation. In this result there was change of motivation, causes behaviour among the traditional sitting posture have affected their sitting work posture. This is true also for the study of Ohsawa, et al (1991) on female vendors sitting postures in a market in north-eastern Thailand. As the result of multiple comparisons treatment by Least Significant Difference (LSD) showed, the long sitting on the sloped chair were significantly than the normal sitting on the balai-chair. The assumption of these result are common style because it is not change work posture.

4. CONCLUSION

The conclussion that could be drawn are: the long sitting work posture on the sloped chair and the normal sitting work posture on balai-chair decrease subjective feeling complaints more than long sitting work posture on the floor.

REFERENCES

1. Bridger, R. S., 1995. *Introduction to Ergonomics*, Singapore: McGraw Hill.
2. Grandjean, E., 1993. *Fitting the Task to the Man, a Textbook of Occupational Ergonomics 4th*, London: Taylor and Francis.
3. Hagglund, G., 1988. The Effect of Age, Occupation an Experience on Performance, in Scott, P. A; R. S. Bridger; J. Charteris (eds), *Global Ergonomics*, Amsterdam: Elsevier, 239-249.
4. Helander, M. G and L. Zhang, 1995. Field Studies of Comfort an Discomfort in Sitting, *J. Ergonomics*, 40(9): 895-915.
5. Kroemer, K. H. E. et al., 1994. *Ergonomics: How to Design for Ease and Efficiency*. New Jersey: Prentice Hall Ltd.
6. Manuaba, A., 1983. Peningkatan Kondisi dan Lingkungan Kerja di Sektor Industri Kecil, *Lokakarya Nasional Peningkatan Kondisi dan Lingkungan Kerja*. Jakarta: Depnaker-UNDP-ILO, 2-4.
7. Nala, IGN., 1986a. Perbedaan Kekuatan Otot Tangan Absolut dan Relatif antara Siswa-siswi SMA di Denpasar, *Kongres VI dan Seminar Nasional VIII IAFI*. Surabaya. 74-75
8. Nala, IGN., 1986b. Kesegaran Jasmani. Denpasar: Yayasan Ilmu Faal Widhya Laksana
9. Ohsawa, et al, 1991. Statistical Analysis of the Posture of Vendor in Talaad (2nd report), *J. Human Ergology*, 20(2): 265-281.
10. Paileeklee, et al, 1995. Development of Mat Weaving Frame for Better Posture Using Ergonomics Principles, *J. Human Ergology*, 24(1): 59-60.
11. Pheasant, S., 1988. Bodyspace: anthropometry, ergonomics and design, London: Taylor and Francis.
12. Rodhal, K., 1989. *The Physiology of Work*. London: Taylor and Francis.
13. Tjokronegoro, A., 1981. *Obesitas*, Jakarta: Komisi Pengembangan Riset dan Perpustakaan, FKUI.

Visual Acuity Disorder Due to Eye Injury at the Central General Hospital, Denpasar, Bali

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Vision is a prime function of the human body. Eye injuries were the main cause of sudden loss of vision. This survey was done from January to December 1999 in Central General Hospital Denpasar by examining all of patients admitted to ophthalmology emergency department, to establish what kind of eye injuries caused deterioration of visual acuity. The survey was a retrospective and descriptive study. From the data collected it was found that disturbance of visual acuity caused by penetrating injuries 22.12%, where blunt injuries 17.40%, foreign bodies 5.60%. Blindness of one eye (monocular) was found in 108 cases (49.85%), 51 of whom were caused by blunt injuries and 57 by penetrating injuries. Five cases (1.47%) were found blind in two eyes (binocular) because of chemical injuries. From the survey it was concluded that penetrating injuries were most prevalent, blunt injuries the second and foreign bodies the third. Mostly the impairment of visual acuity caused by blunt and penetrating injuries and blindness of both eyes caused by chemical injuries. It is advised to protect the eye while doing certain jobs. Increase the workers awareness in the workplace and people on the street.

1. INTRODUCTION

The vision is one of the five senses. Vision has prime important function of the human body. Eighty three percent of the five senses function took by vision. Eye injuries were the main cause of sudden loss of vision. It was reported in USA that 648 cases of eye injuries found from the year 1985 to 1991, 83 % were male with 28 years old average. 48 % of who were alcoholic (Weingeist et.al 1997-1998). Acute pain was the main complaint of eye injuries. Niti (1992) at Denpasar Central General Hospital stated that 43.48 % of 61 cases of eye injuries caused visual disturbances or visual ailments and resulting decline of individual income, high cost of life involving government fund. It was reported in Indonesia that the rate of blindness increase from 1.2% to 1.5% (Sirlan, 1997). Cataract is the main cause of blindness in which visual acuity can be repaired totally. This paper is concerned to finding visual disturbances caused by eye injuries at Denpasar Central General Hospital, Bali.

2. MATERIAL AND METHOD

2.1.Subject

The subjects were all eye injuries patients admitted to emergency clinic of ophthalmology department, Denpasar Central General Hospital.

2.2.Method

This survey was carried out in Denpasar Central General Hospital from January to December 1999. The method: the survey was retrospective and descriptive study. The identity of the patients such as sex, age and eye injuries was recorded.

3. RESULT AND DISCUSSION

The amount of 352 cases was collected during the period of January 1999 to December 1999. In general from table 1 can be seen man suffered from eye injuries 3-4 time more than woman, 81.15 % man and 18.75 woman. Likewise youngster under 12 years old show boys 63% and girls 47% out of 60 children with penetrating eye injuries (Baiyeroju-Agbeja et.al 1998). The result was quite the same in term of man and woman differentiation. Ariturk et.al (1999) reported that 102 cases and 36 cases of man and woman respectively. While 2.8: 1 between man and woman found out by Hasnain and Kirmani (1991). In Bombay the proportion of woman far more smaller than man, 5.8 : 1 (Dasgupta et.al 1990). From the above data it can be assumed that the incidence of eye injuries of man higher than woman.

Table 1 Age and sex distribution of the patients

Age	Sex				Total	
	Men	(%)	Women	(%)		%
0-10	54	15.34	17	4.83	71	20.17
11-20	44	12.50	13	3.69	57	16.19
21-30	101	28.69	21	5.97	122	34.66
31-40	52	14.77	7	1.96	59	16.76
41-50	16	4.55	4	1.12	20	5.68
51-60	14	3.98	3	0.85	17	4.83
>61	5	1.40	1	0.28	6	1.70
Total	286	81.25	66	18.75	352	100.00

The incidence of eye injuries can be seen in table 2.

Table 2 Eye injuries in term of sex.

Injuries	Sex				Total	%
	Men	%	Women	%		
Blunt trauma	89	25.28	24	6.82	113	32.10
Penetrating trauma	99	28.13	19	5.40	118	33.52
Foreign bodies	50	14.21	8	2.27	58	16.47
Chemical	18	5.11	4	1.14	22	6.25
Accident	13	3.69	4	1.14	17	4.83
Thermal	17	4.83	7	1.99	24	6.82
Total	286	81.25	66	18.75	352	100.00

It was clearly recorded that blunt and penetrating trauma was the highest cases among them. In every cases of eye injuries man was always in higher percentage than woman. Ariturk et.al (1999) reported that blunt and penetrating trauma was number one among eye injuries. But Nicaeus et.al (1996) stated that foreign bodies trauma was the highest among the six different kind of eye injuries. In this survey six kind of eye injuries identified: foreign bodies 16.47%, thermal 6.82%, chemical 6.25%, blunt trauma 32.10%, penetrating trauma 33.52% and accident 4.83%. While in German five kind of eye injuries found: foreign bodies 35%, chemical 15.5%, subconjunctival foreign bodies 12%, thermal 11% and contusion 7.4% with the number of 148 out patient cases (Nicaeus et.al 1996). The data found in this survey especially chemical and thermal trauma approximately half than those found in German, but blunt and penetrating trauma found higher. Kids until ten years old suffer from blunt and penetrating trauma, mostly while they were playing, usually using sword and pistol (game). At the end of 1999 where kid pistol so popular most of eye trauma were blunt trauma (table 3).

Table 3 Age distribution in term of eye injuries.

Age	Eye injuries						Total
(year)	Penetr.	Blunt	Foreign	Chemic	Thermal	Accident	
0-10	30	26	6	0	8	1	71
11-20	17	26	3	8	0	3	57
21-30	40	34	24	8	5	11	122
31-40	15	14	20	3	6	1	59
41-50	5	9	5	1	0	0	20
51-60	7	2	0	2	5	1	17
>60	4	2	0	0	0	0	6
Total	118	113	58	22	24	17	352

In table 3 it can be seen that the group of age 21-30 years old took number one in the incidence of eye injuries and than followed by group of age 0-10 years old. The group of age 21-30 considered as active ages with less control but unfortunately the kind of work done for a living was not recorded in the patient medical record.

Table 4. The relation of visual acuity (visus) to eye injuries.

Eye injuries.	Normal visus			Abnormal visus			Visus < 3/60 (blind)		
	OD	OS	ODS	OD	OS	ODS	OD	OS	ODS
Blunt trauma	-	-	50	9	5	1	28	16	-
Penetr.traum.	-	1	38	11	7	-	30	27	
Fore. Bodies	2	1	36	8	7	2	2	-	-
Chemical tra.	-	-	12	2	2	-		1	5
Thermal trau.	2	2	15	2	-	-	-	1	-
Accident	-	1	10	-	-	-	1	2	-
Total	4	5	161	32	21	3	61	47	5

Note:
OD : right eye
OS : left eye
ODS : right and left eye

The number of visual acuity (visus) recorded was 336. Abnormal visus and blind category (visus < 3/60) caused by penetrating injuries found 75 cases (22.12%), followed by blunt injuries 59 cases (17.40%). Foreign bodies took the third place, 19 cases (5.60%). Generally eye complication caused by penetrating injuries resulting in visual acuity deterioration, blunt injuries caused abnormal of ciliaris nerve function resulting in papillary dilatation. While foreign bodies attached to cornea and later on visual acuity will be disturbed. Foreign bodies can also penetrate into anterior oculi chamber, even to posterior chamber.

In the survey 108 cases found blindness in one eye (monocular) (49.85%), 51 cases by blunt injuries and 57 cases by penetrating injuries. Five cases (1.47%) found blind in two eye(binocular) because of chemical injuries. The chemical injuries were harder to be looked after because the patients usually come late. While Wagner et.al (1996) in their research found that 75% of people with trauma induced visual impairment are monocular blind. In general it can be stated that the deterioration of visual acuity depends on how far the eye organ disrupted.

4. CONCLUSION

From the data presented it can be concluded:

- Penetrating injuries took the first, blunt injuries the second and foreign bodies the third.
- Mostly the disturbance of visual acuity caused by blunt and penetrating injuries and blindness of both eye caused by chemical injuries.

It is advised to protect the eye while doing certain jobs. Increase the workers discipline in the workplace and people on the street.

REFERENCES

1. Weingeist Thomas A,; Liesegang Thomas,; Slamovits Thomas : External Disease and Cornea. Basic and clinical science course American Academy of Ophthalmology page: 285-386. 1997 – 1998.
2. Sirlan Farida : Kebutaan di Indonesia.Laporan penelitian di 8 Propinsi Di Indonesia 9 –12 September 1997.(Indonesian).
3. Niti N.K. Rujukan Cedera Mata di Unit Ilmu Penyakit Mata RSUP Denpasar Majalah Ilmiah Universitas Udayana Th.XIX-No.33-Juli 1992.(Indonesian).
4. Niti N K : Prevalensi Kebutaan dan Pola Penyakit Mata di delapan Kabupaten Propinsi Bali Majalah Kedoteran Universitas Udayana. (Indonesian).
5. Ariturk N, Sahin M, Oge I, Erkan D, Sullu Y : The evaluation of ocular trauma in children between ages 0 – 12. Turk J Pediatr 1999 Januari-Mar;41(1):43-52.
6. Hasnain SQ, Kirmani M : A 5 year retrospective case study of penetrating ocular trauma at the Aga Khan University Hospital, Karachi. JPMA J Pak Med Assoc 1991 Aug;41(8):189-91
7. Dasgupta S, Mukherjee R, Ladi DS, Gandhi VH : Pediatric ocular trauma a clinical presentation. J Postgrad Med 1990 Jan;36(1):20-2. Published errtum appars in J Postgrad Med 1990 Apr; 36(2): 103.
8. Nicaeus T, Erb C, Rohrbach M, Theil HJ.: An analysis of 148 out patient treated occupational accidents. Klin Monatsbl Augenheilkd 1996 Oct;209(4):A7-11.
9. Baiyeroju_Agbeja AM, Olurin-Aina OI. Penetrating eye injuries in children in Ibadan. Afr J Med Med Sci 1998 Mar-Jun;27(1-2):13-5
10. Wagner PJ, Lang GK. Mechanical ocular trauma. Curr Opin Ophthalmol 1996 Aug;7(4):57-64

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Subjective Complaints of Clove Pickers

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Majority of farmers in Bali are still using traditional farming tools. *Bangul* is one of them, that is a ladder with one pillar, used by Bali's farmers to harvest cloves. In its operation a farmer prolonged standing on the *Bangul*, caused decrease work productivity. This study is still descriptive research to know subjective complaint of farmers that influence quality his work. With 10 farmers as study subjects, randomly selected from farmers living in Desa Medewi, Jembrana Bali. Subjective complaints were recorded using 30 item Subjective Rating Scale and workload was assessed based on the working heart rate. The result showed that there were significant increases of pulse rate by 37 % but it is categorized as light to moderate workload and after work, 80 % injury particularly of foot.

1. INTRODUCTION

In Bali, The Farmer's work to pick cloves uses the traditional ladder, which to design based on topography consideration so that easily moved and more effective. The ladder is made by one pillar of bamboo that is named *Bangul*.

In its operation, the ladder is put at clove trees edge and tied by three strings. One string is tied to the tree and the other two are tied to another tree. The ladder angles on the ground depend on the clove trees contour. Grandjean (1988) pointed out that climbing ladders is most efficient when the ladder is at and an angle of 70^{o} and the rungs are 260 mm.

Figure 1: Standing work posture of picker of clove on the ladder

The picker of cloves is subjective discomfort to prolonged standing work postures with change of foot position after ten minute due to discomfort. There is also an indication of lowered work productivity and feeling of fatigue occurs during work. (Fig.1)

In this study, a subjective rating scale questionnaire was used to asses workers' feelings or work complaints and heart rate was monitored to determine the work load of cloves picker in Desa Medewi, Jembrana-Bali.

2. MATERIALS AND METHODS

2.1. Materials

Ten males' pickers were chosen as subjects, aged 20 – 35 years and with a minimum of two years length employment old with minimum of two years length employment.

2.2. Methods

- A self rating questionnaire, developed by the Japan Association of Industrial healthy containing 30 items was used to determine workers' subjective feelings complaints. It is divided into three-assignment groups: weakened activity (item 1-10); weakened motivation (item 11-20); physical fatigue by general condition (item 21-30).
- A digital stop watch was used to measure work heart rate as in the ten pulse method (Grandjean,1988)
- This study is descriptive research

3. RESULTS AND DISCUSSIONS

Physical characteristic of the subjects and dimensions of ladder are presented in Table1. The width of the tread (4cm) is not appropriate with the length of foot (23.6cm), due to pressure in the foot is more height and became the one of factors cause to occur feeling fatigue. The average distance of tread is 50.8 cm and the average ladder angle of the ground is 77^{o}, efficient which the rungs that efficient are 26 cm as presented by Grandjean (1988).

Table 1. Physical characteristic of subject and dimension of ladder

Variable	Mean	SD
Subject		
Age (year)	22.2	4.32
Body high (cm)	162.4	1.82
Body weight (kg)	54.4	3.58
Length of foot (cm)	23.6	0.89
Width of foot (cm)	10	0.12
Ladder		
Width of tread (cm)	4	0
Length of tread (cm)	10	0
Distance of tread (cm)	42	2.1
Angle (^{o})	83	2.74

Based on the assessment of the 30 item subjective rating scales of the questionnaire the subjective complaints are as follow:

1. 75 % the workers that felt weakened activity after work and most complained of foot problems. It means the subject sustained work activity becoming fatigue due to standing work posture on the ladder discomfort.
2. 20% the workers felt weakened motivation after work, which means influence of standing work posture on the ladder is not significant.
3. 80% the worker felt weakened physical fatigue by general condition after work, which means the most influence of standing work posture significantly.

Mean values and standard deviation of heart rate before and after work in the prolonged standing position on the ladder, it is measured at every time interval 30 minutes during one day (table 2):

Table 2. Heart rate

Subject	Heart Rate (beats /minutes)	
	Before work	After work
1	70	96
2	65	88
3	68	93
4	68	90
5	70	100
6	67	93
7	65	90
8	67	93
9	68	90
10	70	96
MEAN	67.8	92.9
SD	1.8	3.6

Increasing average heart rate of worker picking clove as 370, but it is categorized as light to moderate workload and after work. It means effect standing, work posture on the ladder insignificantly.

4. CONCLUSION

- Prolonged standing work posture on the ladder give the most influence as feeling weaken physical fatigue by general condition.
- Increasing workload 37% but it is still categorized as moderate work load.

REFERENCES

1. Bridger, R.S., 1995. Introduction to Ergonomics, Singapore: McGraw Hill
2. Chatterjee,s.,Das, C.R., Dey, S. K, Nag, S.K.,1988. Effects of Sudden and prolonged Standing from Supine Posture on Heart Rate, ECG-Pattern an Blood Pressure :Journal of Human Ergology volume 17.
3. Grandjean, E, 1988. Fitting the Task to Man , a Textbook of Occupational Ergonomics 4th , London, Taylor and Francis.
4. Dul, J. & Weerdmeester, B, 1993. Ergonomics for Beginners : A Quick Reference Guide. Taylor & Francis Ltd.
5. Manuaba, A, 1992 . Pengaruh Ergonomi Terhadap Produktivitas. Proceeding. Jakarta.

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Subjective Complaints of Denpasar-Jakarta Bus Passengers

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Transportation in developing country is still a problem. A safe and comfortable transportation should be of everybody concern. The studied was conducted to gather information on subjective complaints of bus passengers in Denpasar to Jakarta route. The passengers were postgraduate students and Faculty members of Ergonomics Program Study, They recorded their own complaints using the Nordic Body Map. The results found are as follows: the bus passengers were complaining of the neck-ache, back-ache and lower back pain, numbness on thighs and legs, and head-ache. These complaints were due to factors such as passengers seats were not ergonomically designed, the air conditioning unit can not be adjusted, time allocation for rest or having meals was not appropriately allocated, and the vehicle velocity. It is concluded, that the subjective complaints of passengers were due to fact that ergonomics interventions on buses do not meet the passengers needs. It is suggested that ergonomics intervention is a must in the design of passenger seats, for a safe and comfortable transportation.

1. INTRODUCTION

Travelling by bus is still the most favorable inter city transportation at a moment. As the mobilization of people from one city to another city has become more frequent, the bus transportation is becoming more important. Tariff for bus transportation is affordable, but unfortunately traveling time on the bus is long. Besides, the limited space in the bus traps the passengers in a static condition during on the journey. Therefore, often resulting a variety of subjective complaints by the passengers.

Based on the studies of Manuaba et al (1970) and Kusmayuni and Suyasning (1976) on the passengers on Denpasar-Surabaya and Denpasar-Malang buses, the subjective complaints were due to non-ergonomic seat for passengers. In other studies (Manuaba and Suyasning 1970, Manuaba et al 1989) it was reported that the seats were not fitted to the anthropometrics of the passengers; by which more subjective complaining were found out on passengers. Another reasons for that were the bus velocity along the way, inappropriate resting time allocation for meal, and microclimate in the bus. From the study, some improvements had been recommended, especially the passenger's seats place for resting or for meal in making the passengers more comfortable along the way. Therefore, this study was conducted on the passengers of Denpasar-Jakarta buses; it is hoped that the subjective complaints gathered become an important input for the appropriate solution in order to make the traveling in a comfortable one.

2. MATERIAL AND METHOD

2.1. Subject

Postgraduate students and Faculty members of Ergonomics Postgraduate School, Udayana University, were chosen as sample for this study. They were participating in a rowing seminar conducted in Jakarta, Bandung and Surabaya from 14-23 November 1999. The subjects were 22 persons, who traveled to and from Jakarta on the bus.

2.2. Method

Their own-subjective complaints were recorded individually, using Nordic Body Map questionnaires soon after arriving at Jakarta.
Then, the data was analyzed descriptively.

3. RESULTS AND DISCUSSION

The physical characteristics of subject in terms of age, height and weight are presented in table 1. Most of subjects are more than 30 years old, so that the muscle adaptation has already reduced therefore resulted the decreased flexibility. It is generally accepted that due to that reason, the body resistant also decreases for a long travelling (Grandjean, 1988; Kroemer et al'1994). From Denpasar to Jakarta, along the ways the passenger's compulsory sit within a static posture for more than five hours in between resting time. The limited space and the resulting limited movements, made it very difficult to change their body positions. In such conditions, part of the body would support the static load and resulted in subjective complaining. As presented in table 2 that neck-ache, shoulder-ache, backache, lower backache, pain on buttock and legs were mostly complained. The neck-ache and shoulder-ache were mostly occurred due to the static position of the neck and shoulder along the journey. The neck' and head' supports were not ergonomically design; the muscles along the neck tried to keep the head in a position and resulted is muscle fatigue.

Table 1
The physical characteristics of subject

NO	PARAMETER	N	MEAN +/- SD
1	Age (yr.)	22	37.36 +/- 7.2476
2	Height (cm)	22	169.40 +/- 6.5295
3	Weight (kg)	22	67.90 +/-12.9354

Backache and low-backache occurred due to that parts of body suffering from over-loaded along the journey as a result of non-ergonomic seat. The similar thing also occurred for buttock and thigh resulted pain and tingling sensation due to static sitting for long duration. The body position could affect the circulatory system. The lower thigh and legs became numbness, and with a little swelling due to slight disturbances on local circulatory system. Beside that, some passengers were also complaining of headache, which might be caused by the air condition can not be adjusted, too lower (50 cm upper the head), and also due to the change of time for meal. As reported by Manuaba et al. (1970) that managing the time for meal appropriately along the journey affects the passenger's comfort.

Table 2
The subjective complaints of Denpasar-Jakarta bus passengers (N= 22 person)

NO	PART OF BODY COMPLAINT	%
0	Upper part of neck	90.5
1	Lower part of neck	86.3
2	Left shoulder	50.0
3	Right shoulder	54.5
4.	Upper part of left arm	9.0
5	Back	54.5
6	Upper part of right arm	9.0
7	Low back	90.0
8	Buttock	90.0
9	Back of buttock	86.3
10	Left elbow	4.5
11	Right elbow	4.5
12	Left lower arm	9.0
13	Right lower arm	9.0
14	Left wrist	9.0
15	Right wrist	9.0
16	Left hand	4.5
17	Right hand	4.5
18	Left thigh	50.0
19	Right thigh	45.4
20	Left knee	45.4
21	Right knee	45.4
22	Left leg	72.7
23	Right leg	72.3
24	Left ankle	36.3
25	Right ankle	36.3
26	Left foot	50.0
27	Right foot	45.4
28	Headache	36.3

Other factors that also affect the passenger comfort are the ergonomic design of seats, and space in between two seats. The stated variables should meet the passenger's anthropometrical parameters (Manuaba and Suyasning, 1970; Suyasning and Kusmayuni, 1976; Manuaba et al, 1989).

4. CONCLUSION

It is concluded, that after traveling by bus from Denpasar to Jakarta, most passengers complaint about the neck-ache, shoulder-ache, back-ache, lower back pain, pain on buttock and numbness on lower legs. The subjective complaining was due to non-ergonomics design of the passenger seats, with the seat fixed in a static position for long duration. Therefore, it is recommended that 1) the bus seat must be ergonomically designed in accordance with the anthropometric dimensions of passengers; 2) Air condition (AC) unit could also be adjusted to suit the passengers comfort needs, and the location of AC blower must be located at a higher level.

REFERENCES

1. Grandjean, E. 1988. Fitting the task to the Man. A textbook of Occupational Ergonomics. 4th Edition. Taylor and Francis. London.
2. Kroemer, K.H.E; Kroemer, H.B; Kroemer, K.E. 1994. Ergonomics. How to design for ease and efficiency. Prentice Hall International, Inc.
3. Manuaba, A; Nala, N; Lodji, B.K. 1970. The Conditions of Denpasar-Surabaya bus passengers. Workshop of Man and Traffic, Jakarta, December 18-21(Indonesian).
4. Manuaba, A; Suyasning, S. 1970. Comport Problems of Busses and Suburban Passengers. Workshop of Man and Traffic, Jakarta, December 18-21(Indonesian).
5. Manuaba, A. Kerana, T. Karna, K. 1989. Ergonomics Problems of Campus "Bemo" Transportation. J.O. Human Ergology: 18 (1) 127-129.
6. Suyasning, S; Kusmayuni, D.M. 1976. Comport Problems of Denpasar Surabaya / Malang Passengers. Third National Congress and Fourth Scientific Seminar of Indonesian Physiological Society (IAIFI) Semarang, February 18-21 (Indonesian).

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

A Comparison of Cultural and Ergonomic Approaches for Sizing Stairs in Traditional Balinese Houses

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Stair in Balinese traditional house is a link between the open space (natah) and the building floor. Essentially, the rise and the tread of stair are defined strongly by the traditional norms and techniques. The stairs as product of traditional innovation is most likely the ergonomics aspect having been taken into account as an important aspect. Based on that reason, it is essential to conduct research in order to explore and investigate the ergonomics aspect of design stair on Balinese traditional house. The research shows that between the stair dimension and the anthropometric data of the house owner have closely relationship, and its design has required the safety and comfortable of the user.

1. INTRODUCTION

One unit of Balinese Traditional House principally consists of *Merajan* (shrine), *Bale Daja* (North pavilion), *Bale Dauh* (West pavilion), *Bale Dangin* (East pavilion), *Paon*/ kitchen (Southern), *Jineng* (granary), *Natah* (open space in centre of building) and *Teba* (back yard of service area).

The elevation of Balinese Traditional House actually is discrepancy or deviation wherein its elevation can be set up from the highest is North pavilion, East pavilion, West pavilion, *Paon*/ kitchen afterward *Jineng*/granary as the lowest. The allocation of house is as one reason why the stair requires in the Balinese Traditional House.

To determine the height and the depth of the stair more much depends on traditional norm and technique that based on the anthropometrics of owner. A design product is defined the owned of the ergonomics characteristics, if its all design is really appropriate with human/people as user [5].

This research would like to find out how far the relationship between the stair that is designed by traditional norm/technique and the owner anthropometrics.

2. MATERIALS AND METHODS

2.1. Material

The research was conducted in Ubud Village, Gianyar on five original traditional houses with purposive sampling. The research had been accomplished on March 14th 2000.

2.2. Method

The method that is used in this research is through observation of the stair dimension and the house owner as well.

3. RESULT AND DISCUSSION

To design the stair on Balinese Traditional House essentially can not be released from the traditional norms and technique, for instance, the elevation of riser is measured by two times of grip while the tread is measured by one times the length of footprints plus one times the width of footprints of the owner of house or head of family (*Figure 1*) [1].

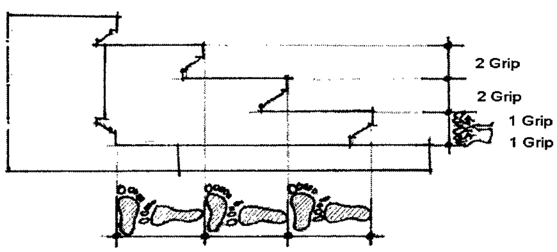

Figure 1. Technique of Determining the Stair Dimension

The outcome of measurement can be seen in Table (1) and Table (2).

Table 1.
Result of Stair Measurement

No	Rise (cm)	Tread (cm)
1	17,2	34,2
2	18,3	37,2
3	17,8	38,5
4	17,6	30,2
5	16,8	35,6
$\overline{X}$	17,54	35,14

The amount of the tread should be determined in an appropriate way; to formulate the measurement of the last tread might fall into the proper dimension. The Balinese measurement has the specific terms, which are popularly used and believed affecting to the house owner. These terms are *candi* (good); *rebah* (bad), *gunung* (good), *rubuh* (bad) and this would be repeated regularly when the tread is more than four (*Figure 2*). This matter is a reason why the amounts of Balinese tread is usually odd.

Table 2.
The Anthropometrics of the House Owner

No	Footprint (cm)			Grip (cm)	
	Length (L)	Width (W)	L+W	G	2G
1	24,8	9,5	34,3	8,6	17,2
2	27,1	9,8	36,9	9,2	18,4
3	27,2	10,1	37,3	8,9	17,8
4	21,0	9,4	30,4	8,7	17,4
5	25,8	9,5	35,3	8,5	17,0
$\overline{X}$	25,18	9,66	34,84	8,78	17,56

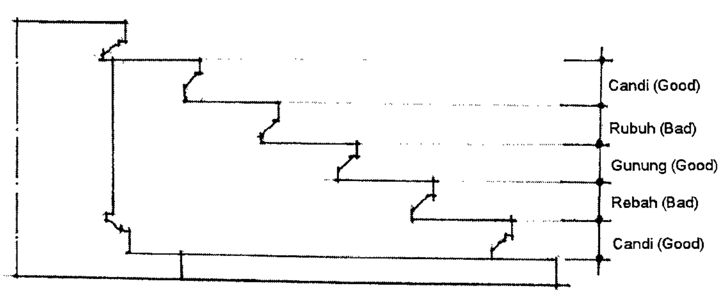

Figure 2. The Determination of the Amount of Tread

The dimension of treads quiet influences to the comfortable of walking when someone walks through a tread. The slope angle of stair also affects to how much energy have to consume to walk out it. The slope angle, which is theoretically considered safe and comfortable, is 25-30° [2].

The table 1 shows that the average of the rise is 17,5 cm. According to the traditional norm, the rise is measured by twice of grip (17,6 cm). Grandjean suggested that the rise that is safe and comfortable is 11-19 cm, while Kroemer recommended 12,5-20 cm. In terms of the anthropometrics of Indonesian grip for percentile 95 is 8,8 cm so the twice of it is 17,6 cm [4] [5]. It implies that the dimension of rise would have a position on the safe and comfortable limit to be passed by most people/human.

The dimension of tread, which can be seen on table 1, is average 35,1 cm. While, the traditional dimension can be found out from the sum of the length and the width of footprints.

Its result is 34,8 cm. The tread, which is recommended, is 25-31 cm [2]. Whereas, Kroemer suggested that it is 24-30 cm. The data of anthropometrics of Indonesian footprints for percentile 95 is 29,1 cm (the length) and 10,6 cm (the width). Its sum is 36 cm [4] [5].

Based on the explanation above, the tread of Balinese traditional house has been in position of safe and comfortable limit to be passed. Due to the material that is used on tread is commonly natural stone. It might be used because it has the hard surface in order to ovoid the slick especially when it is wet.

4. CONCLUSION

The stair of Balinese traditional house, its dimension has been properly designed to be appropriate with the anthropometrics of the house owner through approach of the norm and technique traditional. It means clearly that the stair of traditional house has required the requisite of the ergonomics aspect.

The dimension of rise and tread and material as well has already reflected the requirement of safety and comfort for the user.

REFERENCES

1. Gelebet, I N., Arsitektur Tradisional Daerah Bali, Depdikbud, 1986.
2. Grandjean, E., Fitting the Task to the Man, a Textbook of Occupational Ergonomics, Taylor and Francis, London, 1988.
3. Kroemer, K. H. E., Ergonomics, How to Design for Ease and Efficiency, Prentice-Hall, Inc., USA, 1994.
4. Nurmianto, E., Ergonomi, Konsep Dasar dan Aplikasinya, Institute Teknologi Sepuluh Nopember, Guna Widya, Surabaya, 1996.
5. Pheasant, S, Anthopometry, Ergonomics and Design, Taylor and Francis, London, 1988.
6. Sutalaksana, I. Z., Produk-produk Ergonomis dan Strategi Mewujudkannya, Simposium dan Pameran Ergonomi Indonesia 2000, Bandung, 1999.

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Thermal Comfort in Traditional Balinese Buildings

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Traditional Balinese architecture is commonly related to culture and traditional reasoning. When subjected to several modern problems such as energy demand, pollution and thermal comfort of occupants, traditional architecture becomes less attractive since the definitions behind traditional reasoning are not clear and can be interpreted in different ways. To understand this feature, the study of traditional Balinese architecture approaches by wind engineering and heat transfer, as presented and used in several countries. It appears that traditional Balinese architecture has a strong and significant correlation with several engineering fields, therefore traditional communities can be developed by considering the *Tri Hita Karana* concept in order to reduce cooling loads and improve thermal comfort of occupants.

1. INTRODUCTION

In a tropical country with a warm climate and high relative humidity, natural ventilation proves to be a realistic alternative for thermal comfort of building occupants. Therefore, we start this investigation with a hypothesis that there is a relation between building location and its function of traditional Balinese buildings with thermal comfort of occupants. This study aims to reduce the cooling loads of buildings and improve the indoor thermal comfort by redesign the buildings location. Since the aim of the study is to find a suitable correlation between buildings location and air motion around buildings, the effects of orientation and infiltration are not considered.

1.1. Traditional Balinese community

Traditional Balinese architecture as can be seen in Figures 1 and 2 has always been followed by the people of Bali and contains exalted values that are considered eternal. The Balinese make a clear differentiation between the dwelling-grounds and the unlived parts of the village, those for public use such as temples, assembly halls and market. The village is a unified organism in which every individual is a body and every institution is an organ. The heart of the village is the central square, invariably located in the centre of the village, at the intersection of the two main avenues.

As an organic unit, the structure, significance, and function of the home is dictated by the same fundamental principles of belief that rule the village: blood-relation through the worship of the ancestors, rank, indicated by higher and lower levels, and orientation by the cardinal directions, the mountain and the sea (the cardinal directions also follow the sun rise and sun set). The Balinese say that a house, like a human being, has a head (the family shrine), arms (the sleeping-quarters and the social parlour), a navel (the court yard), sexual organs (the gate), legs and feet (the kitchen and granary) and anus (the pit in the back yard where the refuse is disposed of) [1].

In the southern part of Bali, the place of honour, the higher north-east corner of the house towards the mountain was occupied by the family temple (*sanggah kemulan*) for worshipping their ancestors. Family temple is an elemental version of the formal village temple [1].

Next in importance to the family temple is the building for sleeping-quarters of the occupants (*uma meten*), built towards the mountain-side of the house. This small building is of bricks or sand stone with a thick roof of thatch supported by eight posts and surrounded by four walls. There are no windows and the light comes through the narrow door. This building is the sanctuary of the home and normally where the heads of the family sleep.

The other three sides of the courtyard are occupied by three open pavilions; on the left is the nine posts building (*balé tiang sanga*) the social parlour and guest house, on the right is the four posts building (*balé sakapat*) and at the back is the six posts building (*balé sakanem*). Both four and six posts buildings are small pavilions where other relatives sleep with the children and where the women place their looms to work, respectively. In the lowest part of the land, towards to the sea, the kitchen (*pawon*) and the granary (*lumbung, jineng*) were built.

The better homes often have more elaborate pavilions, by enclosing half of the pavilions with four walls, leaving the other half as an open veranda. This will provide a second sleeping-quarter for a married son. In the house of the well-to-do there is often a great square pavilion (*balé gedé*) with an extraordinarily thick thatch roof supported by twelve beautiful carved posts which is used for social life [1].

The flow patterns around traditional Balinese buildings have not yet been well studied by other researchers. Interaction between airflow and heat transfer around traditional Balinese buildings play the most important role to improving thermal comfort of occupants in order to conserving traditional architecture itself. To understand this feature, the study of traditional Balinese architecture starts by using several key parameters such as wind engineering and heat transfer, as presented and used in several countries [2].

1.2. Natural ventilation and thermal comfort

In traditional buildings, natural ventilation is often used to improve the thermal comfort of occupants in hot humid environments. Ventilation does not depend directly on volumetric air change rates but on local air speeds in occupied portions of the space.

There are two energy sources that create air pressure differences to promote natural ventilation, pressure differences from stack effect and wind pressure distribution where they can act simultaneously. When wind is present, the pressure difference due to wind is generally dominant. Stack effect in buildings in hot climates is usually insignificant since openings are larger and ventilation due to wind ensures temperature differences between internal and external air temperatures are small.

Natural ventilation, utilising pressure differences due to wind, has its widest application in residential areas in a hot humid climate. To achieve maximum airflow through a building, building's form, orientation and exposure must be such that the pressure differences between locations of openings are maximised with respect to local wind characteristics. These pressure differences allow air to enter and exhaust through the same opening [3].

2. SIMULATION OF TRADITIONAL BALINESE BUILDINGS

The airflow around a cluster of traditional Balinese buildings is extremely complicated and difficult to determine by modelling an isolated building (via symmetric conditions), since the buildings are linked to each other. Full scale models of traditional buildings in Figure 3 have been investigated by using CFD to predict the above aspects, since this method can be done more quickly and less expensively than with wind tunnel experiments, and are capable of delivering more detailed and comprehensive information about the flow structure [4].

3. RESULTS AND DISCUSSION

In traditional Balinese architecture, the building indicated as Model 1 is usually used as a kitchen or the parent's sleeping quarters. There are no open surfaces at roof level and only a small door. Therefore, there is no cross-ventilation. The buildings indicated as Models 2 and 4 are used as a granary. These buildings are fully open, therefore cross-ventilation occurs everywhere in the building, except at the roof. The building indicated as Model 3 is used for ceremonies or as an assembly hall. This building is open at the front side but oriented to the centre. In the numerical simulations, all buildings considered to be fully closed.

It can be seen from Figure 4 that both models 1 and 2 produce greater turbulent kinetic energy values than models 3 and 4, on the second and third buildings. The highest turbulent kinetic energy occurs at the second building, followed by the third. The second building is used for ceremonies or as an assembly hall and the third building is the parent's sleeping quarters. The second building -used for meetings- receives the highest turbulent kinetic energy. The use of nine pillars in this building will minimise the momentum effects and avoid the damage caused by the kinetic energy. The parent's sleeping quarters (the third building), which has eight posts, receives a lower turbulent kinetic energy than the second building. From this point of view, the use of pillars appears to indicate the need to protect the building to avoid possible damage, and also can be correlated to safety and comfort of occupants.

The non-dimensional similarity temperature for each building is presented in Figure 5. It can be seen that the non-dimensional similarity temperature at the first building is the lowest one. This can be directly related to thermal comfort of occupants, since the suggested temperature for residences, apartments, convalescent homes and homes-for the aged is higher than that for conference rooms, meeting rooms or auditoriums. The suggested temperature for kitchens and stores is lower [5]. Therefore, it appears that there is a strong relation between buildings location and its function.

Heat transfer coefficients are presented in Figure 6. At the first building, it can be seen that both models 2 and 3 produce greater heat transfer coefficients. At the second building, the result shows that the greater the roof angle, the shorter the reattachment point. Similar results occur at the third building where models 2 and 3 produce greater heat transfer coefficients than models 1 and 4. According to the above discussion, buildings in models 2 and 3 will increase the heat transfer to the surrounding. This is the reason why these models are used as granaries, since rice paddies and any other foods should be stored in a dry and cool place. The air temperature distributions shown in Figure 6 also indicate that the first building produces lower temperatures. This means that the first building is specially indicated to store food and is where the kitchen should be located.

4. CONCLUSIONS

Traditional houses in hot and humid climate zones are designed to utilise the wind for natural cooling. The type of roof affects the wind motion, especially at roof level. In a cluster of buildings, the reattachment point at the second and third buildings is affected by the roof angle (roof pitch).

A flat top roof reduces turbulent kinetic energy. In this study, the highest turbulent kinetic energy occurs at the second building, followed by the third. The use of pillars in these buildings will minimise the momentum effects. There appears to be a relation between the buildings' name given in traditional Balinese architecture and the need to protect them against the damage caused by turbulent kinetic energy. Therefore, the building arrangement should be in the following order: four posts building at the front followed by six posts building, with the nine posts building in the middle and the eight posts building at the rear.

Similarity temperature at the first building is generally the lowest, and it is relatively high at the second and third buildings. According to the heat transfer rate from building to the surrounding, this can be directly related to thermal comfort of occupants, since suggested thermal comfort for residences, apartments, convalescent homes and homes for the aged (third building, the parent's sleeping quarters) is higher than that for conference rooms, meeting rooms or auditoriums (second building). The suggested thermal comfort for kitchens and stores is the lowest (the first building). Therefore, there is a relation between the position of buildings and their function, with the thermal comfort of occupants. Storage rooms and kitchens should lie at the front side, ceremonial and meeting halls should lie in the middle and the parent's sleeping quarters should lie at the rear of the site.

It appears that traditional Balinese architecture has a relation with wind engineering and heat transfer, and designed for improving thermal comfort of occupants. The numerical investigations conducted here provide a contribution to a better understanding of traditional Balinese architecture and some design modifications to improve thermal comfort.

REFERENCES

1. M. Covarrubias, Island of Bali, Oxford University Press, Singapore, 1972.
2. I. G. B. Wijaya Kusuma, Numerical Investigation of Airflow and Heat Transfer in Traditional Balinese Buildings, Ph.D. Thesis, Brunel University, 1999.
3. R.M. Aynsley, W. Melbourne and B.J. Vickery, Architectural Aerodynamics, Architectural Science Series, Applied Science Publisher Ltd., London, 1977.
4. Y.S. Zhou and T. Stathopoulos, Application of two-layer methods for the evaluation of wind effects on a cubic building, ASHRAE Transaction 102 (1996) 754-764.
5. M.D. Egan, Concepts in Thermal Comfort, Prentice-Hall Inc., New Jersey, 1975.

APPENDIX

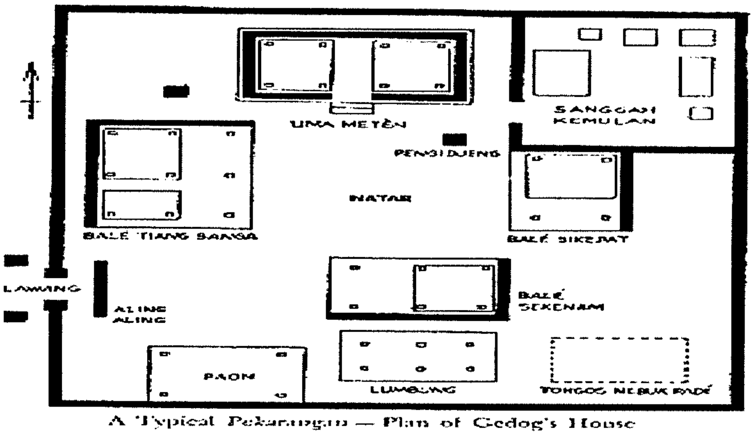
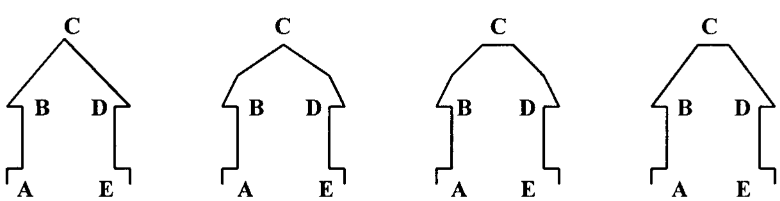


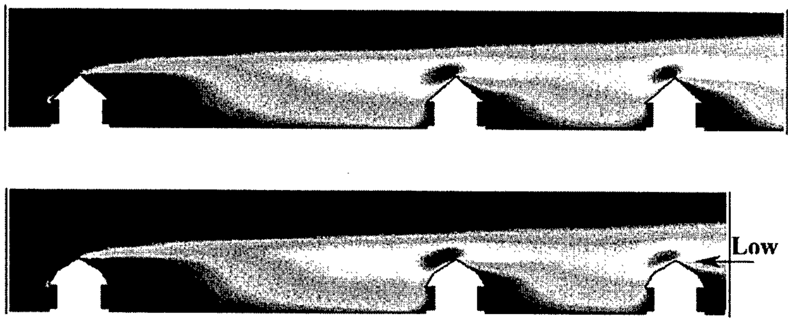
Figure 1. Plan lay out of Balinese house

Figure 2. Traditional buildings



Model 1 Model 2 Model 3 Model 4

Figure 3. Geometry of roof



(b)

Figure 4. Turbulent kinetic energy on traditional Balinese buildings

Non-dimensional similarity temperature

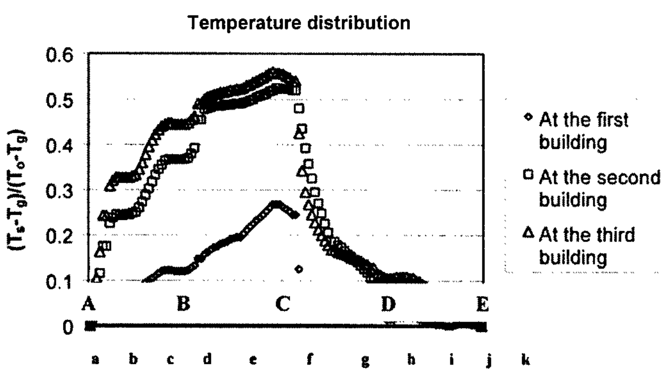


Figure 5. Non-dimensional similarity temperature on building surfaces

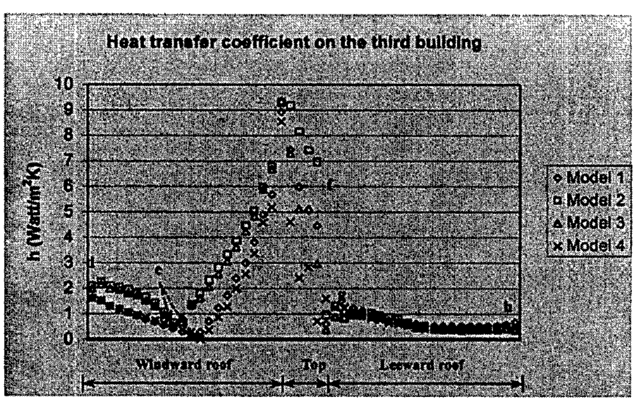


Figure 6. Heat transfer coefficient on traditional Balinese buildings

PART TWELVE

Poster Papers

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Health Assessment and Computerised Methods for Determining Fitness for Work

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Occupational health surveillance is a well accepted means of risk assessment. Tried and tested practices, procedures and processes have been developed, and guidelines for health surveillance using standard medical principals are available.

Fatigue, sleep deprivation, illness, and drug and other substance use in the workplace is perceived to pose a significant threat to safety in the workplace. Employers attempting to discharge their duty of care are faced with implementing identification and control measures to counteract these problems. Unfortunately in a number of situations basic principles regarding health screening have, for one means or another, not been applied to this situation; for example a number of drug and alcohol policies appear to rely on urinary drug screening as a means of risk identification and assessment.

This paper examines issues affecting fitness for work and some of the newer computer based applications which may assist in the management of this problem.

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Why is There a Serious Case of Negligence in the Improvement of Occupational Health and Industrial Safety in Developing Countries?

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To bring public attention to the hindrance of national and international efforts on occupational health and industrial safety, this paper explores some important issues, such as the reasons for the lack of motivation to implement necessary measures in developing countries. Examples are given to show why working people are exposed to a number of occupational problems that result in deleterious effects to their health, safety and well being. In fact, this situation has been so for a long time due to various socio-economic, political and cultural factors. Effective national policies and programs have been rare in many countries due to inadequate resources and facilities and the lack of opportunity to conduct research and studies on work exposure. The reasons for this are the poor implementation of labour legislation and work regulations, and other local constraints in the prevention of occupational health and safety problems. Thus, the major focus should be concentrated on practical solutions that meet actual needs and on local practices to be implemented soon. Unless excessive work loads and ergonomics deficiencies are minimised effectively through proper implementation of work regulations, a proper solution will never be achieved for the sake of industrial production. Until harmful work exposures and occupational diseases are controlled through the implementation of labour legislation, national economy will continue to be hampered. In this context, health and safety surveillance has to be enhanced through epidemiological field studies. Unless this receives proper attention from local government authorities followed by assistance from international communities, proper measures will not be implemented or developed. To implement proper measures, state officials or factory inspectors need to be active, honest and optimistic rather than apathetic. In addition, the attitudes of concerned officials and international organisations should be inclined more towards improving health and safety in developing nations.

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Structural Adjustment for Financing Health and Safety Services in Less Developed Countries

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International funds allocated for development projects for health services and occupational safety in less developed nations controlled by groups which are influenced by global capitalism. Driven by global capitalism objectives, international financiers become biased against socio-political and local health and safety policies of poor nations. Financial packages are thus usually sanctioned, distributed and reimbursed only on strict terms and conditions. Poor countries are then required to comply with them, and commit to changes that are complicated and which neglect the benefit for poor people, cutting government spending and emphasizing privatisation and structural adjustment of public health and safety sectors. The motivation for this is that private sectors must necessarily comply with market dynamics and competition, and this is believed to be more efficient and equitable than local government action. This paper brings a general conception of structural adjustment programs and how their role can continue. It reflects on the inefficient features of this program, replete with the hindering implications for the least developed countries.

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Fast Prototyping of a VRML Based System for Human Safety Training and Accident Simulation

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With the growing use of 3D modeling and animation, it is appropriate to consider its application in raising awareness of accidents and safety precautions. Safety awareness is a vital concern with the rising consequences of accidents occurring around the world. Books, articles and visual recordings may not be adequate to educate people effectively on accident issues. This paper reports an attempt to use VRML and scripting languages to build a virtual world to simulate accidents more vividly for better assimilation by users. Several categories of accidents have been implemented and tested for possible deployment on the internet.

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Improvement in Working Conditions for Microscope Use Inferred from a Physiological Assessment

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Using a microscope is very important for biology research for observing microscopic specimens. When students perform research, they should assume a good position for observing objects. The fact that the table and chair heights for the microscope workstation, can not be adjusted, makes it difficult for the students to assume a comfortable position to enable them to work a long time. To overcome this problem, a study was conducted to improve the workstation based on ergonomics principles, such as utilizing chairs with the most suitable height for observations; advising rest pauses of 3-5 minutes every hour; and placing specimens further away so that the students would have to get up from their sitting position (a kind of active rest). These improvements were intended to overcome unergonomic working positions and to reduce static postural loading. Using pre and post test design treatment, a study was conducted with 24 subjects. Musculoskeletal disorders were recorded by using Nordic Body Map questionnaire. Heart rate was recorded by palpation before and after treatment. The data was analyzed using t test ($\alpha = 0.05$). The results of the study showed a significant decrease in musculoskeletal disorders by about 54% ($p < 0.05$) and working heart rates decreased by about 33% ($p > 0.05$). Thus, it could be concluded that the improvements in working conditions improved the physiological responses of the students. However, improvement in the working heart rate was not significant, as microscope use constitutes only light workload (less than 100 beat per minute).

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

The Working Posture of "*Bokor*" and "*Dulang*" Wood Carvers in Abiansemal Village, Badung, Bali

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This paper reports a study on "*Bokor*" and "*Dulang*" carvers in the process of making of their products. "*Bokor*" and "*Dulang*" are bowls made from wood and used by Balinese to contain offerings used during religious and social cultural activities. It is found that carvers hunch their backs and bow their heads statically for long periods. This leads to discomfort in the neck, shoulder, arm and legs, and backaches in the lower and upper back. In order to prevent such problems, appropriate workstation design was undertaken. The result is higher productivity and fewer complaints.

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Ergonomic Problems of a Digger of Traditional Artesian Wells in Bali

Setiawan

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This paper describes the ergonomic problems of a traditional artesian well digger in Denpasar, Bali. The distribution of water in Denpasar is limited and so many people draw their water for daily life from underground sources. Thus, many people are interested in traditional wells because it is a simple way to get clean water. It needs only a small place and the cost is cheap. The diggers of traditional artesian wells use simple tools. Their work positions, posture, and actions are poor. Their nutrition is also poor and they work in an uncomfortable environment. Ergonomic problems of the digger of traditional artesian wells are as follows. The holder for lifting up tools is made from an iron pipe of 1.5 inches in diameter and is bigger than the maximum grip size (circumference of thumb and forefinger). In wet conditions, it becomes slippery and can cause accidents. The digger works in a standing position. His body is first bent over 45°. To lift up the holder, the body is lifted erect to 10°, and his palm raised 50 cm up with muscle power. The tool is then dropped into the original position and then turned to the left. This difficult task is performed by 4 diggers with 20-40 kg loads for about 8 hours/day for 4 to 5 days. The digging of traditional artesian wells commonly starts at 8.00 and continues to 11.30 a.m., with a break to resume again from 1.30 to 5.00 p.m. This work is performed in an open area at 35-37° Celsius, with great expenditure of energy and sweat. The diggers do not wear clothes and helmet and dirty water and mud keep coming up from the pipe. Their poor nutrition does not support their energy expenditure. Generally, the workers take their breakfast at home before going to work, where they get lunch and then dinner at home. During working, they only drink water. The research is in progress.

Proceedings of APCHI /ASEAN Ergonomics 2000 – Lim *et al.* (Editors)

Noise Evaluation of the Children Games Area at TD Supermarket in Denpasar, Bali

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TD is the oldest supermarket in Denpasar, Bali. It is established around 1986. The supermarket has 1200 employees in many different jobs. For example, 12 workers are deployed in the children games area for the following duties: 2 as cashier, 4 as video game service attendants, 2 served the bom-bom car, 2 worked at the merry go around, and 2 serviced other games. The workers in the games area reported that their jobs are rather heavy mentally and physically, especially when it is crowded. They felt that the work environment is noisier than normal, especially when all the game machinery are moving all day. The objective of this research is to uncover ergonomic problems of working in the games area and the level of noise. It is found that the noise level was over 85 NAB dBA and therefore excessive. The noise may cause negative effects on workers and visitors, for example, headache, fatigue etc. Thus, measures should be taken to reduce machinery noise through appropriate enclosures and rearrangement.

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Working Conditions of Boys as *Dulang* and *Bokor* Handicraftsmen at Abiansemal Village, Badung, Bali

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Bali is famous for exporting handicraft all around the world. The demand of handicraft has been increasing. Thus, products have to be improved both in quality and quantity. However, handicraft workers do not consider the way they work, and so problems often occur with poor work positions. This research is carried out to assess the working conditions of carvers of *dulang* and *bokor* products at Abiansemal village, Badung, Bali. These products are used as containers for cake and vegetable offerings during ceremonies in Bali. The research examines the work posture (carving) of 10 boys, aged 10 – 12 years. Rest and work pulse are monitored with the 10-pulse method. Height and diameter of the product are measured as well as the temperature of work environment. The problems found in the study include musculoskeletal disorders especially in their shoulders and waist, and exhaustion. To avoid these problems, it is suggested that appropriate work tables and chairs be provided.

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Improvement of Air Circulation to Decrease Dust Content and Subjective Complaints Among Employees in the Furniture Industry of Denpasar, Bali

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Furniture industry is one of the industries that support tourism in Bali. However, it is considered an industry that creates air pollution at work and in the surroundings. An air check sampler model 224 PCXR 8 is used to check the pollution level at one of the furniture workshop. The result indicates the heaviest pollution to be in the spraying room due to 4 sprayers. 3 assistants work 2 hours a day in the spraying room which measures 3.8 m in width, 7.2 m in length and 3 m in height. The pollution is measured again using a High Volume Air Sampler, and the result shows a particulate content of 13.5 mg/m3. This level of dust pollution may be compared to the threshold value for total permissible dust of about 10.00 mg/m3 and respirable dust of 5 mg/m3 (OSHA Standard). The spire Analyzer ST 250 equipment is then used to test 14 workers who have worked for about 2 years. The result of the test indicates a change in lung function. Five workers suffer from light, moderate and heavy obstruction, while two workers suffer from light restriction and seven workers are found to be normal. Subject complaints include breathing difficulty, dryness in the throat, feeling thirsty, change in tone of voice, painful and watery eyes. It is then demonstrated that the amount of dust and subjective complaints may be reduced significantly ($p < 0.05$) by installing an exhaust fan to improve air quality in the work place. This result is determined by pre and post test design treatment of subject groups.

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Ergonomic Values Embedded in the Architectural Design of a Traditional Bali Jineng

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The *Jineng* building of Bali traditional architecture is born from function illustrated by the structure of the building. The upper part is used to store rice (paddy), while the lower part is used for work activities such as sitting, guest reception and sleeping/resting. To suit its many functions and activities, the proportion and dimension of the lower part of the *Jineng* has been regulated traditionally in a modular fashion. The basement module of construction and proportion is determined by the width of the column area (*sesaka*) and *pengurip* which follows the body dimension of its owner. So it can be said that *Jineng* is a traditional building in Bali, that is customised to the anthropometric dimensions of its owner. In accordance with ergonomics, the product is designed to fit the user.

An investigation was undertaken to determine whether the design of *Jineng* is indeed an exemplar of ergonomics values. The study was conducted in Mengwi village, Badung Regency province of Bali. 15 Jinengs were measured and their height and area were determined. The data obtained was analyzed qualitatively. From the proportion and height of the bed, it was found that the Jineng has ergonomics values embedded in its design that match its material and shape of construction to the anthropometry and function of the occupant.

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Low Cost Implementation of Ergonomics to Decrease Neck and Shoulder Complaints Among Male Silversmiths at Lod Tunduh Village, Ubud

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Lod Tunduh village is located in the Ubud District, Gianyar regency where people made silver jewellery. Almost all of the jewel smiths work in awkward positions and under inadequate lighting. A study was thus conducted on eleven male silversmiths who have to work for long hours without rest, on objects located very close to the eyes. They were complaining about neck and shoulder aches in addition to visual complaints. A low cost participatory intervention to improve work posture by re-designing the chair and working table was done. A follow-up study was also carried out to determine the effect of the improvements on previous musculoskeletal complaints. Subjective questionnaires were used to assess the complaints. Chi square analysis was then applied on pre and post test design data. The results were as follows. There was a significant difference in the extent of subjective complaints of neck and shoulder aches before and after intervention. Neck complaints before and after intervention were 81.8% and 27.3% respectively, while shoulder complaints before and after intervention were 45.5% and 9.1% respectively. Thus, it may be concluded that low cost ergonomics improvements can be effective in solving the musculoskeletal problems reported by silversmiths.

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An Ergonomics Assessment of the Traditional *Kapak Timpas* Wood Artisan Tool

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This paper reports the results of an ergonomics study of the kapak timpas tool, to determine how well its dimensions meets with users' anthropometry. The results confirmed that the artisan tool is an innovation that is developed in accordance with the anthropometry of workers. The axe like tool has two functions, namely as a woodcutter and a hammer. It is designed like a hammer for nails and to make it easier to grasp when it is used to cut wood to make it straight or to reduce its size. *Kapak timpas* comprises 2 parts. First, the blades are made of hard metal, and second, the stick is made of wood. The side of the blade that looks like a knife edge, is used as a cutter. The other side of the blade is flat, and is used as a hammer. The blade and stick forms an angle to support a comfortable working posture. In ergonomics, it is advocated that for health and safety and work efficiency, human abilities such as skill and strength limit to carry the tool, must be considered appropriately. Thus, the design of the tool should follow function and match the anthropometry of the user to ensure comfort and safe working. The results of this study revealed that these ergonomics requirements have been met.

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Canteen versus Food Allowance for Ensuring the Occupational Health of Hotel Employees

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Work productivity depends on the health status of the worker. As proper nutrition contributes to good health, nutrition should not be neglected. This paper reports a study conducted in two hotels in Sanur, Bali. The hotels apply two different policies in implementing nutrition for workers. Hotel B provided food once a day for all shift workers in the canteen, while Hotel P provided food allowances to its employees. The advantages assumed of providing food in the hotel canteen are: the cost could be cheaper, the quality of food could be monitored, food sanitation and hygiene could be guaranteed, rest time was managed more efficiently, the employees were located more easily when needed, eating time could be used to discuss work problems. The disadvantages considered are: the food provided was not always to employee preferences, the canteen needed special workers and space, and more utensils needed to be provided in the canteen. The advantages assumed of giving a food allowance are: the menu could be changed as desired, employees tended to come to work daily (lower absenteeism), no additional space, workers and food utensils was required, employees viewed the food allowance as additional wage. The disadvantages are: misuse of allowance, quality of food could not be monitored, no guarantee for food sanitation and hygiene, delayed resting time, less togetherness of employees. To assess the real merits of these two systems, 59 workers from the hotels are interviewed and served a questionnaire. Secondary data on absenteeism was obtained from the hotel database. The results showed that for the sake of occupational health, it is better for food to be provided at the hotel canteen, with strict monitoring by the management.

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Content Analysis for an Internet Product Targeted at a Small Group or Closed Society

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Internet content viewing introduces three opportunities, namely the chance for new communication, the discovery of new forms of artistic creativity and the enhancement of world wide web communication links despite an inward looking Japanese community. However, from a psychological viewpoint, the Japanese society has a strong tendency to become a mini closed home page society. Excluding direct intervention, we as professional agents created a new content to facilitate vivid innovation in systems for the business and local community. To ensure good co-ordination and cooperation, business models for information providing systems targeted at companies need to be developed to address real time communication and good one to one relations using E-mail systems. A case study in Morioka (northern city of Japan) showed that cultural power was the most important factor in promoting new content.

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Naturality: A New Concept for the Design of Human-Machine Interfaces

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The development of modern technologies has generated a lot of research on human-machine interaction. This led to a multiplication of concepts, e.g. ecological interfaces, affordances, and active help... Researchers from different disciplines adopted different perspectives: some are user-centred while others are centred on technology. However, both viewpoints are focused on the product, since for product success a coherent synthesis between technology and human-factors is required. Thus, product design and research is now made more complex as they require the adoption of a multi-disciplinary approach.

BERTIN TECHNOLOGIES (consulting company) and the UTC (Compiègne University of technology) are confronted with this problem in the design of interactive complex systems for aeronautics, car, process control, etc. To work effectively, an integrated ergonomics service had to be established to promote collaboration in this direction. A common team was thus set up to trace the evolution of product development concerns in the various disciplines in an attempt to synthesize them.

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A Review of a Systematic Human Design Technology Process

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Human design technology integrates fields like marketing research, ergonomics, cognitive science, industrial design, usability evaluation and statistics (multiple variable analysis), in order to design user friendly products that have broad popular appeal. It is defined then as technology that scientifically analyzes human beings and applies various knowledge related to humans (e.g. physiology, cognitive and behavioral psychology) in specifying design solutions. The technology not only applies to all processes ranging from product planning to design and evaluation, but its logical, quantitative approach can also be applied all the way through to the upstream end of goods production.

In the past we have relied on intuition as we reviewed processes as analytically and quantitatively as possible to make sure that there were no design oversight in the drive to produce sound goods based on user needs. The situation that precipitated the development of a human design technology process was the decoupling of work at upstream stages of product development, where individual supervisors focused solely on their own specific area entirely for show and thereby crippled their ability to generate products with broad-based appeal. Then came a change in thinking in goods production from an emphasis on material requirements to an emphasis on user requirements that necessitated an ability to grasp the overall situation. This paper provides a review of the following steps that describe the new human design technology process developed to facilitate user centered design:

1. Gathering user requirements. This first step is to extract user requirements using various methodologies like task analysis, group interviews and direct observation.
2. Grasping current circumstances. This step determines how users perceive products currently on the market.
3. Formulating product concepts. This step takes the user requirements that have been gathered and condenses them down into 10 items or less based on like functions.
4. Synthesizing a design. This step brings together all the tentative design items that were visually represented and uses them to form a design proposal.
5. Evaluating the design. At this step, target users are invited to evaluate the design proposals using the analytic hierarchy process method.

6. Surveying usage conditions. The step determines how a person uses a product once it has been purchased and it allows the user and the person taking the survey to jointly identify problem areas. The range of studies includes gathering and analyzing user requirements, formulating product concepts and then condensing and evaluating the designs. The next step is production and sales which are followed up by surveys on usage conditions for the consumer product.

The purpose of a Human Design Technology Process is to systematically implement into the product concept the following design concerns:

1) Usability and user interface design concerns (32 items)
2) Kansei design concerns (5 to 9 items)
3) Universal design concerns (5 items)
4) Product liability concerns (PL)
5) Robust design concerns
6) Maintenance concerns

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User Anthropometry (American, Germany, British, French) and Chair Size Produced by a Furniture Company in Silakarang Village, Gianyar, Bali

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The advancement of tourism in Bali has influenced the progress of small scale industry, especially for the furniture industry. In one village in Bali, a company produces many beautifully carved wood furniture products that are exported to America, Germany, England and France. This study is involved with investigating two aspects, namely the shape and anthropometry of the products. The data obtained was analyzed qualitatively. The objective is to assess the design of the product for compatibility with the anthropometry of the user. The result of the research revealed mismatches in the case of the furniture producer in Sikalarang village, where the emphasis was primarily on aesthetics. These anthropometric mismatches were most pronounced for furniture exported to America, Germany, Britain and France. Thus, the situation has raised some apprehension in the long term acceptability of these exported products, especially the well known lion chair.

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