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Human Machine Interface and Usability Issues: Exploring a Preliminary Mission Management System Evaluation Methodology

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ABSTRACT

A preliminary version of a system evaluation questionnaire was trialed concurrent with a mission management system (MMS) concept demonstrator test during June 2000. The questionnaire was designed to examine usability and interface issues relating to the design of the systems or tools, and to provide suggestions for future iterations of the system(s). The returned questionnaires were examined for both the system-related information, and the content and style of the questions themselves. Although some useful information was gathered using this questionnaire, the author concludes that such questionnaire methods should be combined with (for example) behavioural observations in order to provide a more complete picture of optimal system design and user training for the human-machine context.

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Telephone: (08) 8259 5555
Fax: (08) 8259 6567

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Executive Summary

This report outlines an examination of a preliminary evaluation methodology for the human factors issues involved in the human-machine interface (HMI) and usability areas. It is intended that this be the starting point for further development of an evaluation methodology that encompasses not only HMI and usability issues, but also the wider impact of introduced technology on teams themselves. The issues addressed here would include shared situation awareness (SA, for both inter- and intra- team settings), the performance and workload of teams and their members, and the training needs accompanying the implementation of automated tools.

The questionnaire was based around issues outlined in the usability and HMI literature; both Nielsen's usability design heuristics, and items for evaluating cockpit automation design [outlined by Craig and Burnett] were adapted for use in this questionnaire. Items with a specific military focus were also included, as the evaluation method is initially intended for application in the military context. Questions designed to elicit work domain expert knowledge were also included, so that the needs of the end user (in this case, the military) could also be examined, and suggestions be put forward for future iterations of systems being evaluated.

Conclusions drawn from this exploratory work include the following: that additional system-specific detail be included in the questionnaire prior to use in subject evaluations; that a larger number of subjects from all of the necessary groups (ie. technical experts, work domain experts, and novice system operators) should be consulted; that results from system evaluations should be used to determine where more intense training may be needed, in addition to highlighting areas which may require more intensive system development to facilitate user productivity, efficiency and effectiveness; and that questionnaire information is not adequate in and of itself. The information gathered in this way should be supplemented by behavioural observations, including timing the durations of specific activities to ensure that a function rated 'fast and easy to use' is not simply an inaccurate subjective perception.
In addition, it is noted that evaluations of usability should – in this context - be conducted concurrently with evaluations of situation awareness (both individual and shared), inter- and intra- team interactions, and workload in order to produce a more complete picture of the impact of automated tools on the operations they are designed to enhance.

Authors

Monique Kardos
Land Operations Division

Monique Kardos completed a Bachelor of Science with honours in Psychology in 1994, and a PhD(Psychology) in the field of Animal Learning and Behaviour at Adelaide University in 1999. During the course of her studies, she taught Psychology to undergraduates and undertook research field trips with both the Department of Environment and Natural Resources, and the Adelaide Zoo. She joined the DSTO as a research scientist in March 2000, and is currently working on the Land Air Systems and Battlespace Awareness tasks. Her current foci are examining human machine interface issues as part of the development of situation awareness tools, evaluating the introduction of automated tools designed to enhance planning, and contributing to the evaluation of ARH tenderers' responses as part of the AIR 87 acquisition project.

Contents

1. Introduction

Investigating the usability and human-machine interface aspects of tools/systems designed to enhance human functioning is vital to the augmentation of human-machine partnerships in the military context. International Standard 13407[1] clearly defines *usability* in the following terms:

> "the extent to which a product can be used by the specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use."

This is further clarified by the following definitions:

> *Effectiveness*: "accuracy and completeness with which users achieve specified goals".
>
> *Efficiency*: "resources expended in relation to the accuracy and completeness with which users achieve goals".

It follows that evaluations of either prototype or actively employed decision support systems (DSSs) and automated situation awareness (SA) tools should focus on these critical issues. It is beneficial for the organisation implementing the tools/systems to ensure that these are not only operating effectively, but that they do not add substantially to the cost or difficulty of staff training and skill maintenance. Additionally, the users/staff must be able to maintain effective and efficient functioning with these systems under the potentially extreme conditions within which they could be expected to operate[2].

Accordingly, this report outlines an examination of a 'first-cut' usability and human-machine interface (HMI) evaluation questionnaire. The questionnaire is designed to address a series of issues previously identified in the usability and HMI literature as important for:

- Facilitating electronic data management and presentation;
- Facilitating the efficient interaction of humans with PC-based systems;
- Minimising the detrimental effects of tool/system use for users.

In addition, it is supplemented with items designed to elicit from subjects (ie. users, observers, and work domain subject matter experts [SMEs]) information relating to desirable characteristics for future system designs.

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[1] *Human-centred design processes for interactive systems : 1999.*

[2] In the case of military users, this may mean a large variety, including (but not limited to) desert situations, tropical conditions, and snow/blizzard conditions, all of which can adversely affect hardware (and therefore software) system operations.

2. Evaluating tools and support systems

The evaluation of such tools and user interfaces from the human factors perspective – where the results of evaluations comprise important input into the design of future iterations of tools/systems - forms an essential component of the user-centred style of design. It is essential in this process of user-centred system design that both task requirements and context of use be considered. It follows, then, that consulting with the users also forms a vital part of any evaluation methodology. When evaluating systems, the needs of the end users must form part of the evaluation criteria to ensure that the final product will meet these needs.

The effective evaluation of a system in the early stages of implementation is illustrated in the work reported by Huf, Kieboom, Hobbs, Medlow, Jaensch, Barrowcliff and Harvey (2000), where a usability evaluation was conducted on the Command Data Network System (CDNS). A workshop was conducted to evaluate this system, with the participants consisting of a balance of usability design consultants, technical domain experts, work domain experts (ie. Army personnel), and participants of varying levels of experience with the system. The evaluation approach taken was based on Nielsen's (1993) user interface design principles (outlined in Table 1, page 3), and was designed to assess the system against the principles of interface design to elucidate any potential problems in system usability. A series of recommendations emerged which were reported to the system designers as areas needing further development.

For the current work, a list of 'essential' criteria for effective systems was compiled from the general usability and interface literature (including Nielsen, 1993), as well as from the lists of specific display information and the general question areas outlined by Craig and Burnett (1999). Although Craig and Burnett's items were designed for and applied in the context of cockpit automation, many of the questions and issues are as applicable to a ground-based system as an air-based system. Thus, a relatively large number of questions were placed into the following categories outlined by these authors: *display readability, screen layout, functionality, general information, information processing, spatial awareness, information degradation, fatigue,* as well as an overall user rating for general performance on the system(s). The details of each category were tailored to include issues likely to be of interest to military users, as initial system evaluations will be conducted on applications designed for use in the defence arena. Thus, questions ranged from simple display issues ("Information is organised in a clear and uncluttered way" and "Colour coding makes map features easily distinguishable") to the maintenance of spatial awareness ("There are effective cues to maintain accurate spatial awareness") and fatigue issues ("Information overload is a problem for the user"). Questions with a specific military inclination included such issues as the presence or absence of military grid references on displayed maps, and a library of the appropriate symbology for military use.

The systems currently being evaluated using this preliminary methodology were not initially designed with this list of categories as a high priority (*pers comm.* Seymour, R. S: 2001). The development of a workable functionality within a given time and cost frame was of the highest priority, and thus these categories were given less emphasis than they would have been given in a production system. The results of the evaluation should therefore be of interest in terms of the perceived usability of systems designed without explicit usability specification input from the end users. It is not always possible for usability practitioners to have direct input into the design of systems during the initial developmental stages. Thus, an evaluation methodology that can assess the functionalities already provided and suggest improvements (if necessary) to a product in the iterative stages is a valuable tool in such situations.

Some of the issues outlined above were also referred to in an article by Kraiss (1989), who discussed the improvement of user interfaces and the design of effective DSSs. He states that it is vital for any DSS to be integrable with the user's own cognitive processes, as the aim of the introduction of such tools is the extension of the user's cognitive decision-making abilities (Kraiss, 1989). The basic DSS configuration consists of a user with direct access to the system being controlled, who can exchange information with the DSS via the user interface. This relationship is shown below in Figure 1. As this figure shows, an effective interface is vital to ensure that information input and display actively facilitate user functioning.

Table 1. Nielsen's User Interface Design Principles (adapted from Nielsen, 1993).

Principle	Comment
Simple and natural dialogue (ease of navigation)	Ensuring that the application supports the user navigating through the user interface in a way that is obvious and conducive to getting the job done.
Speak the user's language	Ensuring that the terminology is based on users' language, not system oriented terms.
Minimise user memory load	Ensuring the visibility of objects, actions, and options.
Consistency	Ensuring consistency within an application and with other applications used.
Feedback (indication of user operation)	Ensuring the application gives clear, helpful feedback on what the system is doing and what the user needs to do.
Clearly marked exits	Ensuring the user can exit out of as many situations as possible.
Shortcuts	Ensuring experienced users are able to perform frequently used operations especially fast using shortcuts.
Good error messages	Ensuring error messages are clear, concise, and constructive; helping other users to quickly solve the problem.
Prevent errors	Ensuring that the application reduces the opportunity for making errors and allows users to readily fix errors that are made.
Help and documentation	Ensuring that the application contains usable and useful support tools, including online help and documentation.

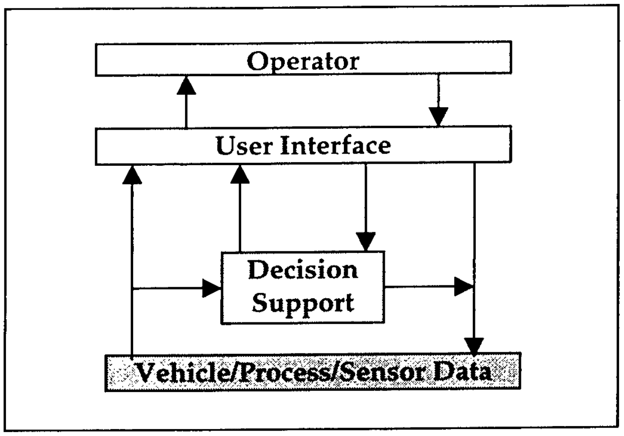

Figure 1. Basic decision support system configuration (adapted from Kraiss, 1989).

As the aim of the introduction of such technology *is* the enhancement of user functioning, questions relating to the support of information management and decision making, problem solving and planning, and error sensitivity should be considered. As there was limited capacity to investigate these issues in the context of this preliminary study, questions regarding learnability, comparative ratings with other systems, difficulties in learning the system, areas which may be lacking in terms of the end user's needs, ease of system awareness maintenance, and suggestions for future design improvements were also included in order to expand on the information elicited by the questionnaire. The issues described above must be addressed in order to create a complete understanding of the HMI issues associated with the introduction of new technologies, and the functionalities which may yet be lacking in the tools provided. These issues will be addressed in future work using a subject pool that includes domain experts, a revised set of questions, and additional observational techniques[3].

Essentially, then, what is needed for the effective application of automation to the military (and indeed, any) field of operations is a user-centred approach which takes the work domain into account as an important part of the "cognitive system" (Flach, Vicente, Tanabe, Monta & Rasmussen, 1998). In this context, the needs of the user are examined and the introduced technology is the instrument with which these needs can be met and human functioning enhanced. That is, this approach seeks to make the interaction between the humans and the work they do optimally efficient and effective. Thus, there must be meaningful evaluation of the interface, the tools' functioning (in terms of end user needs), and the effect the tool has on the user's performance (beyond the first introductory stages). These need to be carried out from a human factors perspective, and not simply from the viewpoint of outright performance scores. This will enable distinctions to be made between purely system-based functioning flaws and the difficulties caused by ineffective human-computer interactions.

[3] These observational techniques are currently under development and will be included in publications following experiments conducted in March 2001.

Difficulties may arise in using evaluations comprised of the subjective opinions gleaned from questionnaires. Attempting to implement potentially contrary suggestions of different users and domain experts could conceivably result in conflicting characteristics listed as necessities for the systems/tools under consideration. These issues should be dealt with in terms of a specific 'user needs' focus by addressing the questions of which combinations of characteristics appear to enhance user functioning, and which combinations produce optimal performance under a wide range of conditions. Here it is evident that initial evaluations (such as the method outlined in this report) will lead to further investigations of usability and interface issues, and changes in future system designs.

In keeping with the team-centred structure of military operations, future investigations in this vein should also include the impact of the graphical user interface (GUI) on *groups* of users rather than dealing solely with individuals. That is, work on 'groupware' for multi-user systems should form at least one focus of future work applied in the military context. Researchers have begun studying aspects of such multi-user systems (see Calvary, Coutaz, & Nigay, 1997), however this appears to primarily be from the perspective of the underlying system architectures. Work has expanded into the area of visualised coordination support for teams involved in distributed decision making (eg. Svenmarck, 1998), where systems implementations are intended to provide more efficient ways of coordinating individuals in complex dynamic systems (pp. 103; see also Brehmer, 1988). Combining this evaluation methodology with assessments of team performance should – in future - provide a more in depth understanding of the complexity of technology introduction into a team situation.

3. Aims

In essence, the aim of this study was to assess the utility of a questionnaire methodology for evaluating the user interfaces and general usability of automated planning and decision support tools. Additionally, any useful information elicited from the users and observers will be applied to future iterations of the evaluation methodology, and as suggestions for developers of the systems/tools.

4. Methodology

4.1 Subjects

Due to the limited availability of subjects, two objective observers (one a military SME, and one with a relatively low level of experience in the military arena) and system experts on two of the individual tools were able to complete the questionnaires and answer the questions.

4.2 Apparatus and tools

A mission management system (MMS) concept demonstrator - involving five different automated information representation and handling tools[4] - was examined using both objective observers' and subjective system users'comments and opinions. Information regarding the users' level of experience with the systems was also obtained as part of the questionnaire.

The MMS concept demonstrator is a working combination of the following systems and tools: Battlescape, Carmen, MapInfo, BCSS and IME. It is being developed under the Land Air Systems task as part of a concept demonstrator Land/Air system of systems (Seymour, Sands, Grisogono, Unewisse, Vaughan & Baumgart 2001). Experience gained with this concept demonstrator will assist DSTO advice to the AIR87 project (the acquisition of ARHs).

The questionnaire itself was designed based on the important HMI and usability issues discovered in the literature. 46 separate statements regarding aspects of the systems were rated on a Likert rating scale (where 1 represented strongly agreeing with the statement, and 7 represented strongly disagreeing with the statement). This was followed by a general rating of ease of use on a 1 to 10 rating scale (with 1 being very easy and 10 being very difficult). Seven supplemental questions were placed at the end of the questionnaire to provide the subjects with an opportunity to record their own ideas and views (in their own words). These questions related to learnability of the system, comparative ease of use, main difficulties in learning to operate the system, areas which may be lacking in terms of the end user's needs, maintenance of system awareness amidst distraction, and suggestions for aspects of future system design.

The objective observers were given the questionnaire fifteen minutes prior to the beginning of system testing[5], and asked to familiarise themselves with the types of issues they would need to rate. They then watched the operators as they used the systems, and rated each of the four available systems concurrently according to their perceptions of the systems' performance in each of the question categories. The observers were allowed to query the system operators to clarify any aspects that were unclear to them. The system operators ('users') were also given the questionnaires fifteen minutes prior to system testing and asked to rate the system they were operating from their more knowledgeable viewpoint. This was carried out in order to provide a more experienced 'hands-on' person's view of the tools.

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[4] These included (in no particular order): BCSS, Battlescape, Smartboard linked with MapInfo, Carmen and Mimio with whiteboard. Unfortunately, Carmen 3.1 (the updated version) was not available in time for this evaluation and so was omitted from the assessment. Brief descriptions of these and other MMS component systems are available in Appendix C.

[5] This was the point at which the wargame commenced and the systems were online and being used to access, input or display data.

The questionnaire is included in Appendix A. Questions were categorised according to the following list:

Category Number:	Category Name:
1	Display readability
2	Screen layout
3	Functionality
4	General information
5	Information processing
6	Spatial awareness
7	Information degradation
8	Fatigue
9	Overall rating of system ease of use

4.3 Procedure

The questionnaires were collected at the end of a two-day period to give the users an opportunity to fill in all the questions. Following this, the ratings, comments, and the style in which the questions were answered were examined in order to elucidate:

- Observer opinions of system/tool performance;
- User opinions of system/tool performance;
- The suitability of the question wording for eliciting the target information;
- Any need to modify the length of the evaluation questionnaire;
- What types of information are still missing/require additional elicitation.

Consideration was also given to other potential methods of tool/system evaluation, and work to be conducted in the near future.

5. Results

5.1 Significance of results

The term 'significance' is used here to indicate a meaningful result or relationship between two variables. The alpha level at which significance is assumed is 0.05, which is the conventionally accepted alpha or confidence level. This figure indicates the acceptable probability of the outcome being due to a chance result. That is, when alpha = 0.05, there is an acceptable level of "chance" of 5%, indicating a probability (p) of 95% that the result is meaningful. Thus, if a statistical test returns a p figure below the specified alpha level, it can be said to be a significant result at this level of confidence.

For example, if a test returns a result of (a) $p = 0.03$ (b) $p < 0.04$, then the results can be called significant. The lower the p value, the more significant the result. A p value of 0.000, for example, indicates (by the three decimal place convention of SPSS [6]) that the

[6] Statistical Package for the Social Sciences.

probability of the result being due to chance is *less than 0.00005*. This, it can be agreed, indicates a meaningful result. A significance (p-level) of (for example) 0.380, by contrast, indicates a 38% probability of the results being due to chance, which is unacceptably high. The result in this case is termed non-significant.

These "significance" conventions will be used throughout the results section below.

5.2 Observer and user ratings of the systems[7]

It was interesting to note that the ratings given to systems by the users and the observers were relatively consistent in many areas. The observer and system user ratings appear quite similar for the *display readability, screen layout, functionality, general information and information processing* categories for system 1. This is shown in Figure 2. For example, general preferences in the way information is displayed included large screen displays: subjects' opinions consistently indicated that 'bigger is better'. Ratings data from the questionnaires are shown in Appendix B.

Based on the similarities shown in this graph, the Pearson's r correlation coefficients were calculated separately for categories that displayed similar scores for all raters together, and those with disparate rater scores. Pearson's correlation coefficients for system 1 ratings on question categories 1 to 4 are shown in Table 2 below.

Table 2: Pearson's correlation coefficients for systems 1, question categories 1 to 5.

Rater	*Correlated with Rater*	*Pearson's r coefficient*	*Significance*
Observer 1	Observer 2	0597	0.000
Observer 1	User 1	0.555	0.000
Observer 2	User 1	0.698	0.000

[7] Results will not be presented in terms of the specific systems for two reasons: (a) this is simply a preliminary exploration of the evaluation methodology, and so should not be taken as a final word, and (b) the BCSS project (and thus any evaluation result) is restricted.

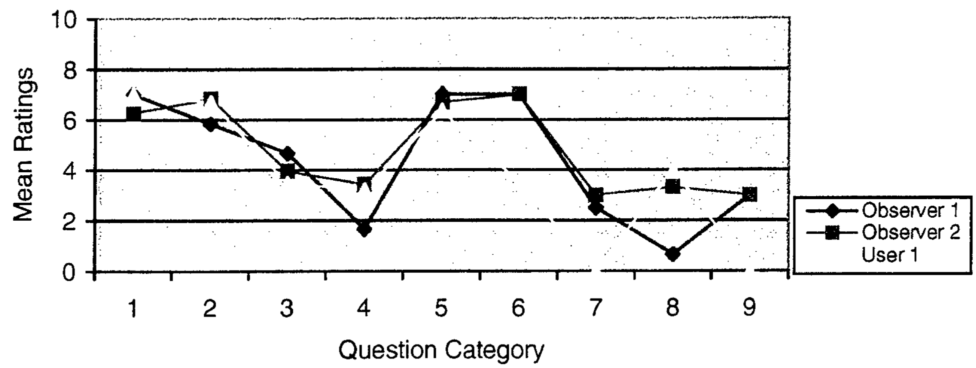

Figure 2: Mean ratings for system 1.

Clearly, there is similarity between the ratings given to the system by the observers and the system user on categories 1 to 5, with a highly significant positive Pearson *r* coefficient. It should be noted that these categories contain question types concerning more easily observable aspects of the systems, while the other categories rely more on the users experiences with the system in order to make a judgement. This may affect the similarity of the ratings, as the observers may perceive functions which apparently require many movements or a larger perceived amount of time to perform as being more difficult to use.

It can be noted, though, that categories 6 to 9 (*spatial awareness, information degradation, fatigue* and *overall system ease of use rating* respectively) show great similarity in ratings only between the observers for system 1. The correlations between observers and the system user are non-significant. These coefficients are shown below in Table 3. The difference in user and observer ratings is possibly attributable to the difference in actual experience with and simply observing the use of a system in operation.

Table 3: Pearson's correlation coefficients for system 1, question categories 6 to 9.

Rater	Correlated with Rater	Pearson's *r* coefficient	Significance
Observer 1	Observer 2	0.735	0.016
Observer 1	User 1	-0.613	0.971
Observer 2	User 1	0.225	0.532

The ratings shown in Figure 3 for system 3 show a somewhat different pattern, with similarities between all raters for categories 1 to 4, and more disparate ratings for categories 5 to 7. Greater similarity between all raters can again be seen for question categories 8 and 9. The correlation coefficients are shown in Tables 4, 5 and 6 respectively.

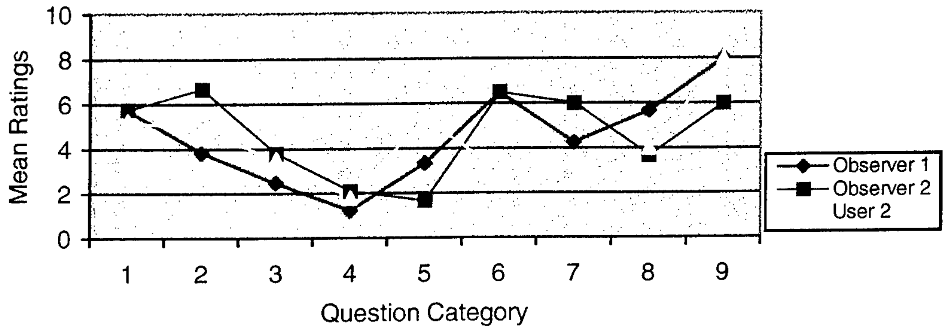

Figure 3: Mean ratings for system 3.

Table 4: Pearson's correlation coefficients for system 3, question categories 1 to 4.

Rater	Correlated with Rater	Pearson's *r* coefficient	Significance
Observer 1	Observer 2	0.610	0.000
Observer 1	User 2	0.482	0.004
Observer 2	User 2	0.433	0.011

As shown in the tables 5 and 6 below, categories 5 to 7 show very disparate ratings, with non- significant correlations between scores on these categories. Categories 8 and 9 show a similar pattern, except that observer 2 and the system user do tend to rate the system similarly on the *fatigue* and *overall ease of use* scales (as displayed by the significant positive correlation in Table 6 below).

Table 5: Pearson's r correlation coefficient for system 3 categories 5 to 7.

Rater	Correlated with Rater	Pearson's *r* coefficient	Significance
Observer 1	Observer 2	0.344	0.364
Observer 1	User 2	-0.534	0.139
Observer 2	User 2	-0.451	0.223

Table 6: Pearson's r correlation coefficient for system 3 categories 8 and 9.

Rater	Correlated with Rater	Pearson's *r* coefficient	Significance
Observer 1	Observer 2	0.677	0.323
Observer 1	User 2	0.812	0.188
Observer 2	User 2	0.978	0.022

It can be expected that the systems scored similarly in some of these categories, in that users of computerised systems tend to have similar types of generalised needs and preferences with respect to displays and layouts. Easy to read fonts, clear pictures, intuitive operations, and lack of onscreen clutter are – for example – common desires in most users of automated systems. In addition, the items in these categories (or the direct consequences of these items) can easily be noted by observers, so there is little constraint on what the observer can see. It is clear, for example, when the symbols and text are easily read and the colour coding is clearly understandable. The main constraint on this observation is that observers' perceptions of ease or speed of use can be affected by operation of the system by an experienced/expert user. That is, a bias towards perceived ease can form on watching an expert at work if the observer does not take this into account.

Discrepancies in subjects' opinions appeared most clearly where the users' experience with the systems came into play. The categories *information processing, spatial awareness* and *information degradation* resulted in quite different scores for the two systems whose users answered the questionnaire compared with the two observers. That is, the users perceived the functions in these two categories as simpler to perform than did observers with little or no experience with the system. This difference in perception appears to be a direct result of familiarity with the system, and is an important indicator of areas where training may need to be intensified. This difference in scores also indicates that a particular grouping of subjects for evaluation purposes is important in order to gain a deep understanding of the system and the training requirements accompanying system implementation. That is, experienced users may evaluate a set of system functionalities as very simple to use, where a novice may find them difficult to comprehend and operate. This type of information is highly useful in designing training protocols, and can highlight areas in which tools have good functionality but in which it may take longer and/or more intensive training to create user proficiency.

The two systems rated only by the observers showed the expected differences in their patterns of ratings. System 2 was a very simple and basic system, which both observes rated relatively consistently. System 4 was, however, more complex. Observer 1 had more experience with the system and communicated more closely with the system user while taking observations, and tended to rate the system as easier to use than did observer 2. The mean ratings for each system by the two observers are shown in Figures 4 and 5 below.

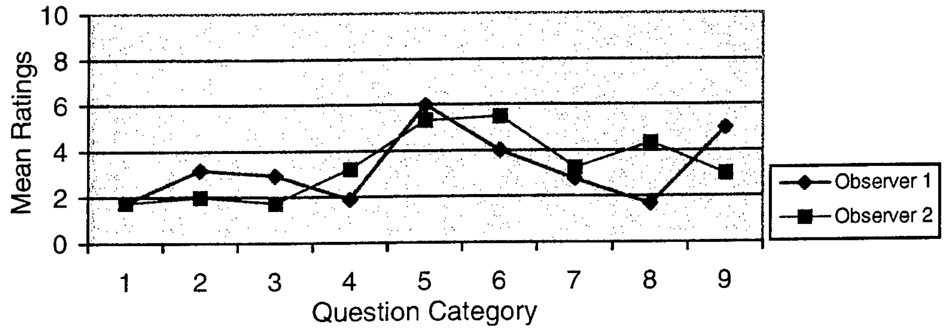

Figure 4: Mean ratings for system 2.

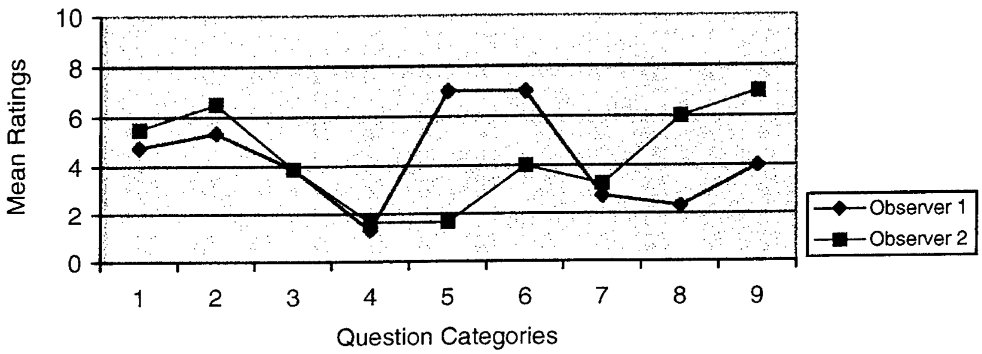

Figure 5: Mean ratings for system 4.

Conducting the question category split using the method applied previously, the categories showing the most consistent similarity in ratings were correlated, as were those showing consistent dissimilarity in ratings. This produced the Pearson's correlation coefficients shown in Table 7 below.

Table 7: Pearson's r coefficients for ratings on system 2 between observers 1 and 2.

System	*Question Category*	*Pearson's r coefficient*	*Significance*
2	1 – 7	0.225	0.147
2	8 & 9	-0.943	0.057
4	1 – 4	0.600	0.000
4	5 - 9	-0.202	0.507

It is apparent that for system 2, the ratings given to question categories 1 to 7 by the two observers show a mild positive correlation (which is nonetheless non significant). Thus, there is a similar general pattern of scores on the given items, but this is not a particularly strong trend. Ratings for categories 8 and 9, however, are strongly opposite; views on the overall ease of use and the issue of user fatigue were very different, possibly reflecting the individual preferences of the observers.

Ratings for system 4 showed a similar pattern to those observed in systems 1 and 3, where questions categories 1 to 4 showed strongly similar scores with highly significant positive correlations (as in Table 7 above). Again, these are the categories which are easily observable and this may help to account for the consistency of ratings between the observers. As stated previously, system 4 was more complex than system 2 in its operations and the methods of accessing its functionalities. Observer 1 had had more experience with the system and communicated more closely with the system user while taking observations than did observer 2, and so tended to rate the system more positively. The differences are apparent in the correlation coefficients generated by comparing scores on categories 5 to 9 for the observers: a Pearson's r of -0.202 indicates the different directions of the ratings, although this pattern was not strong enough to be significant (with $p = 0.507$).

5.3 Question content

It is clear that, although the questionnaire covered many of the more basic aspects of the systems' functioning, there were some aspects that needed further clarification and depth. For example, the first question - regarding the organisation of information in a clear and uncluttered way – elicited ratings with caveats from two of the subjects, and a straight rating from two subjects. This clearly indicates that there are additional conditions that should be considered as part of this question. One possibility for amendment includes the addition of several 'parts' for the question. For example:

Q 1. *Information is organised in a clear and uncluttered way…*

- *(a) When there are less than 10 pieces of information onscreen*
- *(b) When actively updating information*
- *(c) When displaying multiple categories of information*

Here, a variety of possible alternatives should be included in the question, so that a more specific judgement can be made about the capability of the tool in question. Thus, the subjects can rate the tool under each of these conditions, and clearly isolate tools from one another in terms of their capabilities. This is particularly important in critical areas such as information display.

There is also clearly a need for further space to be included in the questionnaire, as some questions elicited comments in addition to the required rating. Space was provided at the end of the questionnaire for notes by subjects, however this would be simplified by including space directly below or adjacent to the question itself. One difficulty is providing adequate space while leaving the questionnaire a reasonable size.

Questions regarding items such as time lags in update rates appear to need more clarity of definition. That is, some definition of "time lag" should be included in the question itself to enable a clear judgement by the subject(s).

Questions regarding the presence and effectiveness of editing (or other) functions should also allow for the subject(s) to outline which functions are present (if this has not been outlined previously by the researcher), and which of these are effective and easy to use. Simplification of these ratings would be achieved if the functions were already described by the researcher in the question list: however, when rating multiple systems simultaneously, this can prove to be a cumbersome manner of presenting information to the subject(s).

Generally speaking, then, questions should be more closely tailored to the individual systems being evaluated, encompassing their current capabilities while leaving room for suggested improvements. This can be difficult when there are multiple systems being evaluated in a single questionnaire, and so a compromise should be reached in terms of the level of detail included.

5.4 Question categories

It would appear that additional categories would be useful in evaluating DSSs or other automated tools. When evaluating planning tools, for example, it would also be useful to gather information on the ease of error correction and prevention, the ability to override computer generated/edited information if necessary, and the ease of accessing 'help' information. This would result in useful information regarding the potential efficiency of use by both expert and novice users, as well as the backup structure available to prompt novice users when they experience difficulties using the system.

5.5 The subject pool

A subject pool with a distinct composition needs to be accessed in order to carry out a full evaluation of any system, particularly those with specific end user applications. In terms of systems or tools with military application, work domain experts must be included as well as the technical domain exerts [those experienced with the system(s)] and inexperienced users (in order to gauge the potential learning curve for tool use). The systems should be studied from all aspects, bearing in mind the eventual aim of enhancing user functioning without adding to the cost or difficulty of user training.

5.6 General comments and suggestions for system design

Some general suggestions to improve the usability of systems intended for military use can be extracted from the questionnaires. In brief, the suggestions include:

- The ability to edit and send information in a distributed fashion would be an advantage (when backbriefing commanders, for example);
- The ability to make symbols "on the fly" would be very useful;
- The ability to generate and label threat domes is an added functionality that is considered essential;
- An "undo" function is critical as a time-saving device;
- Clutter should be reduced as much as possible without losing the vital pieces of information onscreen: this may mean increased screen size should be considered a priority;
- Editing functions should be simple and intuitive;
- Templates should be easily accessible;
- Screen resolution must be sufficient to reduce user eye fatigue;
- The ability to draw manually on a 'touchscreen' type display and have the information recorded for distribution would be an advantage.

As work on systems with these functionalities is currently in progress, future evaluations will need to integrate this information and expand on the detail of the suggestions in order to differentiate between the relative quality of the various system options (or combinations thereof).

5.7 Future research and evaluation methodologies

Research is currently being conducted using a condensed set of usability questions in addition to behavioural observations of users interacting with the systems in question. Data collection will also include the time and the number of movements required to correct errors and perform certain actions integral to the intended use of the tools being assessed, as well as trialing a behavioural assessment of the impact of the tools on the situation awareness (SA, both individual and shared) of the users.

Future uses of the evaluation methodology will also need to focus on the impact of automated tools on the SA of teams as a whole (in settings where groups or teams of people need to rely on the system or tool for enhanced information processing abilities). Enhancing an individual's SA does not automatically enhance the SA of a team, and therefore work must be carried out to ensure that team or shared SA is not degraded by the introduction of automated tools. Evaluation tools are currently being developed for this very purpose.

6. Conclusions

This report outlines a preliminary insight into the usefulness of a paper system evaluation methodology. It is apparent that much more work must be done on the details included in the evaluation questionnaire, and the suggestions for future uses and modifications include the following:

- Additional system-specific detail should be included in the questionnaire prior to subject evaluations.
- A larger number of subjects from all of the necessary groups (ie. technical experts, work domain experts, and novice system operators) should be consulted.
- Results from system evaluations should be used to determine where more intense training may be needed, in addition to highlighting areas which may require more intensive system development to facilitate user productivity, efficiency and effectiveness.
- Questionnaire information is not adequate in and of itself. The information gathered in this way should be supplemented by behavioural observations, including timing the durations of specific activities to ensure that a function rated 'fast and easy to use' is not simply an inaccurate subjective perception.
- Evaluations of usability should – in this context - be conducted concurrently with evaluations of situation awareness (both individual and shared), both inter- and intra- team interactions, and workload in order to produce a more complete picture of the impact of automated tools on the operations they are designed to enhance.

Evaluations of system/tool learnability can be examined in only the most basic way using this type of questionnaire technique. Such evaluations actually require their own intensive investigations, which will then feed their outcomes into the development of user training protocols for each system.

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Appendix A: MMS evaluation questionnaire

Note: The questionnaire has been condensed here for ease of presentation.

Your name:..

The system you are using:..............................

Please rate your level of agreement with the following statements by placing a number from 1 to 7 in the box provided.
The scale is as follows:

1 = strongly disagree
2 = moderately disagree
3 = mildly disagree
4 = undecided
5 = mildly agree
6 = moderately agree
7 = strongly agree

If a statement is not applicable, please place "n/a" in the box.

Display Readability.

1. Information is organised in a clear and uncluttered way.
2. Symbols are easily recognisable (consider both size and colour).
   Comments:...
3. Any on screen text is easily read (consider both colour and brightness).
   Comments:...
4. The colour coding makes map features easily distinguishable.

Screen Layout.

5. Important information is highlighted / stands out.
6. Information is located in the same position on each consecutive screen.
7. The map scale is present on screen and correct.
8. The necessary zoom levels were available and easily controlled.
9. Any menus are organised in a logical way (eg. alphabetically or by function).
10. The necessary coordinates are present on screen and easily legible.
11. Any units of measurement are consistent with military standards.

Functionality.

12. All relevant/necessary information is contained on screen.
13. Necessary information can be accessed quickly and easily without losing the user in the GUI.
14. There is a clear functional relationship between the windows, menus and toolbars.
15. Windows are managed consistently throughout the system.
16. Manipulation of the map and overlay information is fast and simple (compared with other graphics editing packages, for example).
17. Manipulation of the maps and overlay information is intuitive (eg. logical and fluid, similar to Windows, etc).
18. Field labels and icons are consistent across screens.
19. There is need for labelling of timelines in addition to the pop-up labelling already present.
20. Information can easily be checked before being entered.
21. There is a need for an effective undo / redo function.
22. There are precautions in place to prevent mistakes.
23. There are clear, concise and constructive error messages.
24. Warning and confirmation dialogues provide adequate feedback to users.
25. The perishability of the information can be adequately manipulated.

General Information.

26. There is a time lag in information/screen updates. YES / NO
    If so, please estimate the average lag in seconds:.................
27. Symbols are easily entered/drawn. Comment:.........................
28. There is a need for a log of events/history of information.
29. Administrative messages can easily be filed.
30. Any screen dialogue is simple and to the point (ie. no extraneous rubbish).
31. Onscreen dialogue is in the accepted /standard military language.
32. There is need for a library of friendly/enemy symbols to be readily available.
33. There are shortcuts available for experienced users to speed up frequently performed operations.
34. The system gives adequate feedback on what the user is doing/needs to do.

Information Processing.

35. Necessary information can be superimposed/removed quickly and easily.
36. Information can be easily and quickly edited and sent.
37. Information is quickly and easily downloadable.

Spatial Awareness.

38. There are effective cues to maintain accurate spatial awareness.
39. The display should be "north facing".

Information Degradation.

40. There is generally too much redundant information present while operating the system.
41. There is generally too much obsolete information onscreen.
42. There is a need for an effective edit function.
43. The user can easily exit from a situation when / if necessary.

Fatigue.

44. Information overload is a problem for the user.
45. The performance of the system suffers due to data overload.
46. Extended operation of the system by a single user would result in significant levels of fatigue.

OVERALL rate the ease of use of the system on a scale of 1 – 10
(1 = extremely simple to 10 = extremely difficult/complex): _____

============================

General short answer questions:

Name:....................................... System:...

Experience level with system(s):..

1.How easy was the system to learn / become familiar with? Please rate any of the systems you are familiar with on a scale of 1 [very easy] to 7 [very hard].

2. How does it compare with other systems in your experience?

3. What – if any – were the main difficulties with learning to use this system?

4. How easy would it be – in your opinion - for a person with possibly limited experience with computer systems such as this to learn to use it efficiently?

5. Are there any areas that you think / know are lacking in terms of what the end user (ie. military) will want from the system? If so, what are they?

6. Is it easy to maintain system awareness when there are distractions/interruptions occurring? eg. excessive ambient noise, interruptions by other people, etc.

7. Do you have any suggestions for future design of this system in light of its intended use?

Appendix B: Tabulated results from the questionnaires administered.

	Observer 1	Observer 1	Observer 1	Observer 1	Observer 2	Observer 2	Observer 2	Observer 2	User 1	User 2
Questions *System:*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*3*
Display Readability										
1.	7	1	3	6	6	1	5	4	7	4
2.	7	2	7	*9	7	2	7	7	7	6
3.	7	3	6	7	6	2	5	6	7	6
4.	7	1	7	6	6	2	6	5	7	5
Screen Layout										
5.	7	3	5	6	6	3	6	6	7	7
6.	7	4	6	7	7	1	7	6	7	-
7.	-	-	-	-	7	6	6	6	6	7
8.	7	6	4	7	7	Na	7	7	7	3
9.	7	5	1	6	7	Na	7	7	6	5
10.	7	1	7	6	7	2	7	7	7	7
11.	7	1	7	6	7	1	7	7	5	7
Functionality										
12.	7	2	5	6	7	2	6	6	7	6
13.	7	4	1	7	7	Na	6	6	6	5/6
14.	7	4	4	7	7	Na	6	6	6	4
15.	7	5	4	7	4	Na	5	7	7	2
16.	7	7	3	6	6	5	5	6	7	4
17.	7	7	3	7	6	6	6	5	7	1
18.	7	4	6	-	6	4	5	6	7	7
19.	-	-	-	-	-	-	-	-	-	-*1
20.	7	5	3	6	7	5	1	6	-	2/5
21.	7	6	1	6	*12	Na	7	*11	-	7
22.	-	-	-	-	1/2	1	1/2	1	-	1
23.	-	-	-	-	½	1	1/2	1	-	1
24.	-	-	-	-	1	1	1	1	-	1
25.	-	-	-	-	-	-	-	-	-	5
General Information										
26.	-	-	-	-	Na	Na	Yes ~5 sec	Yes ~ 0.5 sec	-	No ~5 sec
27.	7	5	5	6	7	6	3	5	5	5
28.	-	-	-	-	7	7	*10	-	-	2
29.	-	-	-	-	-	-	-	-	-	6
30.	-	-	-	-	-	-	-	-	7	NA
31.	-	-	-	-	7	7	7	-	5	NA
32.	1*8	7	3	-	7	7	7	7	7	*2

33.	-	-	-	-	2	1	1	2	5	-
34.	7	5	3	6	1	1	1	1	*5	3
Information Processing										
35.	7	6	3	7	7	6	5	5	5	6
36.	7	6	3	7	6	4	-	-	7	5
37.	7	6	4	7	7	6	-	-	7	5
Spatial Awareness										
38.	7	2	6	7	7	4	6	1	-	6
39.	7	6	7	7	7	7	7	7	7	*3
Information Degradation										
40.	1	-	6	1	2	6	6	3	-	3
41.	1	-	2	1	2	5	6	3	-	2
42	1	5	7	3	1	2	6	1	-	*4
43.	7	6	2	6	7	Na	6	6	-	5
Fatigue										
44.	1	2	5	1	4	4	5	5	-	5/6
45.	1	2	5	6	-	4	-	6	5 *6	-
46.	-	1	7	-	6	5	6	7	7	7
Overall rating or ease of use	**3 *7**	**5**	**8**	**4**	**3**	**3**	**6/7**	**7/8**	**-**	**8**

*1: Objects can be labelled easily but don't have pop-up labels.
*2: Already has a library of symbols.
*3: It is north facing.
*4: Has an effective edit function, rated 6/7.
*5: Visual feedback.
*6: Screen gets cluttered.
*7: An experienced operator would have no problem adjusting to this system.
*8: Once developed, need not be redone.
*9: No graphics yet, but simple bitmaps available, so is good.
*10: Has system logs.
*11: Has undo function.
*12: Has undo/redo.

Appendix C: Descriptions of system components

Landscape.
The Mission Planning sub-system of the MMS concept demonstrator relies on user interaction with LandScape, a system developed inhouse based on Autometrics Edge Development Option that was 3D visualisation for the digital map display. LandScape gives a realistic, scalable, 3D representation of the earth's surface using a variety of GIS data including digital elevation models, raster data such as satellite imagery and scanned maps and vector data for representing linear features such as hydrology, transport networks, contours and boundaries. In addition, LandScape can display text annotations, map and military symbology as well as customised 3D models and graphics. For example, weapons systems can be graphically represented and their effective ranges displayed in 3D.

LSAP (Land Situation Awareness Picture).
LSAP has been produced under contract by Maptek and is a 3-D visualisation toolkit used to produce 3-D visualisation applications, similar to LandScape. It is a multi-process system where extra applications are designed to provide complex output by putting layers on top of the Carmen core and multiple executables provide the overall application.
The Situational Awareness Picture (SAP) is the most important feature. It is constructed from a terrain and an optional draped image (a geolocated image with intersects which can be draped over the terrain) and all the entities, and is the vehicle thru which operators visualise plans and entities. Line of sight tools can be applied here. The planning for a helicopter pilot can therefore combine terrain features and entity information, and predict from this an optimal path in the SAP. This can then be published to the helicopter itself as a flight plan (Kirby, Seymour & Flay, 2000).

MapInfo
MapInfo is a COTS product which is a comprehensive desktop mapping tool that enables users to perform complex geographic analyses such as redistricting, linking to remote data, dragging and dropping map objects into applications, creating thematic maps that emphasise patterns in the data, for example. It enables live ODBC access to remote databases, cartographic legends, Seagate Crystal reports (industry standard report writing program), and grid surface thermatic mapping. It is compatible with MS Office products, and lines, symbols etc can be added for drawing overlays.

The **Smartboard** is a large screen onto which maps and overlays shown in MapInfo or Battlescape can be projected for clear and simple viewing by users. The large screen enables an increased number of people to view the screen simultaneously (cf. normal computer screen viewing). It also employs a touchscreen facility to allow users to draw at will on the displayed map, although this cannot be saved and shared with other distributed users at this point in time.

Mimio with whiteboard

This is an electronic whiteboard attachment that allows the user to draw plans, symbols, overlays etc on a whiteboard (using the specifically designed pens) and have these automatically appear on a computer screen. These overlays can then be saved and passed on to other staff for use with their own maps. It utilises technology to allow users to draw in large format on a whiteboard and then have the product transferred quickly and easily to an electronic format which can be saved and sent to multiple recipients.

BCSS

The Battlefield Command Support System is a command support system which is currently being trialed and developed by the Australian Army. The Ops component of the BCSS system enables users to send and receive text messages, and to view electronic maps which display the entities on the battlefield and update the positions of these during the battle.

IME

This is an Information Management Engine with an Oracle database. It stores the information necessary to produce the entities displayed on systems such as CARMEN and Battlescape.

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19. ABSTRACT

A preliminary version of a system evaluation questionnaire was trialed concurrent with a mission management system (MMS) concept demonstrator test during June 2000. The questionnaire was designed to examine usability and interface issues relating to the design of the systems or tools, and to provide suggestions for future iterations of the system(s). The returned questionnaires were examined for both the system-related information, and the content and style of the questions themselves. Although some useful information was gathered using this questionnaire, the author concludes that such questionnaire methods should be combined with (for example) behavioural observations in order to provide a more complete picture of optimal system design and user training for the human-machine context.

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DEPARTMENT OF DEFENCE
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ELECTRONICS AND SURVEILLANCE RESEARCH LABORATORY
PO BOX 1500 SALISBURY SOUTH AUSTRALIA, 5108
AUSTRALIA, TELEPHONE (08) 8259 5555