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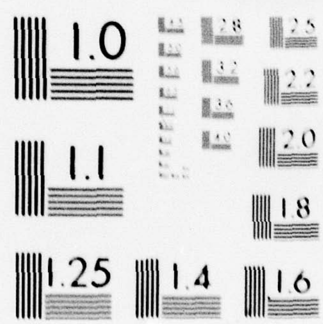

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AMTE(E)-TM79103

PERSONALISED TASK REPRESENTATION

BY

R. GREGORY

Summary

Personalised Task Representation is a system of task analysis that is being developed at AMTE/APU. A worked example of the current PTR system is demonstrated and its rationale and relationship to the more traditional forms of task analysis are discussed. The most important difference between PTR and these other forms of analysis is that it provides the means to take account of the reasons for, and the contexts of, task activities as well as the task activities themselves. PTR thus emphasises the experiential as well as the behavioural components of the task. It is suggested that PTR has the potential to cope with tasks having a high non-procedural content, (eg tactical decision making), where other forms of task analysis break down.

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34 pages
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CONTENTS

		Page
1.	Introduction	7
2.	Rationale	8
	(a) Molecular Approaches to Training: Problems and Difficulties	8
	(b) A Phenomenological Approach to Training	15
3.	Method	16
	(a) The Evolution of the Action Model Format	16
	(b) Personalised Task Representation	21
	(c) Anticipated Developments	26
	(d) Personalised Task Representation and Other Methods of Task Analysis.	27
4.	Summary	30

"The best vantage point for understanding behaviour is from the internal frame of reference of the individual himself."

Proposition VII, Carl Rogers (1951)

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INTRODUCTION

The traditional way in which tasks have been treated in the Services for training purposes has been to apply what might be called a molecular approach. Examples of this approach are, in the Royal Navy, Objective Training, in the RAF, Systems Approach to Training (SAT), and in the USAF, Instructional Systems Development (ISD). These schemes function by attempting to break down tasks into discrete steps which may be performed either in fixed sequence or according to specific predefined contingencies and each discrete step has its own input conditions, required actions and criteria for success. Descriptions in this form are usually known as Behavioural Objectives. The major advantages of such descriptions are that they allow one to define and measure the accomplishment of training goals, and to develop a training program directed at the teaching of these sequences of discrete steps. But there are limitations to such an approach as this and it is the purpose of Section 2 of this paper to discuss these limitations firstly with regard to the sort of task traditionally tackled using a molecular approach (ie tasks with a seemingly high procedural content) and secondly with regard to the kind of task that AMTE/APU is now becoming interested in: ie complex non-procedural tasks. These arguments will be developed by reference to two tasks drawn from the author's own background which will also serve as general analogues of tasks with which we, in the Services, have been and will be concerned. It will be argued that the more a task is centrally concerned with a non-procedural component, the more we, as training technologists, should be attending to the subjective experience the job incumbent or trainee has of his task, and we should be doing this rather than remaining preoccupied with the overt behaviours he may produce. And we will have to attend to the way in which he experiences his task if we are to stand any chance of systematically determining and explaining errors and difficulties, and at the other end of the scale, expertise.

The emphasis on the experiential rather than on overt behaviour for complex non-procedural tasks introduces a rather different approach to the training of these tasks and this may be described as phenomenological, as opposed to the traditional molecular orientation, (see Klein 1977). Section 2(b) will describe some examples of what a phenomenological or experiential approach to training looks like but it must be stressed now that the abandonment of molecular techniques is not being advocated. After all, even complex non-procedural tasks have some procedural component which may still best be taught by traditional methods. It may be more productive then to try to synthesise these approaches to create a method of task representation that not only captures the procedures and predefined contingencies inherent in a task, but which also goes much further, recording the way in which the expert and/or trainee views or experiences the task and therefore the way in which the procedures are uniquely combined by him. What is being referred to here is a facility which captures the operator's psychological model of the task - the way in which he mentally cuts up the task for himself, and in Section 3 a worked example of a method which represents a first attempt to do just this will be demonstrated.

The molecular approach referred to above and resulting in a Behavioural Objectives based training program is one of two major ways in which the process of task analysis has been interpreted. The other approach, of which there are as many examples as there are different purposes, has been to develop behavioural taxonomies. With regard to training, the intention has been to assign the behaviours required of the training course graduate to categories of behaviour, each category demanding particular teaching strategies. This approach has largely failed and although detailed discussions of the reasons for this failure are left to the references, the relationship between this approach and the author's is dealt with in Section 3(d).

2. RATIONALE

(a) Molecular Approaches to Training: Problems and Difficulties

Some years ago, the writer began to learn to drive a car at about the same time as starting a new job. The job involved the operation of a large continuous process brick kiln with the capacity to produce a million bricks every ten days.

In fact, the operation of the kiln was adequately described in the quite extensive list of procedures held by the job supervisor and which were referenced until they had been learned by heart. Each procedure comprised a set of specific actions which was linked to a specific time in the shift, and, where procedures were dependent on each other, clear and straightforward contingencies were laid out.

The kiln itself was a solid rectangle with a top surface area roughly equivalent to the dimensions of a football pitch and standing about 15 feet high. It consisted of 50 chambers, 25 down each side and each side being linked by an enclosed flue-gas tunnel at each end. Such was the operation of this kiln that at all times bricks were pre-heating, firing, cooling, being withdrawn from, and being loaded into, the chambers.

Now, one of the procedures required of kiln operators entailed walking around the top of the kiln gradually raising the temperatures of kiln chambers - usually 5 or 6 on each side by specified increments, at two-hourly intervals, up to a maximum of 1027°C; another entailed the visual inspection of bricks under fire through special portholes, again at regular intervals. But if a particular visual inspection revealed that the stacked bricks had grown too soft and had begun to lean under the heat, the temperature on that chamber had to be reduced immediately, and so on. This is one example of just two fixed procedures with a predefined contingency relationship.

Although the writer achieved a quite reasonable level of proficiency at this job, the average training time for kiln operators was in the order of six months and it does seem plausible to suggest that, had a formalised objective training scheme been used, higher proficiency could have been achieved sooner than this. The high procedural content of this job would seem to lend itself to description and prescription in terms of Behavioural Objectives, (ie cues, actions and success criteria). A major limitation of such an approach, however, even in this familiar type of task may be expressed in terms of what one does as a trainer when certain sorts of learning difficulties occur. It is conceivable, for example, that although a kiln operator can demonstrate that he is able to execute all the procedures required of him, individually, he nevertheless fails to complete all of them by the time his shift ends. Ruling out idleness or irresponsibility, the supervisor might well suspect an inappropriate strategy. But there is nothing in a molecular-based training system that can give the remotest idea about what particular strategy the operator is using - nor even what strategy he should be using,and this is because in such a training system, the trainee is shown what to do, and how to do, each part of it, but he must draw on his own resources to devise ways of mentally linking the procedures together: in other words, the ways in which the experts conceptualise the task are not an explicit part of the system. And if he links them together in a way which is inappropriate or uneconomical it may take considerable time for him to unlearn this and replace it with a more appropriate strategy. Indeed it may be that the supervisor (expert) and trainee have such different ways of perceiving the task that they have a profound communication problem - to all intents and purposes they are not talking about the same job. In such instances one rather drastic solution is for the trainee to be reassigned on the grounds of incompetence and during his time as a kiln operator the writer was witness to just such an incident.

So the kind of difficulty that we are talking about here, and which cannot be helped by continual backclassing of the trainee, occurs when procedures are executed satisfactorily, but inappropriately or inefficiently combined. It should be noted that this sort of difficulty did not continually crop up at the brickworks and this is because of the level at which overall success criteria were set by the supervisors and management.

As long as all procedures were executed satisfactorily, in the correct order where necessary, and within the time allotted, criteria were judged to be met and there was only concern when the criteria were compromised - when the bricks fell over and melted, for example. As long as the job was done, then the supervisor was happy and really didn't worry about the efficiency or otherwise of the strategy used. It might be added that inefficiency was indirectly encouraged since the writer was constantly being asked by the supervisor how he came to be reading the newspaper whilst other operators were observed to be rushing round the kiln every five minutes and sweating profusely with the effort. The supervisor could not or would not appreciate the beauty of a coherent and well-developed strategy. In fact, the anxiety that the writer experienced whilst awaiting managerial footsteps clattering up the steel stairway to the kiln top quickly grew too much for him, forcing a modification of strategy so that everything was done in the same way as before but in twice the time.

But there is a danger in some contexts, in setting criteria too low: it may be that an operator is observed to do all that is required of him for year after year, but executes a disastrous action in situations of emergency simply because his psychological model of the task is not veridical, or contains a spurious but rarely used connection, and it would be interesting to discover how many accidents fall into this category of human error.

The limitations of molecular-based training systems manifest themselves even more severely, however, when the attempt is made to apply these systems to tasks that are essentially complex non-procedural tasks like driving. Whilst objective training would seem to lend itself to the various sub tasks of driving, such as clutch control, and changing gear etc, how could it have been used to teach interpretation of road and traffic conditions? How could the Instructor have set about defining specific training objectives? And it is a reasonable guess that should an Instructor set himself the task of agreeing with other Instructors how specific actions are combined to yield adequate performance of basic driving manoeuvres, he would experience considerable difficulty. Now why should there be such difficulty? The problem here is that molecular type analyses of tasks like driving serve to distort them and this is because they remove the dynamism from tasks that are centrally concerned with dynamic relationships. Try to imagine, for example, a 2-dimensional flow chart describing what a novice needs to know to drive round the North Circular Road in London: it would be hard enough to decide what the decision points and discrete actions would be, let alone capture the important contingencies involved.

What this point is reflecting is the prescribability of tasks. The kiln operator's job is entirely prescribable in a 2-dimensional form - as is evidenced by the existence of virtually exhaustive lists of procedures and contingency relationships. Adequate performance could usually be attained merely by following the procedures as laid down.

Clearly, however, the task of driving is not prescribable. And this statement is true until somebody produces a list of action sequences for every type of environmental condition that a driver and his car might conceivably encounter in the future, together with their interrelations and contingencies. Even if it were possible to draw up such a list, the comprehensibility and utility of the prescription would be open to question, to say the very least.

The point is that although changing gear and not stalling etc are important procedural considerations, what driving is really all about is the continuing construction of a dynamic and high quality relationship by the driver, between himself, his car and the road. The criteria that the driving examiner applied to the writer's driving when he took his test were certainly concerned with gear changing and co-ordination per se, but the examiner was also vitally concerned to assess the aptness with which the writer changed gear etc, ie how his control of the car related to the environment through which he was driving. It is the construction of this relationship that makes up a large part of the solution to the problem of driving and it is this relationship that is lost when the attempt is made to perform a molecular-type task analysis.

But, of course, the driving instructor didn't attempt any such thing, and supplemented his 'here is how you do it'-type descriptions with 'this is why you do it-type explanations. He didn't spend most of his time breaking the task down into action sequences, but most of it injecting explanations at what appeared to be significant moments. He allowed the writer to cut up the task psychologically in his own way - to create his own model of the task which could be adjusted and re-arranged as the Instructor annotated the writer's increasing experience. This was achieved through the Instructor comparing his understanding of the writer's understanding (his model of the writer's model) with his own expert model. In these terms, teaching proficiency could be measured by assessing three distinct components:

(i) The isomorphism of the learner's model of the task and the Instructor's model of the learner's model.

(ii) The degree to which the Instructor can compare his model of the trainee with his own expert model of the task, to arrive at clear and appropriate responses to trainee performance.

(iii) The degree to which the expert's model is actually 'expert'.

We have been talking here as if the task description which a trainer might use as a basis for his training system and the psychological model that he has of the task he is attempting to teach were mutually exclusive alternatives. Miller (1974) also notes the incongruity of the two:

> "Current descriptions and analyses represent the overt facets of the step by step performance of the novice... Seldom do they depict the smooth and co-ordinated performance of the highly skilled and efficient performer".

This quote would seem to suggest that expert and novice performance are radically different, and this suggestion is frequently reflected in our everyday experience of task mastery. The writer remembers well, for example, the relatively sudden and immensely satisfying feeling after a few driving lessons, that the car was no longer carrying him along: he was controlling it - telling it what to do. In other words a shift in perspective had taken place: as a parallel, consider this comment from a USAF instructor pilot:

> "You start off finishing undergraduate pilot training being able to fly, but you are always concerned with remembering everything they told you and not missing a major step. Flying at this time is quite stressful and not enjoyable. Eventually, you get to a point where you are no longer flying the aeroplane, but are feeling yourself fly. And that's when it becomes easy and worthwhile. Before, you were strapping yourself into an aeroplane which you flew. Now you strap the aeroplane on to you and you fly".

Klein (1977), from which this quote has been extracted, adds another example:

> "Experts describe how they start by reading symbols off the

(radar) scope face, trying to remember what the symbols mean and how to tune them in better. But eventually they experience the radar through the scope which they adjust as one blinks an eye to see better ... the shift is from operating a piece of equipment to operating with the piece of equipment. The novice experiences a separation between himself and the equipment he is operating. The expert has eliminated this separation, and is functioning with the equipment, as with a body part".

This shift in perspective may be explained perhaps, by suggesting as Klein does, that the expert comes to understand the task in an holistic way. Thus expert performance is smooth because it reflects current and anticipated task demands simultaneously, whereas the performance of the novice is jerky because he is performing each action in isolation, and fails to understand how each such action fits in to the overall task. Assuming that this shift in perspective is true - and our own subjective experience certainly validates the proposition - it would seem to follow that expert performance is not simply a matter of speeding up action sequence execution so that it looks smooth and coordinated to the naked eye. Further, experts very often don't do things in the sequences that they may be involved in teaching novices. Thus, for example, Klein refers to instructor pilots who, though frequently required to develop Behavioural Objectives descriptions of flying performance, typically admit, informally, that they do not follow these steps when they themselves are flying. And De Maio et al (1976) found that while instructor pilots could find errors in visual displays more quickly than trainees, eye movement data showed that the instructors were using the visual search procedures they were teaching their trainees significantly less than the trainees were. In such cases the path to proficient performance would seem to be travelled in spite of, rather than because of, molecular training materials.

What has been said just now reflects a basic incongruity between the sequential task representation that molecular analysis provides, and smooth expert performance, the latter implying a radically different representation in terms of an expert model.

Consider Figure 1. The expert represents any complex task to himself in terms of a psychological model to which he refers during interaction with the task. Actual expert performance may be seen then, as a physical manifestation of his psychological model. But task analysts are human too (usually, that is) and thus they also develop a psychological model of the task. The expert's interaction with the task is paralleled with the analyst's application of his observational technique, and the expert's performance, with the analyst's resulting task description. The expert's model is expressed in terms of actions and his function as analyst is implicit and often ignored. The analyst's model is expressed in terms of statements about the expert's actions and his function as learner is implicit.

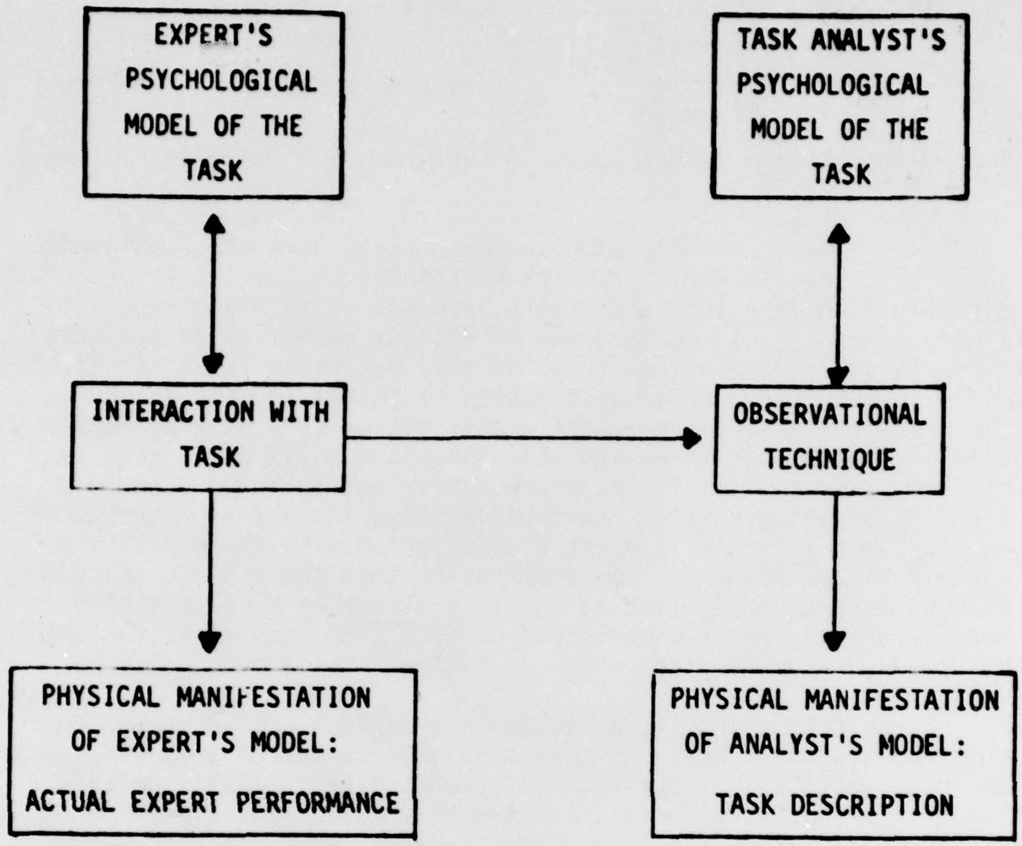

Figure 1. The Analagous relationship between the processes of task performance and task description.

Or more elaborately:

EXPERT		ANALYST	
Task Analysis =	Learning of Task	Learning =	Task Analysis
T/A Method =	Learning Strategy	Learning Strategy =	T/A Method
Task Description =	Performance	Performance =	Task Description

The attempt is being made to demonstrate here that, in producing a task description, by whatever method, the analyst is not directly or objectively describing, and nor is he explaining, the expert's task or his performance of it, but rather he is articulating his own psychological model of it. But there is an important difference between the analyst's view of things and the expert's. The analyst frequently produces a description of a task without actually being able to do the task himself. Vital operationally important information is therefore simply not included. In addition, information that is spurious may find its way in. Whilst we may push the expert to produce a description with the capacity to explain his performance, any description that the analyst may produce will be severely limited in its explanatory power and this is because the analyst's description derives from (and is distorted by) his own psychological model of the task (as shown in Fig 1).

Since this point is particularly important, it is worth putting it another way. As task analysts, we may be very tempted to think that part of our role is to ensure that we stay outside the task - that it might do positive harm to our observational skills if we become too involved. Learning about the task without learning how to do it ourselves means we may view the task with some detachment, freeing us to find the relationships and rules that characterise the expert's performance but which he is too involved to perceive. Ignoring the view that this might be a rationalisation of the fact that analysts rarely have the time to become experts themselves, it is being suggested here that although useful insights may, and have, come of this, we should not presume that because we can see and record rules and relationships, we are explaining what the expert is actually doing. In an analysis of cyclist performance the analyst might say, for example, that a cyclist keeps his balance according to the rule "wind along a series of curves, the curvature of which is inversely proportional to the square of the velocity". But it is hardly plausible to suggest that a cyclist is following this rule as he rides - or indeed any consciously perceived rule. The point is that the rule that describes the performance is by no means necessarily involved in the production of that performance, (Dreyfus, 1972). Now it is not being suggested that we should stop specifying rules drawn from our observations of expert performance. After all, if the presentation of such rules to trainees shortens the training program or makes learning more efficient, such a suggestion is pragmatically invalidated.

What is being said is that if we intend to base any training program we might devise on an explanation of the way in which experts produce performance then we must be careful to do this rather than base it on a description that may have little or no operational significance to the expert. It is, of course, being implied here that the direction in which we should move will make for the transcendence of analyst-oriented descriptions to a situation where we, as training technologists, create the means to facilitate an expert-oriented self explanation - to help him to articulate his own model which is the source of his performance.

There is, then, a requirement for a method which produces a personalised representation of the task. But such a facility, if it is to have the capability to produce a psychological model or customised task description with the potential to explain performance, must not only capture a representation of the task in terms of how the operator is perceiving the task - what verbal headings he gives to subjectively determined task components and how he therefore organises his experience, but must also capture the procedures he uses. It must answer both why? and how? questions. But before the attempt to evolve such a facility is described, a few examples of what a purely phenomenological approach to training looks like will be discussed.

(b) A Phenomenological Approach to Training

The following examples are derived from an article by Gary Klein, (op.cit) and one technique involves the use of imagery. Consider this quote from a pilot trained in air to air combat (and who, somewhat paradoxically, was working with an ISD unit):

> "I know what I'm looking for in the end, how I expect to be bearing in on the target, and I also know how each type of manoeuvre will affect this outcome. I've learned this with experience. The trainee is often trying to solve the attack equations on just one dimension at a time, whereas I can blend all the factors. I tell trainees to try to take a god-like view: not to think of themselves manoeuvring against another aeroplane, but to see themselves from outside their own cockpit, from outside their own aircraft, observing their aeroplane relative to the target. This ability to represent your aircraft from other than your own cockpit helps tremendously, and is developed with experience. In my own mind, I am seeing myself from another point, usually from above and this point moves during the mission. Guys who fly canned manoeuvres, making specific responses to specific situations are usually OK for one or two runs, but then they run out of options. There are too many combinations and they can't handle all the possibilities".

This quotation clearly harks back to the shift in perspective that differentiates expert and novice performance. Another type of shift in perspective important at least in aircrew training is the ability to assume the perspective of others. Cream (1974) found that members of an expert highly co-ordinated crew each had an accurate expectation of the appropriate system operation for each of the other crew members. These expectations are not simply a matter of knowing what messages must be sent and delivered and when, but enable a radar navigator, for example, to make the necessary adjustment to his own performance because he has an accurate appreciation of how essentially unexpected events affect the Electronic Warfare Officer. The training of team members must therefore include techniques which encourage them to understand the nature of other tasks in the group as well as their own - using, for example, role playing methods.

Another technique suggested by Klein is that of the motor analogy: the idea here is to take a short cut to what is sometimes referred to as 'feel for the task'. Here is one such example:

> "The tennis novice is frequently instructed on how to play up at the net in terms of how high to position the racquet face, what angle to play the shot with, how to avoid chopping the ball, how to position and move each foot. The result is typically to leave the novice in a state of instruction-induced paralysis. But if the novice is simply told 'It's like pushing a pie in someone's face', then the result is a smooth co-ordination of arms, body, feet and racquet".

Of course, the tennis player does not play the net exactly as if he or she were holding a pie plate: what remains constant is the co-ordination of movements and the relationships involved. This is why the term 'motor analogy' is used rather than referring to the 'transfer of well-learned responses'. An analogy allows the transfer of relationships even when the individual components are different.

That completes a brief tour of a strictly experiential approach to actual training. In Section 3 is described a method of task representation that we, in APU, have come to know as Personalised Task Representation or the PTR system, and which has been (and is being) designed to elicit the inherent procedures in a task and to record them in a way which corresponds to the way in which the elicitee <u>experiences</u> them.

3. METHOD

(a) The Evolution of the Action Model Format

At the centre of the PTR system as it now stands is a basic descriptive unit conceived of some years ago by a colleague, A. Gardner, and dubbed 'Action Model'. But the concept of the Action Model has evolved and passed through several transformations since that time, and it is worth retracing that evolutionary path to facilitate greater understanding of what currently exists.

The first application of Action Models to task description appeared in a report by F E Myszor (1978) who, at that time, was working with the Unit as a sandwich student. In that report, two distinctions were drawn, firstly between observational and inferential types of task description, and secondly between macro and micro types. Examples of these types appear in the matrix taken from Myszor's report, (Fig 2).

	MACRO	MICRO
OBSERVATION	GROSS ACTIVITY	THERBLIGS
INFERENCE	RIGNEY'S STAGES	APTITUDES
BOTH	ANNOTATED GROSS ACTIVITY	ACTION MODELS GAGNE ANALYSIS

Figure 2: Examples of Task Descriptive Methods applied to Electronics Maintenance Procedures.

Action Models were thus seen as being both observational and inferential since they were designed to provide a format in which the relationship between a stimulus, a response and their underlying cognition could be expressed: they were a means of structuring and presenting, in detail, what occurs both cognitively and behaviourally in the performance of a particular task. Myszor pointed out that the Action Model idea could thus be seen as going further than a Gagné Analysis (1960) by attempting to capture the procedures by which certain performances come about.

Action Models were considered 'micro', because they were designed to describe fairly small units of task behaviour.

What did these early Action Models look like? Figure 3 illustrates the format.

S	s	O	r	R	NEXT
The physical reality of the situation	The salient features of S an operator uses to perform R	("Operate") serves the function of producing response possibilities and then choosing between them	Response model oriented towards general purpose of performing task	Observable response made by operator	Identifies next Action Model in current sequence

Figure 3: Early Action Model Format

Another way of representing this appears in Figure 4 with symbols above the line referring to the external world and symbols below the line referring to the operator's internal world:

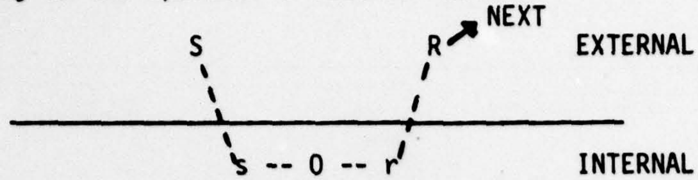

Figure 4: Early Action Model Archetype

Myszor's report went on to describe the development of an hierarchy of Action Models. Following the recording of information in this SsOrR format, it was found that Action Models thus created could be further analysed into component Action Models. This further analysis introduced the potential for generating different levels of description in addition to the sequencing of Action Models corresponding to the task execution order. Each description at the lower levels was designed to make explicit those aspects of a task which were implicit at the higher levels. Ascending the hierarchy was said to be analagous to a person making the transition from unskilled to skilled performance and finding execution of the more minute task elements to be "automatic", affording him the opportunity to attend to higher-level aspects of the task.

The next formulation of Action Models was centrally concerned with symbological change. Figure 5 illustrates the result:

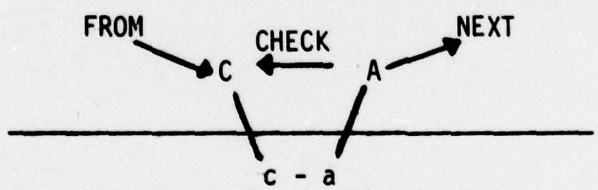

Figure 5: 1st Reformulation of Action Model Format

'Stimulus' was replaced by "Cue", and "Response" by Action. The reason for this change rests in the essential inadequacy of the more traditional terms. The word 'stimulus' is inadequate because it seeks to be totally independent of the respondent. But if we say that its effectiveness depends upon its meaning to the respondent in any way, then it ceases to be a stimulus and becomes a "cue". The same mechanistic externality of 'stimulus' which makes it use nonsense also applies to the term 'response'. Those investigators responsible for the use of these terms (the behaviourists) use "response" to indicate that they are talking about behaviour that is controlled by the stimulus rather than the person, but in doing so they mask the fact that responses have meaning to the person. In reality, then, people (and rats) act rather than respond, and to use the latter term is to deliberately confuse "reflexes" with "actions" in the misguided pursuit of 'objectivity' (Rowan,1973).

The "operate" term has also disappeared from Figure 4 largely because it was found to be unnecessary and a block to parsimony.

From Figure 3 we can see that it was designed to generate the response possibilities listed under "r", *and* choose between them. But if Action Models are to represent *process*, then choice between possibilities should be assumed to occur *either* at "r" or between "r" and "R". And what is this mysterious "operate" process which generates a list of response possibilities? Surely once we have observed R(A) and we have described s(c), this is all we (or the operator) need(s) to infer (generate) the possibilities under r(a). The inclusion of "operate" may be viewed as an attempt to separate processes from the person responsible for them..

The "From" arrow was a natural and obvious addition to the format and the "check" arrow was put in to allow a feedback loop, enabling the same Action Model to be re-used until A is achieved to whatever success criteria are deemed applicable (cf Miller, Galanter & Pribram, 1960).

Having voiced criticism of the stimulus and response terminology, it became apparent that the same criticism could be applied to the entire format, which after all was geared to the belief that somehow external cues come first and are ultimately acted upon in some appropriate way by the skilled operator. But this way of conceiving of things was at variance with the experiential view that operators actively interrogate their environments, *seeking* cues and taking action according to their own psychological representations of the task. (See Section 2 for detailed discussion).

The Action Model format was set for yet another reformulation. The question was, could it be used to record this representation in a way that both reflected the operator's model and allowed for more than just another stimulus-response data collection mechanism?

The format represented in Figure 6 (2nd reformulation) is a much more recent attempt to answer this question.

FIRST REFORMULATION	↘		C	c	a	A	↗	
SECOND REFORMULATION	FROM	TEMPORAL CONTEXT	EXTERNAL CUE	PROCEDURAL CONTEXT	OPTIONS	OPERATOR ACTION	REASON	NEXT
	Identifies previous Action Models in current sequence	Records when the operator does A	Externally observable cue(s)	Operator's general purpose	Methods available to operator to achieve A	Operator's stated Action	Reason operator gives for doing A	Identifies next Action Model(s) in current sequence

Figure 6: 1st and 2nd Reformulations of Action Model Format

The format shown in Figure 6 was designed to be used to elicit the model of the task of Fighter Controlling that the writer holds, and details of that model are presented in the next section. Before moving to that section, however, some account should be given of this second reformulation which led, in turn, to the development of a 3rd reformulation, discussed in the next section.

The FROM and NEXT columns are used to indicate immediate past, and immediate future, Action Models given the execution of the current one. In this way, action sequences are recorded as far as this is possible. There is a one-to-one correspondence between the old C, c, a, A symbols and the new headings, but the relationship is not isomorphic. Under 'a' are now listed the options and methods available to the operator to achieve 'A'. 'A' itself is now not referred to as an externally observable action, but as an action that the operator states he performs - an action that has operational significance for him but which need not be necessarily observable. The PROCEDURAL CONTEXT column (c) initially seemed a good idea but in practice presented considerable difficulty. The original idea was to provide space to record general operator-perceived aspects of the task - rather akin to Neisser's (1976) notion of schemata. It was envisaged that the operator would record his actions, each requiring its own Action Model and attendant details, but that sets of Action Models would cluster under a small number of general, operator-oriented purposes. In the elicitation of the writer's model three such PROCEDURAL CONTEXTS were used:

(1) Preparing for Fighter Manoeuvre

(2) Watching Fighter Manoeuvre

(3) Instructing Fighter to Manoeuvre.

All Action Models created in the elicitation process fell under one of these headings. Upon reflection, however, it became apparent that 'c' as defined in the 2nd formulation was an artefact of the circumstances attending the particular elicitational process carried out. The problem was that because the writer had learnt about Fighter Controlling, rather than having learnt how to Control, some kind of advance organiser system was required to ensure the capture of all available task-related knowledge. To insist on a similar organiser system when real experts are directly accessed by the elicitation process is both unnecessary and inelegant, and this is because the information revealed by such a system is, in practice, automatically captured by the TEMPORAL CONTEXT and REASON columns, as inspection of the writer's model subsequently showed.

The TEMPORAL CONTEXT column was designed to record when the operator performs the action he specifies at A. It thus serves to annotate the EXTERNAL CUE column to give operator-oriented meaning to, in the case of the Fighter Controller, the relative positions of echoes on the radar screen.

The REASON column is perhaps the most important addition to the 1st reformulation. By asking the question "Why do you do what you've said you do in the particular temporal context you have identified?", rather than restricting ourselves to asking "What do you do and how do you do it?", we allow ourselves access to the reasons the operator gives himself for his actions. This, in turn, allows us to construct a picture of the way in which the operator views the task and how he relates the subjectively-determined task components to each other. This aspect of the result of the elicitation process will be clarified in the next section, to which we now turn to examine a part of the writer's model of Fighter Controlling.

(b) Personalised Task Representation

Personalised Task Representation (PTR) is the name adopted for the system being developed by APU which first elicits and then displays the psychological model of a task held by an individual. The system is being designed to reveal the way in which the individual - expert or learner - represents the task to himself, and once such a representation has been externalised, it may be used to provide a data base allowing us access to the elicitee's understanding of the task.

Figure 7 transcribes the column headings in Figure 6 into the questions they actually represent (apart from the artefactual 'c') and which were used in the elicitation of the writer's own task representation. The elicitation process is divided into two discrete stages.

(i) Stage 1

SECOND REFORMULATION	FROM	TEMPORAL CONTEXT	EXTERNAL CUE	PROCEDURAL CONTEXT	OPTIONS	OPERATOR ACTION	REASON	NEXT
Eliciting Questions	What have you done?	When do you do this?*	What do you look at?	---	How do you do this?*	What do you do?	Why do you do this?*	What will you do next?

* The word 'this' refers to the operator action

Figure 7: Headings of Figure 6 Converted to Questions

The Stage 1 procedure entails first of all generating a task activity (what do you do?). Any activity was permitted with the proviso that it had operational significance (ie as the writer understood it: the artificiality of the writer's model must be emphasised - he is not a Fighter Controller). Let us take as an example, from the completed representation, starting from the question "What do you do?" and the reply "Check Fighter course". The next question is "How do you check the Fighter's course?". Following the answer to this, we asked "When do you check the Fighter's course?". Then "What are you looking at when you do this?" and for each TEMPORAL CONTEXT specified, "Why do you want to check your Fighter's course?". Finally, "Bearing in mind what you've said so far, what will you do next?".

Figure 8 shows examples of answers to these questions.

		ACTION MODEL: A_1				
WHERE FROM?	WHEN?	WHAT DO YOU SEE?	HOW?	WHAT DO YOU DO?	WHY?	WHAT NEXT?
--	Target Manoeuvres	Fighter echo Target echo	Monitors echo using Widger and Reads Compass rose	Checks Fighter course	Gathers Fighter course data in preparation for comparison with new T course data	A_2

Figure 8: Example of a "completed" Action Model

Since this is the first to be filled in, nothing can appear in the WHERE FROM? column, but as more Action Models are completed, this column will be annotated if and when "ACTION MODEL A" is referred to under some other Action Model's WHERE NEXT? heading. In fact each Action Model should not be thought of as complete until the elicitation process is quite finished, and this is because Action Model contents are liable to change in pursuit of the aims of cyclicity and parsimony: ideally, a completed PTR should contain no logical inconsistencies and where these are discovered by the procedure the elicitee should be forced to resolve them as far as possible.

Before we move on to consider the contents of 'ACTION MODEL B' it should be pointed out that another question should be asked at this stage. This takes the form "Given your stated reason (to compare Fighter course data with new Target course data) for your current action, (checks Fighter course), what else do you need to do before that purpose can be realised? In effect we are saying to the elicitee: hold your specified TEMPORAL CONTEXT, EXTERNAL CUE(S), REASON and NEXT column contents constant and state all other actions (if any) as separate Action Models. When 'all other actions' have been stated and recorded as separate Action Models, they are linked with the original (ACTION MODEL A_1) and identified under the NEXT column in such a way as to reflect this linkage (A_2 in Fig 8). These clusterings of Action Models are referred to as nodes.

If the response to the question "What else?" is positive, "ACTION MODEL A" is retitled "ACTION MODEL A_1", (as has already been done in Fig 8), the subscript on its own serving to denote that other Action Models are accessed before moving on to ACTION MODEL B*.

* Footnote: It should be realised that the Action Model identification system used here is a gross simplification of the actual coding system used, and this has been done in the interests of clarity.

Figure 9 illustrates Action Model B or, as it subsequently turns out, Action Model B_1. (The reader may have deduced that Action Model "A_2" covers "checking new Target course".)

ACTION MODEL B_1						
WHERE FROM	WHEN?	WHAT DO YOU SEE?	HOW?	WHAT DO YOU DO?	WHY?	WHERE NEXT?
A_1 A_2	Fighter course data, target course data, known	F echo T echo	Assesses course discrepancy	Compares F course with T course	Provides part of data base against which intercept tactics are compared for selection	B_2 B_3 B_4 C

Figure 9: Next Action Model in Current Action Sequence

Stage 1, then, creates a personalised representation of the procedural part of the task as far as this is possible.

In the case of the worked example we are considering, a considerable number of action sequences (strings of Action Models) were generated, of varying lengths and with each node in any sequence comprising one or more Action Models. One measure of the procedurality of the task is achieved by considering the average number of nodes referred to under the WHERE FROM? or WHERE NEXT? columns. Clearly the more nodes there are, the less procedural, and therefore the less prescribable in terms of discrete action requirements, the task is.

What we had ended up with then, was a single level description of the task in the language and terminology of the writer. In order to realise the aim of capturing the writer's model fully, however, and to expose the relational lines between his task components we needed a multi-purpose description with each "level"* above and below the "level"* first elicited automatically reorganising the data in terms of these different purposes.

(ii) Stage 2

The multi-purpose nature of the task representation is best understood by considering the special relationship that exists between the HOW?, WHAT DO YOU DO? and WHY? columns. Consider Figure 10 (which is extracted from Figure 8).

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* Footnote: The use of the word "level" here does not correspond with what Myszor (1978) (Section 3(a)) and Duncan (1973) (Section 3(d)) refer to as "different levels of description". The Stage 2 process will look as if different descriptive levels are being generated, but rather they correspond to different modes of description, having quite different reasons for existence than merely condensing or elaborating whatever data exist after Stage 1.

HOW DO YOU DO THIS?	WHAT DO YOU DO?	WHY?
Monitors echo using widger and reads compass rose	Checks Fighter Course	Gathers Fighter Course Data in preparation for comparison with new Target course data

Figure 10: "Operational" Level of Description

We have already established that the Fighter Course check is achieved by "monitoring the echo using widger and reading the compass rose". But a novice coming to the task of Fighter Controlling, even if understanding the words, may not know what is involved in doing this. What we do, therefore, is to analyse the original HOW? response further by repeating the question HOW? Of course, once we have obtained a response to this second order HOW? question, we need a location for it - a way of incorporating it into the PTR. In fact, this is easily achieved by conceiving of the second order response as being already embedded in the first order response. The second order response represents, therefore, a "finer grain" of analysis and to reveal it, all we need to do is 'roll' the contents of the three columns to the right. Figure 11 does just this, and shows that the action is now concerned with "monitoring the echo using the widger" etc. The means of achieving this is given under the heading HOW? and the reason for performing the action is to check the Fighter's course. But note that 'rolling out' does not just reveal the details of the way in which a course is found: the same method is also used for finding a Target's course, and a Stranger's course. In 'rolling out' therefore we do not just reveal what was previously embedded, but we also actively re-organise the data under the heading HOW? In effect we ask first "How do you achieve your means of achievement?" and secondly "for what other actions and purposes do you employ this second order method?"

HOW DO YOU DO THIS?	WHAT DO YOU DO?	WHY?
Finding a Course 1. Place widger line over echo so that echo appears to track down line. 2. Imagine second line drawn parallel with first and running through radar origin. 3. Where second line intersects compass rose, reading at that point equals course.	Monitors echo using widger and reads compass rose	Checks Fighter course Checks Target course Checks Stranger course

Figure 11: 'Rolled Out' Action Model to reveal response to second order HOW? question

The converse procedure - "rolling in" reveals the location of the second and third order WHY? responses, and these are illustrated in Figures 12a and 12b. Here more general reasons for specific actions are stored and, hence, by studying the second and third order WHY? responses, we are able to see how (in his own terminology) the elicitee is chunking the task.

HOW DO YOU DO THIS?	WHAT DO YOU DO?	WHY?
Checks Fighter course, speed, height, range, bearing of F from origin, bearing of T from F, bearing of S from F	Gathers Fighter course data in preparation for comparison with new Target course data. Gathers F speed etc data in preparation for comparison with new T speed etc data. Gathers F course etc data in preparation for comparison with next T course etc data. Gathers F course etc data in preparation for comparison with Stranger course etc data etc	Gathers Fighter data

Figure 12a: 'Rolled in' Action Model to Reveal Response to Second Order WHY? Question

HOW DO YOU DO THIS?	WHAT DO YOU DO?	WHY?
Gathers F course data in preparation for comparison with new T course data. Gathers F speed etc data in preparation for comparison with new T speed etc data etc etc, etc	Gathers F data Gathers T data Gathers S data	Gathers information about aircraft

Figure 12b: 'Rolled in' Action Model to Reveal Response to Third Order WHY? Question

The elicitation of the writer's model of the Fighter Control task revealed eight third order chunks:

(1) Gathers information about aircraft (Fig 12b)
(2) Gathers information about all other relevant factors
(3) Evaluates information with regard to a particular intercept
(4) Tactically evaluates information
(5) Pre-tactically evaluates information
(6) Implements safety-oriented command
(7) Implements intercept-oriented command
(8) Implements standby command.

These chunk headings are, in themselves, valuable sources of information, but perhaps even more important is the fact that the PTR system allows us to examine exactly what subjectively determined components of the task or sets of Action Models come under each heading.

Note that the REASONS or purposes elicited by second and third order WHY? questions are of a different sort to those elicited by a first order WHY? question. The REASON stated in Figure 10 (first order) is expressed in terms of what comes next in the current action sequence, whereas the REASON stated in Figures 12a and 12b give no such hints about sequencing. In this mode of description (perspective), we are no longer concerned with action sequences, but rather with subjectively determined task functions.

We can, of course, force the elicitee to "roll in" or "roll out" as many times as seems appropriate and it was decided that the limits to these operations were reached when the writer was describing the task at the "level" at which novices could readily understand in the former case, and at the "level" at which the writer arrived at one superordinate phrase, describing the whole task, in the latter. (Cf Duncan's "p" and "c" criterion, 1973).

This description of the PTR system has only been intended to convey an outline of its application - indeed, the next phase of research in the development of this methodology is designed to refine the elicitation processes and procedures mentioned here considerably, and to resolve the problems and inelegancies that currently exist.

In Subsection 3(d), the relationship between PTR and other methods of task analysis are discussed, but before that, it is worth devoting a sub section to PTR developments anticipated for the future.

(c) Anticipated Developments

Subsection 3(b) served to outline that part of the PTR system dealing with the elicitation of the individual's representation of a task. As has already been said, the next major step will be to refine this process. To do this we have conceived the need for a computer program that performs the elicitation for us. It is intended that such a program would constitute a highly interactive dialogue between elicitee and machine, with the computer asking questions and storing, retrieving, transforming and reflecting the responses. It would also, of course, be required to confront the elicitee with any inconsistencies encountered, forcing him to resolve these as clearly as possible.

It is also envisaged that the display of the completed elicitation should be computer based and should reflect the elicitation format.

Figure 13 presents a speculative display design which may also be viewed as a third reformulation of the Action Model unit.

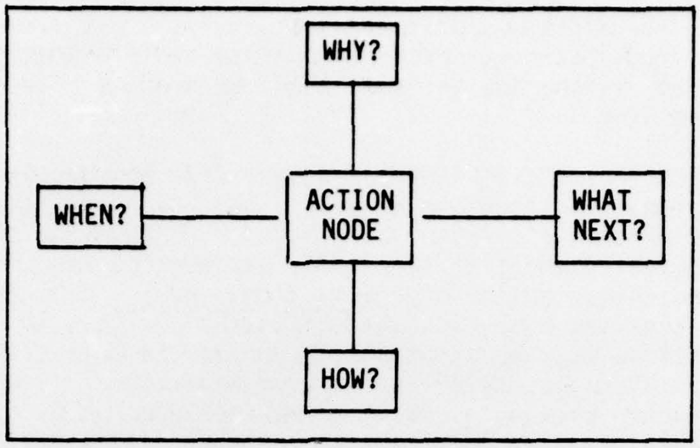

Figure 13: Third Reformulation of the Action Model Unit and a Possible Display Format

In this reformulation, the central action node (which may be one or more actions) describes particular actions, their (joint) temporal contexts, reasons and methods together with an indication of where to go next. The information may be thought of as occupying a computer's VDU, and hence viewed through a "window". This window, in effect, will be moveable so that the entire data base may be looked at or interrogated by traversing the data with the window.

The novice may use the computerised PTR as a student resource by, for example, "rolling out" as described in the last section and thereby transforming whatever information currently fills the HOW? screen area into an action node. In this case, whatever is now occupying the WHY? area will be removed and filled with whatever the current action node is displaying. The converse occurs when the novice "rolls in". The "WHEN?" and "WHAT NEXT?" screen areas also change as appropriate.

An anticipated development of a different kind will revolve around devising techniques which will enable us to compare the representations generated by different experts. We will need some way of deciding whether two experts use the same words in different ways or whether they use different words in the same way; how far they weight the various task components they identify and so on. In fact, work is progressing on a program to achieve these ends, and will be reported on in a later paper.

What can be said now, however, assuming such a development, is that not only will expert-expert comparisons be examined, but so will expert-novice comparisons and research emphasis in this area should enable us to identify and diagnose training problems and hence create a rationale for the development of appropriate training aids.

(d) PTR and Other Methods of Task Analysis

In Section 2 considerable attention was paid to what was termed the molecular approach to task analysis and its various manifestations, eg Behavioural Objectives. Task analysis was viewed as the process by which tasks are broken down into their component parts and sequences (as the Analyst sees them) to produce a task description for training.

This must be distinguished, however, from another view that has been taken by a large number of applied psychologists in their attempts to produce a taxonomy of behaviour for a large number of purposes including employee selection, performance assessment, training and the selection of training equipment. Here (for the most part) the view has been taken that task analysis is a process which classifies task descriptions, expressed in operational terms, according to a previously defined set of behavioural categories such as "problem solving", "decision making" etc. Many classification schemes have been devised, and although it is not the intention to provide a detailed review of these, it is relevant to devote some space to discussion of why there should be so many different schemes. (Reviews and cogent criticisms may be found in Smith, 1965; Farina and Fleishman, 1969; Annett and Duncan, 1967; and Duncan, 1972). Smith, (1965) gives us a clue when he points out that no taxonomist that he had discovered had ever given a satisfactory rationale for his scheme, and often no attempt was made at all. In Section 2 and with reference to Figure 1, it was argued that the application of any method of task analysis (to produce a description in terms of behaviour) represents a process by which the analyst physically realises a particular version of his own psychological model of the task: (it is a version constrained by the analyst's assumed role of "objective describer".) Here we may adjust the wording of this and consider that each development of a particular classification scheme represents the development of a means of process with the potential to aid the realisation of the analyst's psychological model of tasks-in-general, or meta-model. The extent to which the various classification schemes differ (in terms of both the different behavioural categories used and the way in which superficially similar categories are used differently) is a measure of the extent to which the scheme-developers' meta-models differ. And, of course, it is natural that they should differ since the development of any particular classification scheme, for any particular purpose, is bound to reflect the individual developer's theoretical orientations and beliefs about human skilled performance. If one analyst who is required to apply another scheme-developer's behavioural categories finds he cannot do it, it is because the psychological meta-representations the two individuals give themselves are incompatible. Smith (op cit) applies the schemes of R B Miller (1962), Demaree (1961), Willis (1961) and Folley (1964) to the task of Fire Control and concludes that they range from being "of limited utility" to "workable", with Folley's method achieving the best review. It is interesting that these particular words are used: "limited utility" suggesting that the scheme is inherently unsuited to the task and "workable" suggesting that the scheme is suited not just to the task, but to Smith, and it is not surprising that we find Smith more sympathetic with Folley on a variety of points than with the other scheme - authors he discusses.

The kind of explanation offered here for the proliferation of task classification schemes offers a new dimension to the interpretation of the sort of results obtained, for example, by Angell, Shearer and Berliner (1964). These investigators had judges pigeonhole some 40 tasks into the categories of various classification systems, one system being R B Miller's scheme. Although reliability coefficients are not reported, the authors state there was not very good agreement among judges. Farina (op cit) uses these results as evidence for his criticism of schemes using imprecise terms. Implicit in this explanation is the remedy - standardise definitions, But the present writer is attempting to explain Angell et al's results at a much more fundamental level. Low reliability exists not just because the behavioural categories are used differently by different people, and mean different things to them, but because, in turn, the meanings that people give to the categories derive from whatever it is that people acquire in order to act in, and interact with, the world in an intelligent and coherent way (variously referred to as becoming a 'person' (Rogers, 1951, Vygotsky, 1962, 1966, MacMurray, 1961) and acquiring a 'self', (Mead, 1934, Shotter,1975) - and even Miller, Galanter and Pribram's "Image",(1960)). In short, the meanings and individual usages derive from the 'ways of knowing' that characterise people - their <u>cosmologies</u>. It follows from this that it is not enough to define <u>precisely</u> the categories and then hope that the analysts using them subsequently use them in the same way. This "solution" would be as effective as respraying a decrepit motor car in the hope of getting it going again. The result looks good and presents an encouraging view, but the effect is entirely cosmetic until the contents of the bonnet are investigated and understood. It is a case of putting the finishing touches to a major job which has not actually been started.

The work of Keith Duncan flows from his criticisms of the "behavioural classification" approach and this analytic-method author has produced a scheme which assumes the hierarchal organisation of tasks. At first sight, Duncan's (1973) scheme may look fairly similar to the PTR system and because, in fact, it is quite different, it is worth spelling out the nature of the differences.

In the first place, the units of description used are quite different. Duncan's units are 'boxes' which simply record the <u>action</u> observed or expected of the operator. Earlier, in Section 3(a), we saw that the Action Models used in PTR allow for much more elaborate data collection: in particular, temporal contexts and, vitally, <u>reasons</u> for action are recorded.

Secondly, Duncan's scheme assumes that behaviour is hierarchically organised. Hence, each level of description is designed to include all operations found at those levels below it. Whether or not this assumption is justifiable, the PTR system does not make it. (It should be recalled, however, that in Section 2(a) it was argued that expert performance is <u>not</u> the speeded up execution of more primitive (elemental) operations). Under the PTR system, tasks are not represented <u>at</u> different <u>levels</u> of description, but rather <u>in</u> different <u>modes of</u> description (functional, operational and methodological), the transition between modes being achieved by the "rolling in" and "rolling out" procedures.

Thirdly, because Duncan's task representations are organised hierarchically, they may bear little resemblance to the dynamic way in which the operator represents his task to himself, and this, as has been previously argued (Section 2(a)) is essential if we are to explain task performance. Duncan distinguishes between operations and plans. Operations are action statements indicating what is required (the contents of the 'boxes' referred to earlier). If an operation cannot be treated as a primitive (ie it is redescribed), then a plan must be stated. A plan is any selection and sequencing of subordinate operations which completes the superordinate operation. Of course, when the plan corresponds to a fixed sequence of operations, it is easily represented in the hierarchy. Difficulty is encountered, however, when variant sequences of sub-operations may be selected on different occasions; and where rules (predefined contingencies) cannot be stated, the hierarchy can offer no inkling as to what sequence should, in fact, be used. PTR also records fixed sequences and predefined contingencies, but does not break down when the selection of operational sequences becomes ambiguous for, by switching to PTR's functional mode (rolling in) we take up a position where we can explain the sequence actually chosen by the operator whose representation we are studying. This is not the same as "reading off" the plan from the representation, but understanding why a particular plan was used in a particular context at least provides us with more information than a task hierarchy can. This capacity of PTR is, of course, a result of concentrating on experiential, as well as molecular, representations.

This brings us to the fourth and final major point of difference: Duncan gives excellent worked examples of his system of task analysis as applied to process control type tasks. These tasks are certainly complex, but they have an inherent logic - they lend themselves to prescription in terms of well defined sequences of operation executed in the event of well-defined cues. But what of tasks demanding a high degree of 'invent' type skills, such as tactical decision-making? It is difficult to see how Duncan's scheme would cope with these, where most, or a significant proportion, of operational sequences are of an unprescribable nature. The PTR system, on the other hand, was evolved with this latter kind of task in mind, though how well it copes is still a matter of empirical investigation.

If nothing else, these comparisons may have helped to clarify the properties of the PTR system in terms of what it is not; a full definition will evolve with experience of the system as and when it is applied to other sorts of task - particularly the complex non-procedural tasks for which it was designed.

4. SUMMARY

The analysis of task performance into lists or sequences of behaviour was described in the Introduction as taking a "molecular" approach to the treatment of tasks for training purposes, and Section 2(a) went on to show that this approach was sub-optimal. Training programs based on it gave little or no insight into reasons and remedies in the event of learning failure, and this is because the approach does not allow us to see how a learner is representing the task to himself, and therefore the nature of his learning difficulty.

This molecular approach presents special problems, however, when we try to apply it to tasks whose non-procedural content is high, eg driving and tactical decision-making. This is because the approach depends for its representational adequacy on the relatively unambiguous and sequential nature of the tasks to which it is applied - on the high prescribability of tasks.

An ideal solution would seem to involve a method of task representation that reflects the way in which the task performer represents the task to himself, but which also incorporates details of all the procedural and sequential aspects of the tasks that are inherent in it. If this aim could be realised, then not only would we have improved upon the traditional molecular approach to essentially procedural tasks, but we would also have a facility enabling us to understand the performance of those individuals engaged in complex, non-procedural tasks. In effect this aim widens our attention to include the way in which the task performer experiences his task as well as the behaviour or actions he produces.

A first attempt to realise this aim was presented in Section 3(b) when a system, developed by APU, and identified as Personalised Task Representation, was described. One worked example (the writer's model of Fighter Controlling) has been completed and was reported in part. The system has by no means been fully developed and will continue to evolve especially in relation to a series of computer programs to be designed to elicit and display task performer's representations. Anticipated developments were discussed in Section 3(c).

The behavioural classification approach to task analysis - which begins with molecular task descriptions - has been largely criticised elsewhere and references are given (Section 3(d)). One cogent critic, Duncan (1972, 1973) has produced an alternative form of task analysis, and although it may seem to be similar to PTR, Duncan's scheme is quite different. In particular, it fails to reflect the way in which the task is experienced and seems unsuited to tasks with a high non-procedural content.

Future experience with the PTR system, and its application to other tasks will enable present difficulties to be resolved and refinements to be made, and these will be fully reported in due course.

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RG/jms

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