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Title: Capturing Cognitive Task Activities for Decision Making and Analysis

Topic: Decision Making and Cognitive Analysis

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Abstract

This paper addresses some of the difficulties in capturing cognitive task related activities. It is argued that Cognitive Task Analysis (CTA) should be used to assist in capturing cognitive task activities used for decision-making. The strong need for CTA regardless of form is presented; and its association to training and systems design is shown. The nature of cognition is discussed as is the knowledgeable use and handling of task related information and the importance of Knowledge Elicitation methods to aid the discovery and understanding of cognitive tasks is stressed. The many influences on the performance of cognitive tasks are discussed, as are the forms of information most pertinent to the understanding of cognitive tasks. The adverse effects of human heuristics on the performance of cognitive tasks and decision-making are discussed.

Using a high level scenario it is shown that the identification or categorisation of a contact or target can be associated with generic stages of a mission and that this association is a cognitive task. Furthermore, a CTA method is introduced to illustrate the benefits of using such methods to analyse and depict the relationships to work goals of cognitive tasks, task related conditions, and task outcomes - these all as a means of understanding cognitive task activities and their purpose.

1. What are Cognitive Task Activities?

There are many forms of cognitive task activity and associated influences. This paper will address some of the difficulties in capturing cognitive task related activities; initially by discussing forms of cognitive task analysis as a means of capturing task activities.

Cognitive Task Analyses

Cognitive Task Analysis (CTA) encompasses a body of method used to elicit the cognitive tasks that should be performed with relation to the performance of a specific body of work. CTA methods in part can be described as a development from traditional Task Analysis (TA) methods such as Hierarchical Task Analysis (HTA). Most formal CTA methods stress the analysis of the interrelationships between work goals, the means of achieving these goals, and an understanding of the products or outcomes of task performance affecting goal achievement. For the arguments for one such method see Woods and Hollnagel, 1987.

As stated above, CTA addresses the relationships between goals. It also allows analysis of how a work process functions, on the use of work contingencies or alternative methods of performing work, and on the examination of task supporting conditions in a task. Furthermore, it promotes an understanding of the consequences and uncertainty caused by a deterioration or removal of task conditions. Through its structure it can define the source and form of task cues (for example, a slow response from another team to a request for information) and the probable consequences.

CTA methods have grown out of the need to explicitly identify and acknowledge the basic requirements inherent in performing complex tasks. Such basic requirements encompass the knowledge, mental processes, and decisions that are needed to allow task performance. These requirements increase in importance as system tasks become increasingly automated and human tasks become increasingly complex and knowledge use related. CTA represents a process for discovering cognitive practices, as applicable to a particular system or field of endeavour, in order to discover areas when a complex system might be improved. Note that in this paper a system is considered as encompassing both human and machine.

CTA and TA

There are very many ways of approaching CTA. Note however that in the UK there is a strong body of opinion that CTA is merely an extension of traditional forms of TA.

> *" .. it is recommended that an analyst should only undertake detailed cognitive analysis after undertaking a general task analysis to understand the context in which cognitive processing is required, and then deciding where such effort is justified."* Ainsworth, 2004

For convenience all TA techniques can be divided into three forms, namely:

1) Knowledge Elicitation (KE) techniques used to discover, elicit, and understand the forms of specific work tasks and their properties; (Hoffman, Shadbolt, Burton, and Klein, 1995).
2) Formal techniques for the analysis, depiction, validation, and improved understanding and use of task knowledge; [Kirwan and Ainsworth, 1992; Schraagen, Chipman and Shalin, 2000]
3) Constructs of mental models, often computer based, to assist the understanding of human task concepts. [Rumelhart and Norman, 1990; Pew and Mavor, 1998]

The intention of this paper is to concentrate on the first two forms.

Academic and Practitioner Approaches

Regrettably, a dichotomy can be seen to exist between practitioners and academics. One view is that the Human Factors (HF) practitioner exists in the mire of work and has little to contribute to research. The alternate viewpoint is that the HF academic lives in an Ivory Tower, with little awareness of the realities of work. The truth is that both viewpoints are over-generalizations. The researcher gives direction to the practitioner and can help prevent the practitioner from entering nugatory work practices. Conversely, the practitioner should help the researcher by highlighting current problems in the understanding of work and suggesting ways to resolve these problems in practice. However, an acknowledged gap exists between the products of the researcher and the application of these products to the sphere of actual problems that occur in everyday working practise [Moore, 1995].

One manifestation of that gap is an insistence by some academics to persist in the use of traditional TA methods related to the analysis of observable and physical tasks. This persistence on the presumption that task related cognitive activity is solely associated to the observable.

However, cognitive tasks predominate in many areas of work, but are not observable, and are sustained by a knowledgeable, goal directed use, of received information and external cues. Observable task activities associated with cognitive work can be infrequent and may poorly indicate the underlying cognitive tasks on which they depend. Furthermore, observable activities associated with cognitive tasks may only be performed in order to obtain feedback to help confirm the status of cognitive tasks and activities and to help in the maintenance of information inputs needed for the support of cognitive tasks. Taking this latter position, it can be seen that CTA performance cannot be solely based on observable tasks and activities

Paper Aims

This paper will discuss – assisted by an example case - some of the difficulties in capturing cognitive task related activities. Also addressed will be the difference between the elicitation of the use and handling of knowledge within cognitive tasks, and that related to task analysis of observable tasks in the performance of military tactics. Good tactical performance being inexorably linked to quality decision-making, system command and control.

2. The Understanding of Work

Cognitive task activity mediates all work. Understanding the nature of any work requires an understanding of its purpose and the goals supporting that purpose. This section will consider some of the major influences on work performance.

The general purpose of work is to satisfy specific needs of the organisation owning the work, moderated by the context under which that organisation exists [Cassell and Symon 1994]. Specific organisational needs are satisfied through utilising the best available and accepted resources, through the fulfilment of legitimate tasking placed on those parts of the organisation charged with the work performance, and from results on an agreed employment of the human skills and work systems to meet specific work goals. The influences on work practice are many but can be considered to include work goals, time, functional requirements, performance requirements, constraints, influencing conditions, environmental effects, levels of effort, plans, tasks, customs, and the means of performing the work. From the above it can be argued that:

"Quality is conformance to requirement" [Crosby, 1979].

However, if system requirements are purely related to engineered system properties they will ignore requirements for cognition as related to such as system related command, control, decisions, management, supervision, operation, or maintenance.

> *"What is left to the human by system design are the truly complex cognitive and judgmental tasks. But the system development process, instead of putting the primary emphasis on the characterisation and aiding of these key tasks, often concentrates instead on the design of the material parts of the system."*
> [MacLeod & McClumpha, 1995].

Cognition and Consciousness

Cognition in the human implies consciousness. Consciousness is the basic ingredient of awareness and is the property that links the human with their environment and community. The quality of conscious behavior depends on quality of cognition. Cognition has many definitions but can be described as an ability to use and handle knowledge to adapt to different and changing environments. In contrast, mental or psychological processes cover a larger remit of mind functions, physiological processes, emotion, and long and short term memory. Cognition encompasses the processes, analysis, attitudes, and knowledge/experience basis that support judgment and choice. Quality manifestation of all four is represented by high expertise in work performance.

Currently, the fusion and application of the above four categories requires the application of human expertise in the workplace. The machine can accurately assess situations and conditions within its immediate remit, and can perform quality and timely work. However, the machine has no awareness of itself, the purpose of its inbuilt processes, or of its performance goals. The ultimate management, control, and direction of the machine reside with trained human operators, supervisors, or managers.

However, to understand cognitive tasks requires an understanding of the system, its environment, and the expertise of the worker.

System, Work, Cognition, Context, and Expertise

The more complex a system the greater the problems in efficiently integrating the work of the human component into that system. With a complex system, the human may have difficulties in maintaining a concept of system performance and fitting that concept to the human role within the system.

The extent of these difficulties is lessened through training and the development of expertise. Such difficulties may not only exacerbate problems that the human finds in system related work but may also encourage the human to enter incorrect or inappropriate inputs into the system. Therefore, the human performance associated with a complex system must be assisted in an attempt to ensure that awareness is sustained, that the human is aided in the obviation of human system related errors,[1] is also helped to skillfully maintain a necessary defined role within the system, and is neither overworked nor bored by inactivity.

> *"It needs to be recognised that some essential human machine system functions can be purely cognitive".* [MacLeod and Taylor, 2000].

The human catalogue of skills transcends the physical [Welford, 1978], especially when the human has to cope with complexity and uncertainty. Cognition is hidden and may be either abstract or have some manifestations in observable human activity. Thus, the processes of human judgement and choice are also hidden. For example, the human assessment and judgement of the quality of equipment related information might be a continual background task with no directly associated manifest actions on the part of the equipment observer. However, if the observer's judgement leads to choice and that choice requires action such as might be related to system command and control, an observable human activity will result. Therefore, physicalistic system functions may or may not have equivalence to relevant and important cognitive tasks of the human component of the system. This is a source of uncertainty in the design and usage of systems as:

> *"Is it possible that our advanced command and control systems will require cognitive human performance that defies our ability to measure and predict? .. What none of the existing models are much good at is analysis of cognitive behaviour."* [Miles, 1993]

Thus, it is sensible that better consideration is given to the important role of human cognition within human machine systems during the specification and later analysis of the functions and tasks associated with advanced military systems.

All work performance occurs in some form of work environment and context. Thus any analysis of work should be based on an understanding of the relevant aspects to work performance of the environment and its context. However, the understanding of

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[1] Human system related errors could be operator, maintainer or designer based or be based on a combination of all the 3. For consideration on error forms see (Rasmussen 1986; Reason, 1990).

existing work is not that simple in that understanding needs to have knowledge of the system and context within which the work is being conducted, the skills and expertise being applied, the effort required to perform the work, the time constraints on completion, the required quality of the product, and the goals of that work. The understanding of new forms of work associated with complex and novel systems is several orders of magnitude more difficult than the understanding required on existing systems.

However, in all of the above circumstances the understanding of the influences of system operating environments is a valuable assistance to the understanding of the nature of work, the system properties required to address that work, and the system architecture required to allow a system performance that is capable of meeting system work goals. To achieve the needed congruence of system properties to required system performance within the constraints of the working environment necessitates an understanding of the information and cues that must be attended to through cognition. This understanding is reliant on the use of appropriate knowledge.

The Association of Information and Knowledge

Understanding is associated with awareness and is founded on the skilful use of knowledge by the individual or team. To understand the nature of knowledge you need to be aware of the differences and associations between data, information, knowledge, and possibly wisdom. The following is an explanation of these differences and associations from Ackoff, 1989 and illustrated in Figure One:

- **Data**: symbols
- **Information**: data that are processed to be useful; provides answers to "who", "what", "where", and "when" questions
- **Knowledge**: application of data and information; answers "how" questions
- **Understanding**: appreciation of "why"
- **Wisdom**: evaluated understanding
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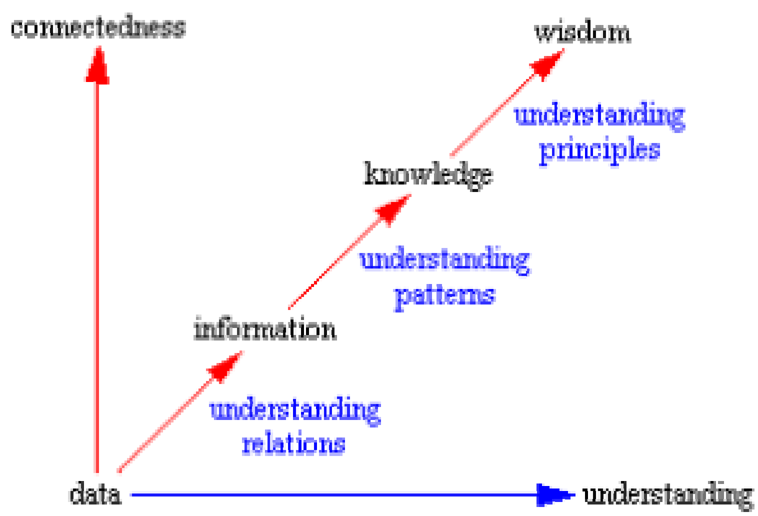

[Ackoff, 1989]

Figure One: Relationships between Data, Information, Knowledge, and Wisdom

Skills develop in association with the knowledgeable use of information. The performance of these skills is mediated by the attitudes possessed by an individual, team, or organisation. The next section briefly considers the interrelationships of Knowledge, Skills and Attitudes.

Knowledge, Skills, and Attitudes

Traditional task analysis techniques, by focusing on the observable and sequential task sequences in work, largely ignore expertise as indicated by the seamless integration of a person's or team's usage of their Knowledge, Skills, and Attitudes (KSA). In the UK Aptitude is also an important consideration but more with relation to personnel selection than to their subsequent training.

The capture of Knowledge, Skills, and Attitudes (KSA) requirements for UK military personnel, and the related KSA Training, are called for by the Joint Services Publication (JSP) 502 with relation to the conduct of Training Needs Analysis (TNA) with the Systems Approach to Training (SAT)[2].

Knowledge is the handling and use of the facts and information on a state or condition of the environment and situation to allow appreciation, understanding, and performance as appropriate to context. Knowledge is imbued in the individual and team through education, training, and experience. Skill can be defined as the application of knowledge as mediated by the type of task, related performance goals, and the level of expertise in the application of a skill or combination of skills. The basic innate capability of an individual to develop skills is termed aptitude.

However, the manifestation of an individual's or teams knowledge and skill is mediated by their attitudes to what they are doing. Attitudes are strongly related to motivation. Cognitive attitudes or values can be trained but are also strongly influenced by issues related to the relevant society, culture, organisation, involved personalities, and the appreciated status of the individual or team within their group.

Knowledge and skills are directly related to the performance of work tasks, expertise being indicated by the quality of the application of knowledge and skills to the achievement of work goals. Attitudes influence task performance but are generally manifest within the overall performance of job related work rather than to the particular performance of a task or group of tasks. Attitudes also influence the appreciation of the time available to perform work, timeliness being a condition placed on all work.

The Importance of Time to Work Performance

All work performance is mediated by time. Time spans for any form of work, and its associated work stages, are always set as a goal of the work. Sometimes the work time dictate is explicit, representing a component of specific work goals. Sometimes the time span of work is more implicit being related to the skilled performance of the work and traditional expectations on the time span needed for the work completion. Sometimes the time span is dictated by external events affecting the performance of work.

[2] The Systems Approach to Training – an Introduction, Army Code 70670 (Pam 1) (Rev 93).

Regardless or the form of work consideration on time, two forms of time exist that are applicable to the skilled performance of work, namely clocked time and appreciated time. [Bartlett, 1958; Volta, 1985,] Clocked time is set by the adopted earth clock measurement of years, months, days, hours, minutes and seconds. In particular, all machines work by clocked time and human life and work are largely dictated by this form of time. Appreciated time is predominately a human based consideration of the time needed to complete work, varies with work expertise, but can be partly imbued into machine-based knowledge by the human designer.

In system engineering terms machine appreciation of time or task would probably be defined as cognitive functions.

Cognitive Functions

Mediating between operator system tasks and activities are the operator's system related Cognitive Functions. Thus:

Intended Task >> Cognitive Function >> Activity >> System Feedback

However, human cognitive work related activities reside within mental processes and are different from the cognitive functions as might be matched to engineered systems. The human cognitive functions have properties of awareness and assessment; the machine solely has properties of assessment.

From a consideration of the influences on cognitive activity, the next section will use a case based approach to indicate the important of cognitive tasks and activities to the performance of modern military work.

3. Basic Foundations of Mission Performance

A case in the illustrative sense will be argued and presented to exemplify the elicitation of knowledge and tactical function [MacLeod, 2000] and use of knowledge with relation to task conditions, task goals, and the skilled appreciation of time. This case will be based on the authors' experience and related to relevant research.

The case will illustrate how to elicit and capture what use and handling of knowledge should be performed, for the conduct of a particular military tactic, and how the discovery of cognitive tasks and activities can add to an accumulated body of knowledge that is directly related to the understanding of the performance of observable activities and tactical decisions. A KE approach will be mooted that is directed by context, environment, the form of information available and relevant training.

It will be further argued that the form of the captured knowledge on cognitive tasks can be directly used in a form of CTA (considering goals and available means, as argued by Hollnagel, 1993) applicable to the analysis of both individual and team work, and thus to many areas of operational concern. However, cognitive tasks do not exist in isolation but are part of a complex interaction between human and machine that directs a system towards the achievement of its work goals. Figure Two illustrates some of the involved complexity and associated information flows.

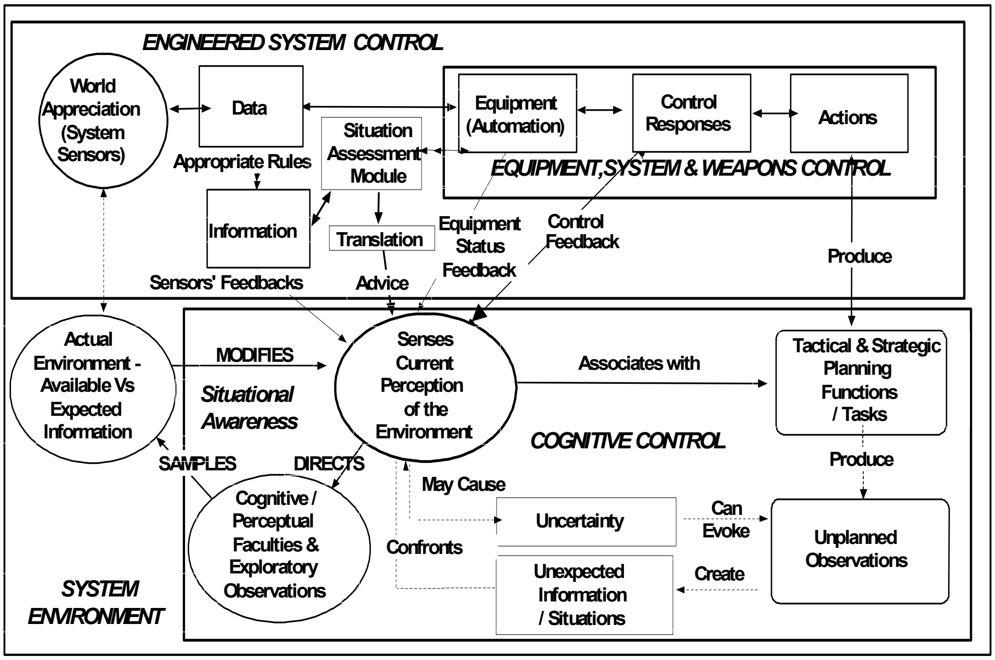

Figure Two: A Complex Model of Control for a Human Machine System
(Part acknowledgement to Neisser, 1976 and Hollnagel, 1995)

Figure Two also indicates some of the information flows that may inhabit and support a system. However, there are distinct forms of information flowing around any system and these forms should not be confused. For example, some of the information forms most pertinent to the control of dynamic system processes are:

- *Ephemeral Information*: Information with a short term value e.g. platform speed, direction;
- *Collateral Information:* Supporting information to the performance of a mission often in the form of map and planning information, information on enemy capabilities and intentions, information on environmental forecasts;
- *System Information:* Information on the state of system processes e.g. Built In Test (BIT).
- *Environmental Information*: Information on the actual mission environment obtained by system sensors or through operator senses e.g. missile warning, weather observation;
- *Tactical Information*; Information pertaining to the performance of tactics and associated results;
- *Expertise:* Information selection, retrieval, and analysis related to cognition (the use and handling of knowledge).

The use of the wrong form of information for specific tasks can cause confusion and have critical consequences to the maintenance of SA and the associated performance of a mission. For example the confusion of Ephemeral and Collateral information can be dangerous. The map is not the territory!

As previously stated, TA has tended to focus on physical manifestations of work and infer from them the supporting cognitive activities. Similarly, most work observers also tend to focus on visible work activities. It is argued that in future the work analyst must endeavour to take a different approach to the study of work. That approach involves gleaning knowledge of work goals, work constraints, the influences of the environment, the work situation, information flows and their periodicity, interactions within the engineered system, and the expertise and strategies of the worker. This mooted approach may not sound new. However, the emphasis of the approach is on the consideration of information and cues as the fuel for cognitive tasks and their associated functions. Thus CTA must primarily be concerned with the unobservable, complemented as required by details obtained from observable tasks where this is possible.

The following section will argue that cognitive tasks and activities can perform a generic function with the associating mission stages and the identification of objects of interest.

4. Mission Stages and the Identification of Objects

Generic stages of a mission are closely linked with the categorization of types of confidence on the identity of objects within the mission area of interest. All missions are argued to have the following stages, not all necessarily existing together depending on the context and the military Rules of Engagement in force.

- *Search.* Looking for an object of interest / target. The type of object /target will be given in the pre mission brief;
- *In Contact.* Possible in contact with an object of interest. This stage involves the gathering of some form of evidence that the contact one of interest to the mission;
- *Localisation.* Localisation of an object of interest. The localisation of an object or target may be fraught with difficulties depending on the environment, the sensor suite available, and the degree co-operation or hostility of the object in question.
- *Tracking*. The achievement and maintenance of an 'accurate' position, course, and speed of object. The degree of tracking accuracy will depend on the intentions with relation to the object.
- *Attack or Curtailment*. The activity required to obtain the evidence and accuracy obtained allowing attack performance or the curtailment / containment of the object's activities to assist own purpose.

Associated with the above is a need to determine that a discovered object is of interest, this through a process of determining the object's identity or categorisation. Associated with the processes involved in categorisation will be degrees of confidence (for example assessment of identity might be labelled as possible, probable or certain). To give one form of object / target categorisation, listed below are the standard definitions used in recognition training for the United Kingdom Royal Navy, Army, and Royal Air Force are produced by the Joint Services Recognition Training Committee.

- *Detection.* An awareness of a phenomenon of potential military significance;
- *Classification*. The assessment of the detected object into a broad class e.g. tank, destroyer, fixed wing aircraft, submarine, missile;
- *Recognition.* The determination whether the detected object is friendly or hostile;

- *Identification.* The designation of a classified object by name e.g. T72 Tank, Akula Class Submarine, Spruance Class Destroyer, and Tornado Ground Attack Aircraft.

The connectivity between the stages of a mission as associated with the definition of a contact identity is indicated by Figure Three. The use of those Skills required to progress through the stages of a mission is related to external cues and the progressive accumulation of information and knowledge on the object and target [3]. In turn, the ability to accumulate the required knowledge is strongly related to the available levels of cognitive skill and expertise. Here we have referred to the knowledgeable use of skills as a means of sustaining tasks for the satisfaction of the goals of task performance.

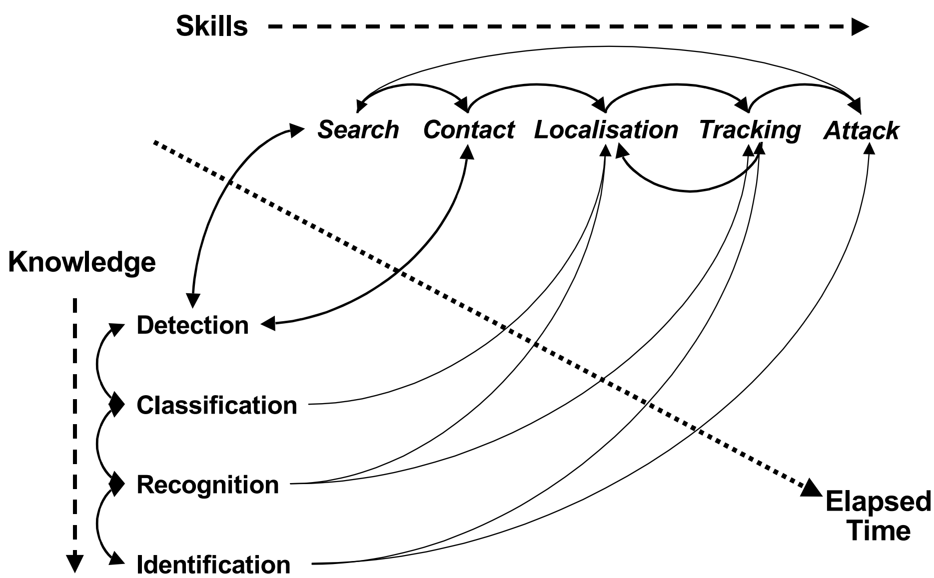

Figure Three. Postulated Association between Stages of a Mission and the Definition of a Contact

5. Discussion on an Illustrative Case

The case will be based on a hypothetical storyline where tactical use is made of the Doppler Principle to illustrate a means of attending to an object through the progression of the stages depicted in Figure Three (basis of the Doppler Principle is that the detected sound from an object is at a higher frequency if the object is approaching than if the object is departing. A practical example is given by the change of sound to an observer as a train passes through a station without stopping).

Throughout the discussion examples will be given on the use of information for mission conduct, this as a means determining the cognitive tasks that should be undertaken for this type of mission.

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[3] Note that with certain changes of name the postulated model could also be of used to examine different levels of abstraction of a scenario. As an example consider changing the initial word 'Search' to 'Investigate' and this followed in order by 'Discover', 'Form & Source', 'Trend', 'Resolution' and, in parallel, equivalent changes to the knowledge related 'Recognition Terms'.

The Example High Level Storyline

The basic storyline is that of an aircraft searching for a submarine within a designated area of the ocean, obtaining a contact on a deployed sensor buoy, developing knowledge on that contact from the buoy sourced information, and in parallel localizing the contact and determining its velocity prior to tracking the contact.

Before initiating the dropping of sensor buoys (commonly termed sonobuoys) the aircraft tactician will have knowledge on the expected characteristics of the contacts of interest, information on the chances of one or more of these contacts being in the mission area, and a knowledge of the tactics that should be used to search for these contacts (i.e. using Collateral and Tactical forms of information). In addition, the expertise of the tactician will encompass knowledge of aircraft performance and its sensors (both designed and in real time [i.e. using Ephemeris, System, and Expertise forms of Information), of the current air and oceanographic environments, and of their influences on the expected performance of the sonobuoys he selects and deploys into the water.

Once the deployment of the required number of sonobuoys has been completed, the tactician will then position the aircraft in some form of holding pattern and await an indication of a contact of interest on one or more sonobuoys.

The discussion that follows is for illustration only and is not intended to depict any particular mission or the gambit of resources that a tactician might use in the outlined circumstances. Reference to Figure Three is advised.

A contact of interest is gained on a Sonobuoy. That gain relates to the *Detection* of a contact that may be significant and the phase of the mission then changes from *Search* to *In Contact*. If the *In Contact* is assessed as being of no significance to the mission (i.e. the frequency *Classified* as emanating from an ocean passenger liner), the mission reverts to the *Search* phase. However, if the *In Contact* information cannot be dismissed as irrelevant, further actions are taken to obtain more evidence to assist the build up of knowledge on the object. From these actions certain predictions are made on the forms of improved information to be expected from the contact. Depending on the fulfillment of these expectations, the tactician then employs the aircraft and its sensors in order to achieve *Localization* and *Classification* of the object / target prior to proceeding to its *Recognition,* the start of the *Tracking* phase and, progressively, a higher probability *Identification* of the Target. Figure Four illustrates the stages presented by the storyline.

From the start of the storyline to this point the tactician has used several forms of information and from these initiated certain actions and completed a number of tasks to fulfill short-term goals. These short-term goals are related to the briefed mission goal(s) that may be to search for, localize, and track underwater contacts of significance. In wartime these goals might be related to the conduct of an attack on the contact. Note that the many additional forms of information that might be available to the tactician have not been considered by the illustration given in this paper.

Observable actions and tasks in themselves will not give an indication of the particular performance of cognitive tasks. Note also that the mission activities in the storyline have been primarily dictated by outside events and by the extent that these outside events are meaningful and can be associated with the achievement of mission goals. This state continues throughout the progression of the mission.

The route to the discovery of the existence of particular forms of cognitive task and activities relies on the investigator/analyst obtaining a good knowledge of the subject area and the work involved in that area. They then progress to the elicitation of information on the tasks using various KE methods. The following section suggests some questions that might be asked as part of a KE activity.

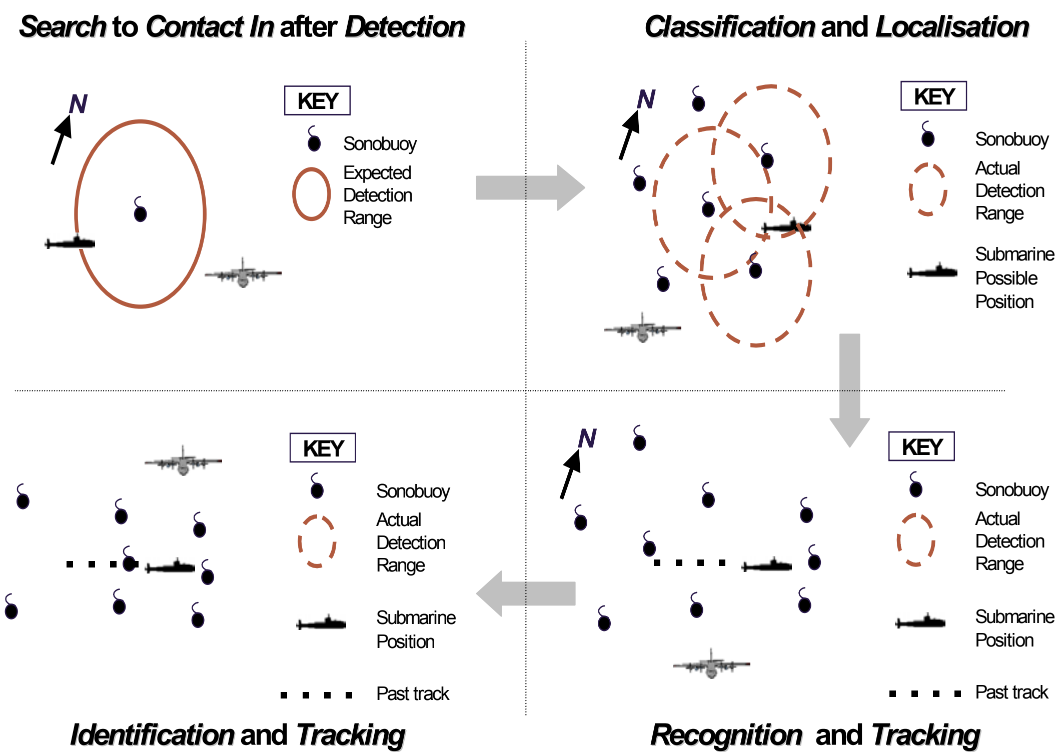

Figure Four. Progression through Mission Stages and Categorisation of the Target

Illustration of Forms of Generic KE Questions

Through the participation of the tactician in KE activities the following list of generic questions illustrate what can be investigated to provide relevance to the actions or lack of actions on the part of the tactician.

- What information was obtained?
- Was it as expected?
- What did that information mean (i.e. knowledge on the target or confirming/changing the stage of the mission)?
- What were the uncertainties with the information?
- How was the information analysed?
- How fast does received information have to be compared or combined?
- How often was it was analysed?
- Are there any time constraints on the analysis;
- Can the information be refreshed?

- Is the information retained and if so where?
- What are the possible errors that can be made in the analysis of the information?
- Are there known types of error that can be made and how do you recover from them?
- How were information trends established?
- Are there any prescribed rules or tactics associated with your use of the information?
- How are uncertainties resolved?
- Who can you contact for advice if required?
- From your consideration of the information and your knowledge on the contact/target – what prompts tactical actions?
- What was the form of association of the results of the analysis with the feedback on the conduct of the contact / target resulting from the performance of tactics?
- What was expected from the performance of a tactic?

Analysis Errors Evoked by Human Heuristics

Following from the question on error in the previous section of this paper, the influence of immutable human heuristics on human error will be briefly discussed. There are many inbuilt human heuristics that can influence the accuracy of human work [Tversky and Kahneman, 1974; Sage, 1981]. Four of the most influential to the work postulated by the storyline will be briefly presented. They are termed:

- Availability;
- Representativeness;
- Confirmation;
- Anchoring and Adjustment.

Availability. This heuristic represents the tendency to classify a situation or object to a category that is readily remembered or that has been recent. Considering the given storyline, the error possible through this heuristic would be considering that the contact information afforded immediate recognition to the contact prior to, and possibly negating, the proper confirmatory analysis of contact related information.

Representativeness. This heuristic involves the stereotyping or typecasting of a situation. Again considering the storyline, the possible misassumption that the contact is proceeding in a certain direction, without obtaining confirmatory evidence, based on the knowledge that the last three recent contacts of significance have all been going in that direction.

Confirmation. This heuristic influences a person to search for information to confirm a belief rather than seeking for information that might challenge that belief. Thus in the process of recognition of a contact this heuristic might compound any errors made under the influence of the Availability Heuristic by ignoring the absence of specific information vital to the confirmation of contact recognition. The imbued bias here could be fruitless examination of other information not related to the specific task in an attempt to make that information support the assumed identity of the contact.

Anchoring and Adjustment. This heuristic evokes the tendency to believe that the original approach to a situation is the correct one regardless of any evidence to the contrary. It is manifest by the actioning of small adjustments to repetitions of the chosen approach regardless of the amount of contrary evidence. The influence of this heuristic is often seen in tactical performance where an initial error made in the use of information is compounded by the lack of recovery from that error in subsequent tactical performance. As an example of this heuristic, in the case of the use of Doppler information an early presumption that a detected frequency is high or low without knowledge of the centre or baseline frequency will lead, if not corrected, to the continual performance of an inept localization and tracking of a target.

6. Understanding Cognitive Tasks using CTA

The argument for using a method of TA based primarily on cognitive tasks and activities is not meant to negate the usefulness of other more traditional methods where their use is appropriate. However, it is important that the TA method used to analyse and represent cognitive task and activity details is capable of understandably presenting the pertinent knowledge and information gleaned by the use of KE methods.

CTA methods have grown out of the need to explicitly identify and take into account the basic requirements inherent in performing complex tasks. Such basic requirements encompass the knowledge, mental processes, and decisions that are needed to allow task performance. These requirements increase in importance as system tasks become increasingly automated and system tasks become more complex and knowledge use related. CTA is a process for discovering cognitive practice in a particular field of endeavour in order to discover areas when a complex system might be improved. This section will discuss the use of Goals Means Task Analysis (GMTA), to identify possible improvements.

Goals Means Task Analysis (GMTA)

GMTA is a form of CTA. GMTA specifically addresses the goals of task performance through a consideration of the means of achieving these goals including making explicit the conditions needed to support task performance. Moreover, teamwork can be analysed from a task perspective as the outputs of one member's tasks, or of the tasks performed by another team, can be the conditions needed to support the task performance of another individual or team. Therefore, the method can be used to support the understanding of task performance within mixed and coalition force operations. Furthermore, the method is capable of considering the quality of the products of task performance and their influence on the quality of performance of other tasks, and /or sub goal achievement, as a route to the satisfaction of the overall work goal(s).

GMTA is essentially a predictive analysis method in that it is concerned with what a system is supposed to do, although it can be applied at any stage of a system life cycle, and can be developed and modified to mirror design decisions. In a top down fashion, it first involves the determination of the mission objective, then the goals of the various mission sub-tasks and the conditions under which they should be carried out to meet the goals. Tasks can be described at various levels of detail, depending on the requirements of the analyst. It is partly derived from the well known method of task analysis, HTA. The results of GMTA can be relatively easily transformed into HTA or Goals, Operations, Methods and Systems Approach (GOMS) analysis forms. Furthermore, this form of analysis can be used both within the Systems Approach to

Training and as a tool to assist systems analysis. For a detailed description of GMTA, see Hollnagel, 1993.

Table One gives some comparisons between the utility of GMTA and HTA.

Table One – Comparison of Some of the Properties of GMTA and HTA

GMTA	HTA
Focus on work **goals and the means** to achieve them	Focus on **actions / activities**; goals are implied
Resulting structure highlights **logical conditions** supporting system functioning (i.e. means of achievement)	Resulting structure highlights **order of actions.** Best use with sequential and procedurally based tasks
Applicable to both **existing and future** systems – Focus on 'Joint Cognitive System'	Applicable to **existing systems** and their description
Describes required tasks in general as a basis for functional congruence	Describes human functions / tasks, **usually presupposes function allocation**
The **order and organisation of functions** an **integral part** of description	The **order and organisation of activities** provided as **supplementary** information
Can be used to **synthesise / generate task descriptions**	Most appropriate for the **analysis of already organised activities**
Originated from the school of **Cognitive Systems Engineering**. Acknowledges trace to HTA, functional analysis, system design processes.	Originated as a method to assist the **definition of the training process**
Suitable for the **iterative examination of external effects on dynamic systems** (i.e. also supports analysis of task performance associated with a strong requirement for innovation)	Bests for task with a **significant planning / procedural component** (i.e. little requirement for innovation)

GMTA is an economical method of collecting and organising task related information and can be used to focus on crucial aspects of the task such as aircraft safety or conditions for successful task completion. The tabular format of the analysis can be used to record aspects of decision making and as a framework for the production of task analytic simulations for the examination of mental workload, design efficiency, operator decision etc. For Human Computer Interaction (HCI) design, the details of the GMTA task analysis can be mapped onto the requirements for operator task support.

Hollnagel, 1993, describes the basic components of GMTA as follows:

> *Goal.* A Goal describes a condition or state that is necessary for the completion of a task or task step.
>
> *Task.* A Task is an organised *collection* of actions carried out by an operator in order to achieve a goal. These actions are referred to as *task steps*. A task enables achievement of goals.

Pre-Condition. Pre-conditions define the conditions that must be satisfied for a task or task step to be carried out. Each task or task step may have one or more pre-conditions. Existing preconditions can also apply to more than one task simultaneously and may require the formulation of new sub goals and tasks.

Execution Condition. Execution conditions describe conditions that must be satisfied *during* the performance of a task. Execution conditions are not stated if they are implied by their task descriptions. Execution conditions usually refer to temporal constraints and relations to other task steps.

Post Condition. Post condition describes the product of a task step. In GMTA there are two types of post conditions: principal outcomes and side effects. Principal outcomes are what is expected from task performance. Side effects are unanticipated outcomes of task performance that may assist or detract from that required from the task performance. In the worst case side effects may require a reformulation of short term goals or the readdress of a task.

Plan: All work must be planned with relation to goals, resources, effort, timings, and the information required.

The components of GMTA and their interrelationships are illustrated in Figure Five.

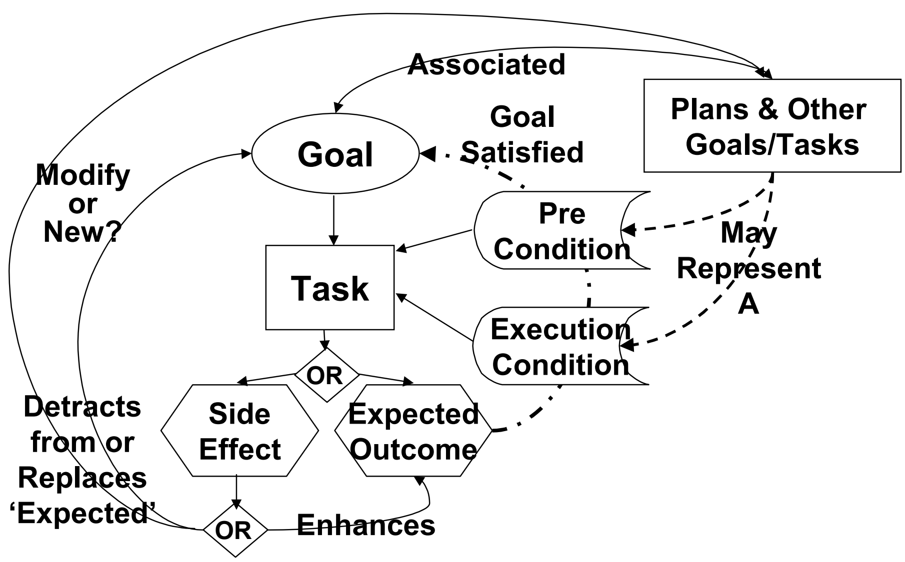

Figure Five. A depiction of a GMTA Structure

Note that as the performance of work is a dynamic process, it should be understood that the use of static depictions of work must obviously have drawbacks in the fidelity of their representation of work, this regardless of the efficacy of methods used. One way of addressing this issue and its implications to the accuracy of task analysis is to develop static TA methods that can be directly applied to the build of dynamic task analytic simulations or other equivalent dynamic simulations.

Consideration on GMTA Utility against Storyline Cognitive Tasks

Considering the given storyline, and the details of Figures Three and Five, the overall goal of the mission is to track an underwater object deemed to be significant (or attack a target depending on the Rules of Engagement in force). The next level of sub goals is in relation to the satisfactory completion of the generic stages of the mission. Sub sub goals will be related to obtaining accurate Doppler information on the target through timely Sonobuoy placement

Pre conditions and execution conditions will be primarily related to the maintenance of accurate Doppler information as a support to the analysis of the object's performance. In addition these conditions will additionally support associated judgments and choices made post that analysis as applicable to the performance of tactics.

Also related to the above will be the timely positioning of the aircraft for the dropping of Sonobuoys as associated with decisions made on optimizing Sonobuoy deployment to maintain best contact with the target depending on the stage of the mission.

Side effects will be either to the benefit of the tactical work, in that more information than expected is obtained on the target, or be detrimental in that target contact on the Sonobuoys are providing poor Doppler information necessitating a rethink on task performance or on the adjustment of current sub or sub sub goals to maintain progress towards the satisfaction of the overall goal (i.e. to maintain tracking or perform an attack on the target as required).

Considering the representation of the given storyline, the above knowledge and information capture could be verified through the use GMTA to depict cognitive task and activity information and knowledge as gleaned by the application of KE methods with the assistance of tactician Subject Matter Experts (SMEs).

7. Conclusion

This paper has presented an argument for the application of CTA to assist in the capturing cognitive task activities used for decision-making and analysis. The specific roles of CTA and traditional forms of TA were highlighted.

The nature of cognition was discussed, as was the basis of cognition within the knowledgeable use and handling of task related information. Some of the difficulties in capturing cognitive task related activities were discussed. The importance of adequate KE to aid the discovery and understanding of cognitive tasks was stressed. The many influences on the performance of cognitive tasks were discussed, as were the forms of information that needs to be understood within cognitive tasks, their uses and potential dangers. The adverse effects of human heuristics on the performance of cognitive tasks were briefly introduced.

Using a high level case it was argued that the identification or categorisation of a contact or a target can be associated with generic stages of a mission and that this association was a cognitive task. Furthermore, a CTA method, GMTA, was introduced to illustrate the benefits of using that form of CTA method to analyse and depict the relationships to work goals of cognitive tasks, task related conditions, and task outcomes - these all as a means of understanding cognitive task activities and their purpose.

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