A Pragmatic Cognitive System Engineering Approach to Model Dynamic Human Decision-Making Activities in Intelligent and Automated Systems

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ABSTRACT

The Defence R&D Canada – Valcartier has undertaken R&D work to provide Canadian warships with a revolutionary decision support capability explicitly designed to make the automation transparent and provide warfighters with effective and trusted decision support. This effort uses cognitive system engineering (CSE) as the essential design framework. CSE approaches are well suited to deal with decision support issues but are in practice very expensive to conduct, time consuming and more important, generally inefficient from a design process perspective. With the latter limitations in mind, a pragmatic CSE approach, known as the Applied Cognitive Work Analysis (ACWA), was developed to bridge, in a structure, efficient and converging way, the gap between cognitive analysis and design. As a result, the cost to conduct CSE analyses using the ACWA approach is reduced and the analysis-design efficiency is significantly improved, therefore making easier the identification of decision-aiding concepts suited to provide effective decision support.

This paper presents a brief overview of CSE analyses methods and their benefits. The paper will describe in more detail the actual CSE approach, known as the Applied Cognitive Work Analysis (ACWA)[1], used in decision support R&D investigations. Finally, the paper presents some lessons learned when using ACWA for a specific project.

1.0 INTRODUCTION

Command and control (C2) can be associated to a dynamic human decision making process. In military environments known to be non-collaborative, the C2 process is stressed mainly by real-time and uncertainty issues. Indeed, the technological evolution constantly increases the lethality and the reach of the weapons, the scope of the battlefield and the tempo of the engagement. Successful exploitation of tactical resources

[1] ACWA is a method developed by Aegis Research Corporation's Cognitive System Engineering Center located in Pittsburgh.

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(e.g.: sensors, weapons) during the conduct of C2 activities is *decision dependent* and therefore is linked with the modelling and design of the C2 algorithms to support the decisions and/or cognitive demands in a timely manner using uncertain information. Decision support is thus required to cope with human limitations in such environments. This emphasizes the need for real-time, computer-based Decision Support Systems (DSS) in order to bridge the gap between the cognitive demands inherent to the accomplishment of the C2 process and the human limitations.

Typically, a technological perspective of C2 has led system designers to prescribe decision support solutions to overcome many of the domain problems but without knowing explicitly the decisions and cognitive demands that needed to be supported. This and the lack of knowledge in CSE have in the past jeopardised the design of helpful computerized aids aimed at complementing and supporting human cognitive tasks. Moreover, this lack of knowledge has most of the time created new problems in trusting the supporting tools and human in the loop concerns. Therefore, formal DSS design approaches, such as cognitive engineering analyses, are required to understand the problem before prescribing any automation solutions. The Defence R&D Canada - Valcartier has undertaken R&D work to provide Canadian warships with a revolutionary DSS in support of their C2 (e.g.: tracking, identification, situation and threat assessment and tactical resources management) in the context of above water warfare. This effort uses one specific CSE approach as the essential design framework.

This paper presents a brief overview of CSE analyses methods and their benefits. This overview is done in light of a feasibility study done at DRDC Valcartier to investigate the applicability of Cognitive Work Analysis (CWA) to model decision support in command and control. The paper will describe in more detail the actual CSE approach, known as the Applied Cognitive Work Analysis (ACWA), used in support ongoing decision support R&D investigations. This ACWA modeling method is a pragmatic adaptation of the CWA method in order to cope the limitations related to applying CWA. Finally, the paper presents some lessons learned when using ACWA for a specific case study.

2.0 COGNITIVE SYSTEM ENGINEERING ANALYSES

CSE analyses are defined as approaches that aim to develop knowledge about the interaction between human information processing capacities and limitations, and technological information processing systems. The usefulness of a system is closely related to its compatibility with the human information processing. Therefore, CSE analyses focus on the cognitive demands imposed by the world to specify how technology should be exploited to reveal the problems intuitively to the decision maker's brain.

2.1 Cognitive Work Analysis

Among the procedures developed to identify cognitive processes, there are the Cognitive Task Analysis (CTA) and the Cognitive Work Analysis (CWA). There are only subtle and ambiguous differences between these two procedures. Moreover, their labels are frequently used in an interchangeable manner in the literature. However, the CWA can be seen as a broader analysis than the CTA. According to Vicente [Ref. 1], traditional task analysis methods typically result in a single temporal sequence of overt behaviour. This description represents the normative way to perform the task. However, traditional methods cannot account for factors like changes in initial conditions, unpredictable disturbances and the use of multiple strategies. The use of the traditional task analysis brings an artifact that will only support one way to perform the task.

Vicente proposes an ecological approach in which the three factors above are considered. The ecological approach, which can be seen as a CWA, takes its origin in psychological theories that were first advanced by

Brunswick [Ref. 2] and Gibson [Refs.3-4]. These researchers raised the importance to study the interaction between the human organism and its environment. The perception of an object in the environment is a direct process, in which information is simply detected rather than being constructed [Ref. 4]. The human and the environment are coupled and cannot be studied in isolation. A central concept of this approach is the notion of affordance. The affordance is an aspect of an object that makes it obvious how the object is to be used. Examples are a panel on a door to indicate, “push”, and a vertical handle to indicate “pull” [Ref. 5]. When the affordance of an object is obvious, it is easy to know how to interact with it. The environment in which a task is performed has a direct influence in the overt behaviour. Hence, the ecological approach begins by studying the constraints in the environment that are relevant to the operator. These constraints influence the observed behaviour.

The ecological approach [Ref 6] is comparable to and compatible with Rasmussen’s abstraction hierarchy framework [Refs 7-8]. Rasmussen’s framework is used for describing the functional landscape in which behaviour takes place in a goal-relevant manner. This abstraction hierarchy is represented by means-ends relations and is structured in several levels of abstraction that represent functional relationships between the work domain elements and their purposes. With the ecological approach, Rasmussen has developed a comprehensive methodology for CWA that overcomes the limitations of traditional CTA by taking into account the variability of performance in real-life, complex work domains.

Conducting CWA requires conducting sequentially five different type of analysis. As indicated in Table 1, findings from each analysis activity provide a specific type of design information that are captured using a specific modelling tool.

Table 1: CWA Phases

Phases of CWA	Kinds of Information	Modeling Tools
Work Domain Analysis	Purpose and structure of work domain	Abstraction-decomposition space
Control Task Analysis	Goals to be satisfied, decisions/cognitive processing req'd	Decision ladder templates
Strategies Analysis	Ways that control tasks can be executed	Information Flow Maps
Social Organisation and Cooperation Analysis	Who carries out work and how it is shared	Annotations on all the above
Competencies Analysis	Kinds of mental processing supported	Skills, Rules and Knowledge models

CWA seems to be the best choice to answer questions related to understanding the C2 task. Recently, a feasibility study to investigate the applicability of CWA for C2 was performed to confirm this [Ref. 9]. The study revealed that the methodology is well suited to deal with decision support design issues but is in practice, if done in a full scale (all sequential CWA phases) for a small problem, time consuming and very expensive to conduct, and the quality of the findings is dependent on subject matter experts’ availability and on the skills of the people conducting it. In addition, the study did not show the gap between cognitive analyses and design making the DSS engineering process inefficient.

3.0 APPLIED COGNITIVE WORK ANALYSIS

The ACWA methodology [Ref. 10] emphasizes a stepwise process to reduce the gap to a sequence of small, logical engineering steps…each readily achievable. At each intermediate point the resulting decision-centered artifacts create the spans of a design bridge that link the demands of the domain as revealed by the cognitive analysis to the elements of the decision aid.

The ACWA approach is a structured, principled methodology to systematically transform the problem from an analysis of the demands of a domain to identifying visualizations and decision-aiding concepts that will provide effective support. The steps in this process include:

- Using a *Functional Abstraction Network* (FAN) model to capture the essential domain concepts and relationships that define the problem-space confronting the domain practitioners;
- Overlaying *Cognitive Work Requirements* (CWR) on the functional model as a way of identifying the cognitive demands / tasks / decisions that arise in the domain and require support;
- Identifying the *Information / Relationship Requirements* (IRR) for successful execution of these cognitive work requirements;
- Specifying the *Representation Design Requirements* (RDR) to define the shaping and processing for how the information / relationships should be represented to practitioner(s);
- Developing *Presentation Design Concepts* (PDC) to explore techniques to implement these representation requirements into the syntax and dynamics of presentation forms in order to produce the information transfer to the practitioner(s).

In the ACWA analysis and design approach, design artifacts are created to capture the results of each of these intermediate stages in the design process. These design artifacts form a continuous design thread that provides a principled, traceable link from cognitive analysis to design. However, the design progress occurs in the thought and work in accomplishing each step of the process; by the process of generating these artifacts. The artifacts serve as a post hoc mechanism to record the results of the design thinking and as stepping stones for the subsequent step of the process. Each intermediate artifact also provides an opportunity to evaluate the completeness and quality of the analysis/design effort, enabling modifications to be made early in the process. The linkage between artifacts also ensures an integrative process; changes in one-artifact cascades along the design thread necessitating changes to all. Figure 1 provides a visual depiction of the sequence of methodological steps and their associated output artifacts, as well as an indication that the process is typically repeated in several expanding spirals, each resulting in an improved Decision Support System. The following subsections describe briefly the ACWA steps but the reader should read Reference 10 for a more complete and detailed description of the methodology.

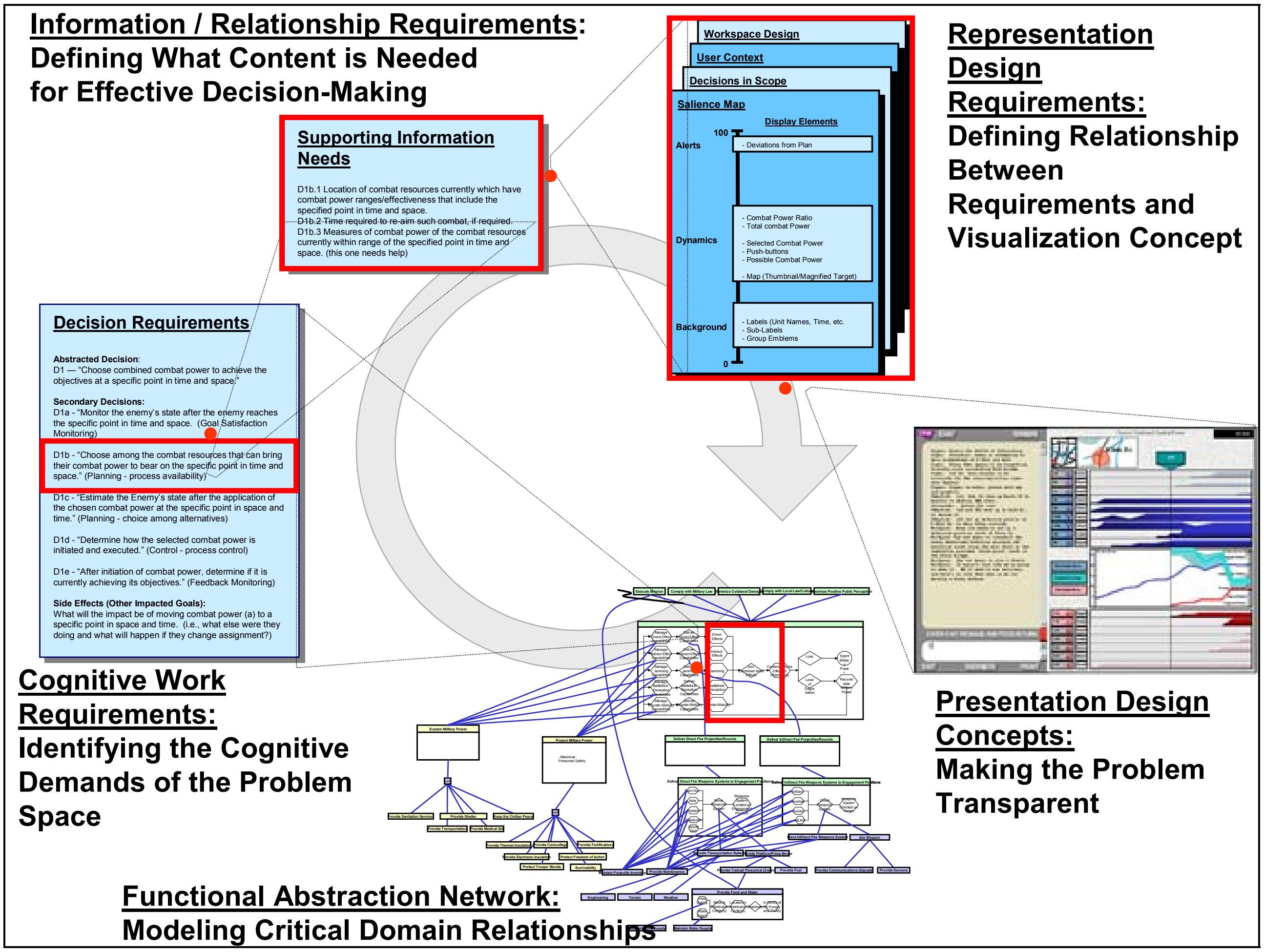

Figure 1: A sequence of analysis and design steps create a continuous design thread that starts with a representation of domain concepts and relationships through development of decision support requirements to creation of visualization and aiding concepts and rapid prototypes with which to explore the design concepts.

3.1 Modeling the Work Domain

The work domain analysis is performed based on a variety of Knowledge Elicitation (KE) activities. This involved interactions with expert practitioners in the domain and included face-to-face interviews with the experts, watching the experts work in the domain, and observations in simulated exercises with scenarios crafted to address specific aspects of the work domain. In practice, this is an iterative, progressively deepening process. The key is to focus on progressively evolving and enriching the model so as to ultimately discover an understanding of the goal-driven characteristics of the domain that will lead to an understanding of the decisions practitioners are faced with in the domain.

The phrase 'bootstrapping process' has been used to describe this process and emphasize the fact that the process builds on itself [Ref. 11]. Each step taken expands the base of knowledge providing opportunity to take the next step. Making progress on one line of inquiry (understanding one aspect of the field of practice) creates the room to make progress on another. One starts from an initial base of knowledge regarding the domain and how practitioners function within it (often very limited). One then uses a number of KE techniques to expand on and enrich the base understanding and evolve an ACWA model from which ideas for improved support can be generated. For example, one might start by reading available documents that provide background on the field of practice (e.g., training manuals, procedures), the knowledge gained will raise new questions or hypotheses to pursue that can then be addressed in interviews with domain experts, it will also provide the background for interpreting what the experts say. In turn, the results of interviews or exercises may point to complicating factors in the domain that need to be modeled in more detail in the Functional Abstraction Network (FAN). This provides the necessary background to create scenarios to be used to observe practitioner performance under simulated conditions or to look for confirming example cases or interpret observations in naturalistic field studies.

The FAN provides a framework for making explicit the goals to be achieved in the domain and the alternative means available for achieving those goals. High-level goals, such as impacting a critical function, are decomposed into supporting lower-level subgoals. This provides the basis for identifying – through subsequent steps in the analysis and design process – the cognitive activities that arise in the domain and the information needed to support those decisions. The FAN enables the designer to determine where decision-making is likely to be difficult due to the fundamental characteristics of the domain. For example, the FAN helps convey places in the problem space where objectives compete with each other (e.g., where choices have to be made that require some level of sacrificing of one objective in order to achieve another, perhaps more heavily weighted, objective), or otherwise constrain each other (e.g., where the satisfaction of multiple goals need to be considered in determining the best course of action).

3.2 Modeling Cognitive Demands

With the FAN representation of the work domain as the underlying framework, it is possible to derive the cognitive demands for achieving domain goals. In our methodology, we refer to these demands as cognitive requirements. Thus, the term 'decision' is used in a broad sense. Based on the underlying premises of the modeling methodology, these decisions center around goal-directed behavior, such as monitoring for goal satisfaction and resource availability, planning and selection among alternative means to achieve goals, and controlling activities (initiating, tuning, and terminating) to achieve goals [Ref. 12] as well as collaboration activities in team settings [Ref. 13]. By organizing the specification of cognitive requirements around nodes in the goal-means structure, rather than organizing requirements around predefined task sequences (as in traditional approaches to task analysis), the representation helps insure that the resulting design concepts reflect a decision-centered perspective. The resulting decision support concepts will thus support domain practitioners in understanding the goals to be achieved and what decisions and actions need to be taken to achieve these goals.

The cognitive demands that are derived from a cognitive analysis of the work domain constitute a second key modeling artifact – *Cognitive Requirements (CR)s*. CRs are tied directly to nodes in the FAN and provide an intermediate artifact that forms the essential part of the design thread, eventually providing an end-to-end connection from goal nodes in the FAN to supporting decision support concepts.

The FAN forms the basis for the structure of the decision-making activities that will be reflected in the Decision Requirements. For example, every Goal node in the FAN has associated "Goal Monitoring" types of decisions. Likewise, Processes have associated "Process Monitoring" decisions. Similarly, there will always be "Feedback Monitoring" types of decisions related to assessing whether actions are achieving desired results as well as monitoring side effects of actions. Depending on the relationships between nodes in the FAN, there will be decisions related to "Control" (e.g., selection of alternative means to achieve a particular goal) and “Abnormality Detection / Attention Focusing”. Table 2 contains an example ‘template’ of these generic CR’s that are used to stimulate the identification of specific CRs at each of the nodes in the FAN:

Table 2: Template of Typical Decision Types

Generic Cognitive / Decision Requirements	
Monitoring / Situation Awareness:	
Goal Monitoring:	***Feedback Monitoring:***
Goal Satisfaction: Are the function-related goals satisfied under current conditions?	**Procedure adequacy**: Is the current procedure achieving the desired goals?
Margin to Dissatisfaction: Are goal limits/restrictions being approached?	**Control action feedback:** Are the operator control actions achieving their desired goals?
Process Monitoring:	***Control:***
Active processes: What processes are currently active? What is the relative contribution of each of the active processes to goal achievement? Are the processes performing correctly?	**Process control:** How is the process controlled for process deployment, tuning for optimum performance, termination?
Process element monitoring: Are the individual processes and their components working as they are supposed to?	**Manual take-over:** If intervention is required, what actions must be taken?
Automation monitoring: Are automated support systems functioning properly? What goals are the automated support systems attempting to achieve? Are these appropriate goals?	
Abnormality Detection / Attention Focusing:	
Limit Crossing: Has any goal or process component exceeded an established administrative, procedural, or design limit?	
Procedure ‘trigger’: Has any goal or process component reached a value that a procedure uses as a triggering event?	
Automatic system ‘trigger’: Has any goal or process component reached a value that an automatic system uses as an initiating value?	

The key issue here is that this template is not meant to be a rote, ‘turn the crank’ type of process. Rather, these questions are meant to be a guide to stimulate thinking about relevant decision-making in the context of a FAN model of the target work domain. Each domain is unique in the decision-making demands imposed on the human operators. As such, each work domain will require slightly different variants of these questions. Successful elucidation of decision requirements will also depend on corroboration from multiple data sources, including case studies, interviews, observations, etc. In addition, guiding insights can come from research on similar work domains as well as basic research on human cognition, decision-making, biases, and errors. For example, previous work on decision making in dynamic, high-risk worlds can guide analysis and interpretation of analogous worlds in terms of potential points of complexity, typical decision making difficulties and strategies, and critical characteristics of difficult problem-solving scenarios.

3.3 Capturing the Means for Effective Decision-Making

The next step in the process is to identify and document the information required for each decision to be made. Information requirements are defined as the set of information elements necessary for successful resolution of the associated decision requirement. This set of information constitutes the third key modeling artifact – *Information Requirements (IR)s*. The focus of this step in the methodology is on identifying the ideal and complete set of information for the associated decision-making.

Information Requirements specify much more than specific data elements; it is data in context that becomes information [Refs. 14-15]. The data-to-information relationship can be complex and require a significant amount of computations and/or transformations. For this reason ACWA is a design approach that has a much deeper impact on the entire DSS architecture than merely the look and feel of the final GUI. For example, in the case of a thermodynamic system, an IR might be 'flow coefficient with respect to appropriate limits.' This requires the estimation of the parameter 'flow coefficient' derived from model-based computations and sensor values and the comparison of that parameter against a limit referent. The degree of transformation required can vary from simple algebra to complex, intelligent algorithms. Reference 16 provides an example of Information Requirements that could only be satisfied by an advanced planning algorithm and significant data transformations.

In addition, it is important to note that identifying Information Requirements is focused on satisfying the decision requirements and is *not* limited by data availability in the current problem-solving environment. In cases where the required data is not directly available ACWA provides a rationale for obtaining that data (e.g., pulling data from a variety of previously stove-piped databases, adding additional sensors, or creating 'synthetic' values). This is a critical change from the typical role that Human Factors Engineers have had in the past (designing an interface after the instrumentation has been specified). Consequently, this type of an approach is fundamentally broader in scope than other approaches to interface design that do not consider the impact of Information Requirements on system architecture specifications [Ref. 17].

The specific context and concatenation of data to form Information Requirements depends on the specific Cognitive / Decision Requirement being satisfied. The same data elements can be cast into Information Requirements in different ways that support very different decisions.

Just as the FAN representation provided the framework for the derivation of decision requirements, the decision requirements provide the essential context for the information requirements because they indicate the factors (and thus information) that will need to be considered in making decisions.

3.4 Linking Decision Requirements to Aiding Concepts – Developing and Documenting a 'Model of Support' using the Representation Design Requirements

The FAN and its associated CWR and IRR 'overlays' constitute a solid foundation for the development of the aiding concepts to form the Decision Support System. The design of the Decision Support System occurs at two levels: at a micro level to ensure that each presentation element effortlessly communicates its information to the user; and at the macro level to ensure that the overall collection of presentation design concepts (the Decision Support System in a holistic sense) is organized in an intuitive way that does not add its own "manage the Decision Support System" cognitive burdens to those of the domain.

This step in the ACWA process develops the specification of the display concept and how it supports the cognitive tasks and is captured in Representation Design Requirements (RDR) for the eventual development of Presentation Design Concepts (PDC). The RDR defines the goals and scope of the information representation in terms of the cognitive tasks it is intended to support (and thus a defined target region of the FAN). It also provides a specification of the supporting information required to support the cognitive tasks. An RDR is another span of the bridge that helps to link the decisions within the work domain to the visualization and decision support concepts intended to support those decisions. In many cases, multiple design concepts may be generated that attempt to satisfy the RDR's requirements. Typically, other supporting artifacts are generated at this step in the process as required to specify such issues as presentation real-estate allocation, attention management (salience) across the information to be presented, etc.

The RDR also represents a critical system design configuration management tool, critical for ensuring coverage of the functional decision space across all presentations and presentation design concepts. The RDR begins the shift in focus from 'what' is to be displayed to 'how', including annotations on relative importance that maps to relative salience on the visualization, etc. A complete RDR is actually a set of requirements 'documents', each describing the requirements for the intended representation of the IRRs. It contains descriptions of how all presentation mechanisms of the domain practitioner's workspace are to be coordinated, how available audio coding mechanisms are allocated, similarly for visual, haptic, and any other sensory channels to be employed. The RDR is not only a compilation of information developed earlier, it has the added value of a more complete description of the behaviors and features needed to communicate the information effectively as well as an allocation of the Information / Relationship Resources across the entire set of displays within the workspace. When done correctly it is still in the form of a 'requirement' and not an implementation. This artifact becomes a key transition between the Cognitive System Engineer, the System Developer, and the System (Effectiveness) Tester.

The RDR also provides one important ancillary benefit, as long as the domain remains unchanged, the RDR serves as an explicit documentation of the *intent* of the presentation *independent* of the technologies available and used to implement the Decision Support System. As newer technologies become available, as their interaction with human perception become better understood, the technologies used to implement the RDR requirements can evolve.

3.5 Developing Presentations – Instantiating the Aiding Concept as Presentation Design Concepts

From the RDR's specification of how information is to be represented within the decision support system, the next step of the ACWA process is the explicit design of Presentation Design Concepts (PDCs) for the Decision Support System. (A similar process is used for the design of auditory, visual, or other senses' presentations of the RDR's specification.) This final step requires an understanding of human perception and its interaction with the various presentation techniques and attributes. As such, it requires considerable skill and ability beyond cognitive work analysis. The actual design of a revolutionary aiding concept is probably one of the largest 'design gaps' that is needed to be bridged within the ACWA process. The ACWA design practitioner must be fluent in the various presentation dimensions: color, layout, line interactions, shape, edge detection, etc. Essentially the designer must really understand what characteristics of presentation implicitly specify about the interaction with the user's perception. The conversion of the requirements in the RDR to a sensory presentation form in a PDC requires considerable skill and background in these areas. With the RDR as a guide, the sketches, proposals, brainstorming concepts can all be resolved back against the display's intent and requirements. The issues of how it is perceived can best be done with empirical testing of prototypes, and often requires considerable tuning and adjustment to achieve the representational capabilities specified in the RDR.

Of all the steps in ACWA, this final presentation development requires a significant background in presentation technologies, human perceptual characteristics, and how they interact. The other ACWA artifacts, notably the RDR, do provide a test basis to iterate the presentation design concepts. By testing each proposed display prototype against the single indicator question of "does it support the decisions it is supposed to as defined by the RDR?" it is possible to at least identify unsuccessful attempts and continue to design toward a more successful one. This last step across the gap is often difficult, but the ACWA methodology has made it a much smaller step, from a much more solid footing than would be the case if attempting to directly design a presentation without its RDR precursor.

4.0 LESSONS LEARNED FROM THE ATAC PROJECT

The first three steps of the ACWA approach, as described in the previous section, were used during the initial phase of the ATAC (Advanced Threat Assessment Capability) project for the Canadian Navy. One important requirement for that project was to use a formal modeling and design approach that allowed one to trace back the origin of a specific algorithm development. The ACWA approach in concert with a systematic documentation methodology (FAH and its artifacts) was found very useful in the ATAC project as it provided the means to meet that traceability requirement.

The documentation was iteratively revised and expanded and served as the main reference material to conduct/structure interviews or training session with subject matter experts. The documentation was to also used during brainstorming design meetings and helpful for progress review meetings.

The ACWA was found to be opportunistic and flexible when new knowledge elicitation activities arise and when the scope of the project itself expanded significantly. The important thing to note here is that the modelling and design work and documentation did not collapse when these scope expansions occurred but in fact adapted very well.

At the end of a three days meeting with naval officers, where the objective was to validate the modelling effort done using the ACWA approach during the ATAC project, the subject matter experts acknowledged the value of the work and characterized the resulting FAH and artifacts as “brilliant and robust” with respect to the captured naval C2 domain knowledge.

The next phases of the ATAC project are the derivation of system design concept specifications (including the last two steps of the ACWA approach) and the development of the capability based on the resulting system design concept specifications. Even though the ACWA approach was found useful in the initial phases of the ATAC project to understand the problem before prescribing any automation solutions, no C2 DSS has yet been developed and therefore the complete value of the ACWA method for C2 related problems is still to be demonstrated. On the other hand, this type of demonstration/evaluation is not trivial to do.

While work continues at the Defence R&D Canada – Valcartier toward the design of DSSs, an even greater challenge is the evaluation of the dynamic human decision-making performance when using a newly designed computer-based decision support capability. Such assessment must be focused on the net (human-system combination) decision-making effectiveness and allow to answer questions like:

- Does this new C2 decision aid capability support the decision-maker’s cognitive demands during his C2 activities?
- Does this new C2 aid capability provide the right set of information in support of a specific cognitive demand?
- Does this new C2 aid capability increase the net (human-system combination) decision-making effectiveness?

Current evaluation methods are immature and focus on system technical attributes or crude memory tests. This is clearly not enough.

5.0 CONCLUSION

In light of the military C2 process and its domain constraints, this paper presented a brief overview of CSE analyses methods and their benefits. This overview described CSE analyses as approaches that focuses on the cognitive demands imposed by the world to specify how technology should be exploited to reveal the problems intuitively (affordance concept) to the decision maker's brain. The paper also described CSE methods as well suited to deal with decision support issues but are in practice very expensive to conduct and more important inefficient from a design process perspective.

One specific CSE approach, known as the Applied Cognitive Work Analysis (ACWA), The paper presented in more details used in support of ongoing decision support R&D investigations. The ACWA methodology emphasizes a stepwise process to reduce the gap to a sequence of small, logical engineering steps…each readily achievable. At each intermediate point the resulting decision-centered artifacts create the spans of a design bridge that link the demands of the domain as revealed by the cognitive analysis to the elements of the decision aid. As a result, the cost to conduct CSE analyses using the ACWA approach is reduced significantly and the analysis-design efficiency is drastically improved, therefore making easier the identification of decision-aiding concepts suited to provide effective decision support.

Finally, the paper presented some lessons learned when using ACWA for a specific case study. Finally, ACWA lessons learned while used during a specific project was discussed in this paper along with issues related to the performance evaluation of dynamic human decision-making DSS.

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