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# Applied Cognitive Task Analysis (ACTA) Methodology

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The primary goal of this project was to develop streamlined methods of Cognitive Task Analysis that would fill this need. We have made important progression this direction. We have developed streamlined methods of Cognitive Task Analysis. Our evaluation study indicates that the methods are usable and aid in the development of important, accurate training materials addressing cognitive issues. In addition, we have developed a CD-based stand-alone instructional package, which will make the Applied Cognitive Task Analysis (ACTA) tools widely accessible. A survey of the software conducted with both Navy Instructional Systems Specialists (ISSs) and private sector Instructional Designers indicates that the software is successful in communicating the ACTA techniques.

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# Foreword

This technical notes describes work jointly sponsored by the Navy Personnel Research and Development Center's Cognitive Skills (COPE) project and the Small Business Innovative Research (SBIR) program. The COPE project is part of the Navy Exploratory Development Program Element 0602233N, Work Unit FW33T23.08, sponsored by the Office of Naval Research.

The stand-alone CD-ROM instructional package, which was produced by this project, is available from the sponsoring agency for military organizations and from the performing organization for civilian organizations.

We appreciate the support and cooperation from the Electronic Warfare (EW) technicians at Fleet Training Center Pacific and Fleet Information Warfare Center in San Diego, CA; the EW "A" school in Pensacola, FL; and the Fireground Commanders from Beavercreek, Centerville--Washington Township, Fairborn, Huber Heights, and Kettering, OH who served as Subject Matter Experts (SMEs) throughout the course of this project, so that the ACTA methods could be tried, tested, and refined. In addition, we would like to thank the graduate students from the California School of Professional Psychology, San Diego State University, the University of California at San Diego, the University of Dayton, and Wright State University who participated in our evaluation study. Their honest reactions to the ACTA methods and willingness to try them provided valuable insights into the usefulness of the methods. Sandra Seamans and Todd Cantrell of Multimedia Learning Inc. were of great help in developing and designing the instructional software. Beth Crandall of Klein Associates made a large contribution to the project, providing input to the design of the ACTA methods and the design of the evaluation study, as well as expertise as a Cognitive Task Analyst in the firefighting domain. We would also like to thank Rose Olszewski who managed the immense coordination effort required for the evaluation study, and helped with data analyses. We are especially grateful for the support and cooperation of the COTR, Dr. Josephine Randel, who played an active role in the project, contributing to the refinement of the methods, aiding in the design of the evaluation study, and coordinating access to **SMEs.**

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# Executive Summary

## Problem

Traditional Behavioral Task Analysis techniques used by Navy Instructional Systems Specialists (ISSs) to design and revise courses provide little guidance in eliciting cognitive information. The Navy Personnel Research and Development Center recognized a need to develop methodologies that would enable ISSs to systematically incorporate more cognitive information into Navy courses. Existing Cognitive Task Analysis techniques tend to be labor and resource intensive, require extensive training to conduct, and are usually not feasible for use in an applied setting. The need for an Applied Cognitive Task Analysis (ACTA) methodology to be used by Navy ISSs and other Instructional Designers in designing and revising courses drove this project.

## Objective

The primary objectives of this project were as follows:

- To develop a set of ACTA tools that elicit important cognitive aspects of expert performance, and that are easier to learn than earlier Cognitive Task Analysis Methods.
- To conduct an evaluation study investigating the usability, validity, and reliability of the ACTA tools.
- To develop a stand-alone instructional package to train ISSs and private sector Instructional Designers to use the ACTA tools.
- To prepare for the commercialization of the ACTA tools.

## Approach

Our approach was to work from our own experience conducting Cognitive Task Analysis and the experiences of other researchers as described in the literature to formulate candidate methodologies. We then conducted a user analysis, interviewing Navy ISSs, Navy instructors, and private sector Instructional Designers. The goal of this user analysis was to understand the methods currently used by Navy ISSs and private sector Instructional Designers, the challenges these training professionals face, and the environment in which these training professionals operate. Findings from the user analysis guided revisions and refinements of the candidate methods. Subsequently, workshops were conducted for both Navy and private sector audiences to gain feedback from potential users of the ACTA tools. The tools were continually refined based on this feedback.

Once a strong set of ACTA tools had been established, an evaluation was conducted to investigate the usability, validity, and reliability of the methods. In the final portion of the project, a stand-alone instructional package in the form of the multimedia software was developed to teach Navy ISSs and private sector Instructional Designers to use the ACTA tools.

## Conclusions

The goal of this project was to begin to move Cognitive Task Analysis out of the research community into applied communities. We have made important progress in this direction. We have developed streamlined methods of Cognitive Task Analysis. Our evaluation study indicates that the methods are usable and aid in the development of important, accurate training materials addressing cognitive issues. In addition, we have developed a CD-based stand-alone instructional package which will make the ACTA tools widely accessible. A review of the software conducted with both Navy **ISSs** and private sector Instructional Designers indicates that the software is successful in communicating the concepts behind the ACTA techniques and the procedure for conducting each technique.

## Recommendations

There are several areas in which we would recommend future research to expand on what has been accomplished with the current ACTA project. First, there is a need for team Cognitive Task Analysis methods. Although team issues are not a factor in all cognitively complex tasks, there are certainly many situations in which team issues are critical. Methods aimed at better understanding information flow among team members, roles and functions of team members, etc. are needed. Secondly, the ACTA techniques could provide valuable information for systems and interface design. Thus far our efforts have focused on applying ACTA to training design and course revision. Future research could adapt the ACTA techniques for use by system and interface designers.

A third recommendation for future research is to examine the means by which training should be administered to teach cognitive skills. What types of cognitive skills are best taught in the classroom vs. in an actual work setting? Are new training techniques required to sufficiently address the cognitive demands of today's workplace? In addition, future research should investigate whether effective knowledge elicitation and representation tools can be developed that reduce the role of the interviewer in this process. Can portions of the Cognitive Task Analysis be automated? Is it possible for a Subject Matter Expert (SME) to conduct a Cognitive Task Analysis on himherself? A final direction for future research is to identify better metrics to assess the usability, validity, and reliability of Cognitive Task Analysis tools, so that different methodologies can be compared.

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# List of Acronyms

Applied Cognitive Task Analysis (ACTA)
Electronic Warfare (EW)
Incident Commander (IC)
Instructional System Specialists (ISS)
Subject Matter Expert (SME)
Navy Personnel Research and Development Center (NPRDC)
Naval Education and Training Program Management Support Activity (NETPMSA)

# Introduction

The impact of technology on many tasks and functions has resulted in greatly increased demands on the cognitive skills of workers. Howell and Cooke (1989) have argued that with advances in technology and machine responsibility, we have increased (rather than lowered) cognitive demands on humans. More procedural or predictable tasks are now handled by smart machines, while humans have become responsible for tasks that require inference, diagnoses, judgment, and decision making.

The increase in the cognitive demand placed on workers has created a need for training that targets cognitive skills. In most cases, however, the task analyses that drive training development are conducted using methodologies that focus primarily on behaviors. Behavioral task analytic techniques, which have proven so effective for cataloging the functional and procedural aspects of tasks, are often not adequate for understanding cognitively-complex tasks. The training community needs tools that will allow access to experience-based cognitive skills. Without such tools, more and more of the critical job elements will be missed altogether—neither adequately identified nor documented and therefore not included in training programs.

The primary goal of this project was to develop streamlined methods of Cognitive Task Analysis that would fill this need. The intent was to provide tools that would allow Instructional Designers to capture cognitive as well as behavioral requirements during the task analysis phase of course design. It was important to develop techniques that could easily be incorporated into existing analysis procedures. In addition, because existing Cognitive Task Analysis techniques tend to require extensive training and considerable time and resources to implement, there was a need to develop streamlined techniques that could be learned and applied quickly and easily due to the time pressure under which most Instructional Designers work.

This Klein Associates project originated as Phase I Small Business Innovative Research contract. The initial 6-month effort resulted in a prototype streamlined Cognitive Task Analysis approach. This report documents the ensuing Phase II, 31-month effort to refine and finalize the streamlined approach to Cognitive Task Analysis; evaluate the approach to assess its usability, validity, and reliability; and develop stand-alone instruction so that the approach could be widely disseminated. In the process of accomplishing these objectives, an analysis of the potential user population was conducted to ensure that the streamlined approach to Cognitive Task Analysis would in fact fulfill a need in the user community and be presented in a usable format. In order to assess the streamlined Cognitive Task Analysis tools, a 6-hour workshop was developed so that the tools could be presented to a number of potential user populations for both informal feedback and a formal evaluation study. The four major accomplishments of this effort are as follows:

- The development of a set of Applied Cognitive Task Analysis (ACTA) tools that elicit important cognitive aspects of expert performance, and that are easier to learn than earlier Cognitive Task Analysis methods.

- The development of a stand-alone instructional package, including a CD-based multimedia instructional tool, a pamphlet outlining the content of the CD, and job aids to assist in conducting the ACTA techniques.
- The execution of an evaluation study providing data that indicate that graduate students using the ACTA techniques are consistently able to elicit experience-based, cognitive information and generate accurate, important training materials based upon the information obtained using ACTA.
- The execution of a software review, which indicates that both Navy Instructional System Specialists (ISSs) and private sector Instructional Designers found the stand-alone instructional package to be easy to use and informative.

For the purpose of introduction, we include a brief description of each of the ACTA tools, and an analysis tool termed the Cognitive Demands Table in this first section. Details of how the tools were developed and evaluated, as well as a description of workshops and multimedia interactive software designed to train Instructional Designers to use the ACTA techniques are included in the body of the report.

## Task Diagram

The Task Diagram elicits a broad overview of the task and identifies the difficult cognitive elements. Although this preliminary interview offers only a surface-level view of the cognitive elements of the task, it enables the interviewer to focus the more in-depth interviews (i.e., the Knowledge Audit and Simulation Interviews) so that time and resources can be spent unpacking or uncovering the most difficult and relevant of those cognitive elements.

The Subject Matter Expert (SME) is asked to decompose the task into steps or subtasks. The interviewer limits the SME to between three and six steps, to ensure that time is not wasted delving into minute detail during the surface-level interview. After the steps of the task have been articulated, the SME is asked to identify which of the steps require cognitive skill. The resulting diagram serves as a roadmap for future interviews, providing an overview of the major steps involved in the task and the sequence in which the steps are carried out, as well as which of the steps require the most cognitive skill.

The Task Diagram interview is intended to provide a surface-level look at the task, and does not attempt to unpack or reveal the mental model of each SME. Efforts to delineate a mental model can quickly degenerate into a search for everything in a person's head as Rouse and Morris (1986) have pointed out. In this interview, we recommend that the SME be limited to six steps and advise the interviewer not to get dragged down to a level of detail that is best captured by other interview techniques.

## Knowledge Audit

The Knowledge Audit identifies ways expertise is used in a domain and provides examples based on actual experience. The Knowledge Audit draws directly from the research literature on expert-novice differences and expert decision making. The Knowledge Audit has been developed as a means for capturing the most important aspects of expertise while streamlining the intensive data collection and analysis methods that typify studies of expertise.

The Knowledge Audit is organized around knowledge categories that have been found to characterize expertise. These include: diagnosing and predicting, situation awareness, perceptual skills, developing and knowing when to apply tricks of the trade, improvising, metacognition, recognizing anomalies, and compensating for equipment limitations. Clearly, we could have included many more items, but our intent was to aim for the smallest number of high impact components.

The Knowledge Audit employs a set of probes designed to describe types of domain knowledge or skill and elicit appropriate examples. The goal is not simply to find out whether each component is present in the task, but to find out the nature of these skills, specific events where they were required, strategies that have been used, and so forth. The list of probes is the starting point for conducting this interview. Then, the interviewer asks for specifics about the example in terms of critical cues and strategies of decision making. This is followed by a discussion of potential errors that a novice, less-experienced person might have made in this situation.

The examples elicited with the Knowledge Audit do not contain the extensive detail and sense of dynamics that more labor intensive methods such as the Critical Decision method (Klein, Calderwood, & MacGregor, 1989) incident accounts often do. However, they do provide enough detail to retain the appropriate context of the incident. It is not expected that all probes will be equally relevant in each domain. After a few interviews, interviewers can easily determine which probes have the highest payoff. Although the Knowledge Audit does not capture the depth of relationship of a Conceptual Graph Structure or other intensive methods, it does address a full range of aspects of expertise that are usually neglected by behavioral task analytic methods.

The output of the Knowledge Audit is a table containing an inventory of task-specific expertise. This table includes examples of situations in which experience has been called into play, cues and strategies used in dealing with these difficult situations, and an explanation why such situations present a challenge to less-experienced operators.

## Simulation Interview

The Simulation Interview allows the interviewer to better understand the SME's cognitive processes within the context of an incident. In operational settings, the point of the job is typically to act upon the environment in some manner. Behavioral task analyses are designed to specify the type and sequence of actions involved in performing a task, but say little about the judgment and decision-making requirements, such as troubleshooting, diagnosis, situation assessment, sensitivity to critical cues, and selection of courses of action within that environment. The research literature has shown judgment and decision-making processes to be central to proficient performance of complex tasks (Howell & Cooke, 1989; Klein, 1993). Identification and exploration of information surrounding high consequence, difficult decisions can provide a sound basis for generation of effective training and system design.

The Simulation Interview is based on presentation of a challenging scenario to the SME. We recommend the interviewer retrieve a scenario that already exists for use in this interview. Often, simulations and scenarios exist for training purposes. It may be necessary to adapt or modify the scenario to conform to practical constraints such as time limitations. Developing a new simulation specifically for use in the interview is not a trivial task and is likely to require an up-front Cognitive Task Analysis in order to gather the foundational information needed to present a challenging situation. The simulation can be in the form of a paper-and-pencil exercise, perhaps using maps or other diagrams. In some settings, it may be possible to use video or computer-supported simulations. Surprisingly, in our experience, fidelity is not an important issue. The key is that the simulation present a challenging scenario.

After exposure to the simulation, the SME is asked to identify major events, including judgments and decisions. Each event is probed for situation assessment, actions, critical cues, and potential errors surrounding that event. Using the same simulation for interviews with multiple SMEs can provide insight into situations in which more than one action would be acceptable, and alternative assessments of the same situation are plausible. This technique can be used to highlight differing SME perspectives, which is important information for developing training and system design recommendations. The technique can also be used to contrast expert and novice perspectives by conducting interviews with people of differing levels of expertise using the same simulation.

## Cognitive Demands Table

After conducting ACTA interviews with multiple SMEs, we recommend the use of a Cognitive Demands Table to sort through and analyze the data. Clearly, not every bit of information discussed in an interview will be relevant for the goals of a specific project. The Cognitive Demands Table is intended to provide a format for the practitioner to use in focusing the analysis on project goals. We offer sample headings for the table based on analyses we have conducted in the past (difficult cognitive elements, why difficult, common errors, and cues and strategies used), but recommend that practitioners focus on the types of information they will need to develop a new course or design a new system. The table also helps the practitioner see common themes in the data, as well as conflicting information given by multiple SMEs.

The report is organized as follows: The *User Analysis* section describes our early analysis of the potential user population. The *Evolution of ACTA* section details the evolution of the ACTA tools and the factors that impacted the development of the tools. The *ACTA Workshops* section includes a description of the workshop used to teach graduate students to use the ACTA techniques so that we could evaluate the methods, and a discussion of how the ACTA workshops were adapted for different audiences. In the *Evaluation Study* section, a detailed report of the evaluation study conducted to assess the usability, validity, and reliability of the ACTA methods is provided. The final portion of the project required the development of stand-alone instructional materials for the ACTA techniques. A full description of these materials and the rationale for the design of the materials is included in the *Stand-Alone Instruction* section. The final section, ***Conclusions and Future Research***, contains conclusions from this project and recommendations for future research. In addition, five appendices are included containing a review of the relevant expertise literature, sample materials from our workshops, additional data from the evaluation study, ACTA Software Pamphlet and the ACTA Job Aids, and Instructions from the Software Review.

## User Analysis

The development of the ACTA tools began in Klein Associates' Phase I effort of this study and was finalized in the Phase II effort documented in this report. In the Phase I effort, candidate Cognitive Task Analysis tools were identified based upon a survey of existing Cognitive Task Analysis techniques and our own experience conducting Cognitive Task Analysis. The Phase 11 effort began with an analysis of our intended user population. Although U.S. Navy ISSs were identified as our primary user population, the needs of private sector Instructional Designers were also investigated. A secondary goal of this project was to build streamlined Cognitive Task Analysis techniques that could be commercialized beyond the Navy.

The reason for conducting the user analysis was to ensure that the ACTA techniques would be useful to our target audience. We interviewed four Navy ISSs, three Navy instructors, and three private sector Instructional Designers. In these interviews, we explored each interviewee's current job responsibilities, the types of courses developed and revised, and the tools currently used to capture the task for which a course was being developed. In addition, we presented our ideas for the ACTA techniques. At the time of the user analysis, the ACTA techniques included the Knowledge Audit and Simulation Interview, which are described in the introduction to this paper, and a Team Schematic Interview aimed at unpacking team interactions and information flow.[1] Our intent was to better understand the environment in which our potential user population worked, find out where existing tools were lacking, and gauge the acceptability of the candidate Cognitive Task Analysis techniques identified in the Phase I effort.

This analysis revealed that both ISSs and private sector Instructional Designers work under time pressure in developing courses. Many indicated that they would like access to tools that would allow them to capture the cognitive elements of a task, but that these tools would have to be highly efficient if they were to be used at all. Details about the environments in which our interviewees work and reactions to our candidate Cognitive Task Analysis techniques are included below.

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**[1]The Team Schematic Interview was abandoned as one of the ACTA techniques because feedback from potential users indicated that it would not be generally applicable. However, the need expressed for such a tool in domains where team issues are key indicates that additional work in the area of team Cognitive Task Analysis tools would be fruitful.**

Navy **ISSs** work in conjunction with instructors to develop and revise courses. The instructors are Subject Matter Experts (SMEs) for the course they will teach. For example, an experienced Electronic Warfare (EW) technician will serve as an instructor for the EW school. ISSs thus rely on the instructors for content knowledge and expertise in performing the task to be taught. **ISSs** work with instructors to capture this knowledge and formalize it into course materials.

Few new courses are developed in the Navy. Completely new jobs rarely arise in the Navy. It is much more common for an existing job to evolve, adding or replacing skills as new equipment and new tactics become available. Thus, **ISSs** and instructors spend the bulk of their time revising existing courses to adapt to the changing state of the world. In situations in which a completely new piece of equipment is developed, the contractor who built the equipment generally delivers a first-generation course on how to operate the equipment. Future generations of the course are revised and adapted by the Navy **ISSs** and instructors.

The most recent publications describing the tools currently used by the Navy to revise courses and develop course materials are the NAVEDTRA 130/131 series. These documents clearly lay out how to apply the Instructional System Design process (Gagne & Briggs, 1974) within the context of the Navy. These materials do include information about how to gather content information for a course. Suggested methods include examining existing materials relating to the task, on-site observations/interviews, and a jury of experts. Although interviewing experts is suggested, little guidance is offered as to how to conduct the interviews or what types of information to explore. In addition, a somewhat discouraging note is included "...interview methods require considerable effort. Because of the massive amounts of data and information that must be tabulated and summarized, you may not have the resources to implement these methods, (pp. **3-10).**" The result is that ISSs tend to rely on existing materials describing the job and the ability of the instructor (who is also an SME) to unpack hisher own expertise.

There is **a** wide range in terms of cognitive content for the courses the Navy offers. It is not necessarily true that every Navy course would warrant a Cognitive Task Analysis. The ISSs we interviewed indicated that they could easily judge which of the courses they oversee require difficult cognitive skills and are critical enough to make Cognitive Task Analysis a worthwhile endeavor.

ISSs see a need to get more cognitive information into the courses that are offered by the Navy. The current process encourages instructors to "personalize" a course, which consists of going through and adding illustrations and exercises that will highlight difficult cognitive elements of the job based on that instructor's experience on the job. Although this personalization process tends to work well, it is idiosyncratic in that the sea stories and exercises offered vary from one instructor to the next, depending on hisher personal experience. As a result, some instructors may make good use of sea stories to provide context and illustrate difficult judgments, decisions, perceptual skills, metacognition, etc. In other cases, sea stories may simply serve as entertainment with little instructional value. ISSs recognize that course tools that would allow cognitive skills to be addressed consistently, regardless of the instructor, are needed.

In general, the Navy instructors were more critical of the concept of capturing expertise and including it in courses than the ISSs. The instructors believe that cognitive skills and expertise are learned on the ship via on-the-job training. As products of the current Navy training system, they believe that it works well. There is a fear that to try to document expertise and cognitive skill, so that it can be included in a course, will result in a list of procedures that do not adequately capture the concepts and skills. The result would be additional coursework with little relevance to the actual job.

Private sector instructors voiced a frustration that cognitive skills are not captured well and are hard to teach. The need for tools such as ACTA was recognized by most of our interviewees. Some, however, echoed the concerns of the Navy instructors that these types of skills can only be acquired via experience.

Financial concerns also play a role in the Navy's training environment. There is currently a push to reduce time spent in training. Training budgets are currently very tight. The need to offer quality courses in as little time as possible is critical. It would be important that the ACTA tools not result in increased training time.

In addition to pressure to use course time efficiently, private sector Instructional Designers have considerable pressure to reduce the time needed to develop a course. The fact that time pressure is an important constraint for both Navy and private sector Instructional Designers proved to be a guiding principle for us as we continued to refine the ACTA techniques. The need to balance the thoroughness and depth of the methods we developed with the time constraints of our intended users was a constant tension throughout the method development.

Both ISSs and instructors resonated to the idea of an interview technique termed the Simulation Interview that would be structured around a simulation. Scenarios and simulations are currently used in many Navy courses. The use of our cognitive probes to help SMEs unpack their own processes as they approach a task was met with enthusiasm. In addition, instructors saw these probes as a potential teaching tool.

In our interviews with Navy personnel, the idea of an interview technique aimed at unpacking team interactions and information flow got mixed reviews, depending on the type of course for which the interviewee was responsible. For jobs that require information flow among several team members, a team-focused technique was viewed as a potentially useful tool for capturing and representing information. However, many of the people we interviewed were not working on courses for which information flow was a critical element.

The description of the Knowledge Audit, a technique that probes specific aspects of expertise, evoked a positive reaction from the Navy ISSs and instructors. In these interviews, discussions of specific probes helped us to cull the long list of probes we started with for the Knowledge Audit to a set that could be easily learned and implemented in a 1-hour interview.

Reactions to the ACTA techniques were generally favorable in the private sector. Many of the Instructional Designers we spoke with had developed their own methods with many of the elements we suggested via experience. They confirmed that to document and disseminate these types of techniques would be of value to many Instructional Designers as they search for methods that will help to capture cognitive skills.

# Evolution of ACTA

This section describes the rationale behind each of the ACTA tools and the Cognitive Demands Table. In addition, the evolution of each technique is described.

The methods presented here are complementary; each is designed to get at different aspects of cognitive skill. The first technique, the Task Diagram interview, provides the interviewer with a broad overview of the task and highlights the difficult cognitive portions of the task to be probed further with in-depth interviews. The second technique, the Knowledge Audit, surveys the aspects of expertise required for a specific task or subtask. As each aspect of expertise is uncovered, it is probed for concrete examples in the context of the job, cues and strategies used, and why it presents a challenge to inexperienced people. The third technique, the Simulation Interview, allows the interviewer to probe the SMEs cognitive processes within the context of a specific scenario. The use of a simulation or scenario provides job context that is difficult to obtain via the other interview techniques, and therefore allows additional probing around issues such as situation assessment, how situation assessment impacts a course of action, and potential errors a novice would be likely to make given the same situation. Finally, a Cognitive Demands Table is offered as a means to consolidate and synthesize the data, so that it can be directly applied to a specific project.

### Building a Road Map: The Task Diagram

The first component of ACTA is the Task Diagram (Figure 1). Its function is to embed the Cognitive Task Analysis within the task and to focus the rest of the interviews on the cognitively challenging parts of the task. The expectation is that one would undertake a Cognitive Task Analysis in the context of a specific project for which understanding the cognitive components of a task is necessary. The goals of the project would thus determine which task (or set of tasks) should be studied. Cognitive Task Analysis is most valuable for tasks that have an important cognitive component. To some extent, the Task Diagram is a mental model of how the SME views the task, but it is very simplified. We recommend limiting it to six elements in order to obtain a broad overview of the task. This interview does not provide the structure and probes needed to obtain an in-depth detailed account of the task. Initially, the Task Diagram included two stages of decomposition. Each cognitive element identified in the initial Task Diagram became the topic for its own Task Diagram. We found that this added a layer of complexity with little payoff. Participants in our workshops found that the initial Task Diagram was sufficient to provide a broad overview of the task and identify the cognitive elements to be probed in later interviews. We do allow for the likelihood that incidents will arise in which the initial Task Diagram will not provide sufficient information for the interviewer to progress with the Cognitive Task Analysis. In such cases, we would recommend a second stage of decomposition. This decision is left to the interviewer's discretion.

We considered other approaches here, specifically concept mapping and team schematics, but these proved impractical. We had used concept maps in a number of projects. Although we found the information gathered via concept mapping to be useful, the technique was difficult for some researchers to learn and especially difficult to standardize across researchers. The resulting concept maps were often idiosyncratic and difficult to communicate to people who did not participate in the interview.

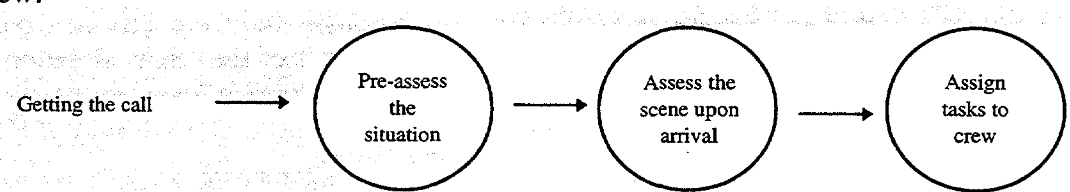



**Figure 1. Task diagram of Fire Ground Commander's job in commanding crew.**

We also considered a team schematic that would capture the major elements of the task, identify the team members, and outline the flow of information among the team members for each major task element. This technique was abandoned early in the project as our user analysis indicated that team elements and information flow were key issues for only a subset of domains for which Navy ISSs are responsible.

**Capturing Aspects of Expertise: The Knowledge Audit**

The research on the nature of expertise and expert-novice differences indicates that skilled performance involves a number of factors over and above the facts and rules a person has learned. These factors must be taken into account if training systems are intended to develop or enhance cognitive skills necessary to attain expertise.

The Knowledge Audit was developed to focus on the following factors that contribute to expertise—to elicit information about diagnosing and predicting, situation awareness, perceptual skills, developing and knowing when to apply tricks of the trade, improvising, metacognition, recognizing anomalies, and compensation for equipment limitations. The Knowledge Audit is a straightforward technique that asks the SME how each of these aspects is involved in the task being studied and poses follow-up questions regarding the cues and strategies an expert relies on and what presents difficulty for inexperienced people (Figure 2). The Knowledge Audit identifies ways expertise is used in a domain and provides examples based on actual experience.

The Knowledge Audit draws directly from the research literature on expert-novice differences and our own Critical Decision method studies of expert decision making. (See Appendix A for a review of the expertise literature, which impacted the development of the Knowledge Audit.) We have developed the Knowledge Audit as a means for capturing the most important aspects of expertise while streamlining the intensive data collection and analysis methods that typify studies of expertise. Specifically, the Knowledge Audit probes were based on an understanding of how experts make decisions. There are several aspects to expertise in decision making. The Knowledge Audit probes are based around these aspects of expertise.

- **Past and Future Probe (Diagnosing and Predicting, Mental Simulation).** When experiencing a situation, experts are able to figure out how that situation developed, and they can think into the future to see where the situation is going. Among other things, this allows the expert to head off problems before they develop (de Groot 1946/1978; Endsley, 1995; Klein & Crandall, 1995; Klein & Hoffman, 1993).

- **Big Picture Probe (Situation Awareness).** Novices may only see bits and pieces of a situation. Experts are able to quickly build an understanding of the whole situation, the "big picture" view. This allows the expert to think about **how** different elements fit together and affect each other (Endsley, 1995; Klein, 1997).

| Aspects of Expertise | Cues and Strategies | Why Difficult? |
|---|---|---|
| **Past and Future**<br>E.g., explosion in office strip: search the office areas rather than source of explosion. | Material safety data sheets (MSDS) tell you that explosion in area of dangerous chemicals and information about chemicals.<br>Start where most likely to find victims and own safety considerations. | Novice would be trained to start at source and work out.<br>May not look at **MSDS,** to find potential source of explosion, and account for where people are most likely to be. |
| **Big Picture**<br>Big picture includes source of hazard, potential location of victims, ingress/egress routes, other hazards. | Senses, communication with others, building owners, MSDS, building pre-plans. | Novice gets tunnel vision, focuses on one thing (e.g., victims). |
| **Noticing**<br>Breathing sounds of victims. | Both you and partners stop, hold your breath, and listen.<br>Listen for crying, talking to themselves, victims knocking things over. | Noise from own breathing in apparatus, fire noises.<br>Don't know what kinds of sounds to listen for. |
| **Operating without vision.** | Keep in touch with wall, feel for windows/doors, means of egress.<br>Use touch more, feeling for objects at head level, on ground, rope to solid objects outside building.<br>Garage provides more hazards; knowing hazards in building types.<br>Listen more actively. | Navigation through building, avoiding hazards, get used to working for 30-60 minutes without light. |

**Figure 2. Knowledge Audit of search and rescue procedure with Fireground Commander.**

- **Noticing Probe (Perceptual Skills).** Experts are able to detect cues and see meaningful patterns that less-experienced personnel may miss altogether (de Groot, 1946/1978; Klein & Hoffman, 1993; Shanteau, 1985).

- **Job Smarts Probe (Heuristics, Tricks of the Trade, Contextual Practices).** Experts learn how to combine procedures and work the task in the most efficient way possible. They do not cut corners, but they do not waste time and resources either (Klein & Hoffman, 1993).

- **Opportunities/Improvising Probe.** Experts are comfortable improvising—seeing what will work in this particular situation. They are also able to shift directions to take advantage of opportunities (Dreyfus & Dreyfus, 1986; Shanteau, 1985).

- **Self-monitoring Probe (Metacognition).** Experts are aware of their performance, they check how they are doing and make adjustments. Experts notice when their performance is not what it should be (due to stress or fatigue, for example), and they are able to adjust to get the job done (Cohen, Freeman, & Wolf, 1996; Glaser & Chi, 1988).

- **Anomalies Probe (Perceptual Skills, Situation Awareness).** Novices don't know what is typical so they have a hard time identifying the unusual or atypical. Experts can quickly spot unusual events and detect deviations, and they are able to notice when something that should happen does not happen (Chi. Hutchinson, & Robin, 1988; Klein, 1989; Klein, 1997; Klein & Hoffman, 1993).

- **Equipment Difficulties Probe.** Experts know that their equipment can sometimes mislead. Novices usually believe whatever the equipment tells them, they don't know to be skeptical (Cannon-Bowers, Salas, & Converse, 1992).

Changes made to the Knowledge Audit method throughout this project consisted primarily of minor refinements. It has been used throughout the course of the project by Klein Associates' interviewers who have found it to be a useful tool. It was also used by graduate students, novice interviewers, as a further testbed. There were two primary alterations to the method. The first was to reduce the number of probes so that the Knowledge Audit would accommodate the necessary time constraints. The second was to eliminate jargon and incorporate more everyday language so that the interviewer could understand the concept of the aspect of expertise being probed and also so that the SMEs could understand what they were being asked. We also learned that providing an explanation of each probe was a useful way to introduce the question and to elicit more concrete responses based on the SME's own experiences. These explanations were added to the probes and provided for a better interview.

**Understanding Decisions and Judgments: The Simulation Interview**

The Simulation Interview draws on the experiences of the SME in an exercise where the SME is asked to use his/her expertise to provide a description of what actions s/he would take at each decision point in a specific scenario, followed by an explanation of his/her situation assessment at that point in time, what information s/he is relying on to make that assessment, and errors an inexperienced person might make in that situation (Figure 3). The Simulation Interview draws on the Critical Decision method, (Klein, Calderwood, & MacGregor, 1989), verbal protocol analysis, and other think-aloud methods. Simulation-and incident-based interviews have been used successfully in many domains (Bell & Hardiman, 1989; Clarke, 1987; Cordingley, 1989; Diederich, Ruhmann, & May, 1987; Flanagan, 1954; Grover, 1983; Hall, Gott, & Pokorny, 1995; Klein, Calderwood, & MacGregor, 1989; Thordsen, Militello, & Klein, 1992). The Simulation Interview was developed based on our experiences using simulations and scenarios to provide the background needed to understand the rich, contextual elements of a task. Critical Decision method probes have been incorporated into this technique.

| Events | Actions | Assessment | Critical Cues | Potential Errors |
|---|---|---|---|---|
| On-scene arrival | Account for people (names).<br>Ask neighbors (but don't take their word for it, check it out yourself).<br>Must knock on or knock down to make sure people aren't there. | It's a cold night, need to find place for people who have been evacuated. | Night time<br>Cold –> 15 degrees.<br>Dead space.<br>Add on floor.<br>Poor materials: wood (punk board), metal grinders (buckle an break under fire).<br>Common attic in whole building | Not keeping track of people (could be looking for people who are not there). |
| Initial attack. | Watch for signs of building collapse.<br>If signs of building collapse, evacuate and throw from outside. | Faulty construction, building may collapse. | Signs of building collapse include: What walls are doing (cracking).<br>What floors are doing (groaning).<br>What metal girders are doing (clicking, popping).<br>Cable in old buildings hold walls together. | Ventilating the attic, this draws the fire up and spreads it through the pipes and electrical system. |

**Figure 3. Simulation Interview with Fireground Commander.**

One of our concerns for this part of the ACTA toolkit was that the Instructional Designer might have trouble generating or finding a scenario or simulation capability. However, during the development of ACTA we tried several different types of scenarios from textual case studies, which describe a scenario and various developments in the scenario, to slightly more complex scenarios using props (such as maps for planning courses of action or for getting an idea of the situation), through high-fidelity complex simulations that are sometimes found in military training situations. Our success with applying scenarios and simulations with varying degrees of fidelity gave us confidence that an Instructional Designer would be able to find or generate a means of conducting this interview.

A further concern was in the nature of the probes to use at each decision point or development in the scenario, as well as how to record that information. We worked with several different variations of probes as well as a number of different table types for recording information. The final probes and table formats were decided upon based on our own experiences with workshop participants and with our evaluation study.

## Knowledge Representation: Cognitive Demands Table

Our final challenge in developing the ACTA techniques was to provide a method that would consolidate the data gathered via the three ACTA techniques and multiple SMEs to a representation that would capture the cognitive aspects of the task as well as providing meaningful input into training materials. We decided to use another table format to capture the themes and high level commonalities across interviews (Figure 4). This representation grew from our own efforts to come up with Decision Requirements Tables, or Decision Requirements Inventories. These tables were intended to represent the critical decisions and judgments in a task and how these decisions and judgments are made. These tables provide the Instructional Designer with the means to structure and analyze the data. The column headings are not rigid, they can be adapted to suit the goals of the project and to capture information that the designer finds useful for training recommendations or interventions. We adapted these tables in order to allow the Instructional Designer to pull information from multiple interviews into a single consolidated representation that could serve as a permanent record of the Cognitive Task Analysis. These records can serve as a reference for future training interventions for cognitive skills training. Other means of recording these data may be in the form of the examples and incidents that were recorded as parts of the Knowledge Audit interview. These stories could be used as a means to capture sea and war stories as well as form the basis for cognitively challenging training exercises.

| Difficult Cognitive Element | Why Difficult? | Common Errors | Cues and Strategies Used |
|---|---|---|---|
| Knowing where to search after an explosion | Novices may not be trained in dealing with explosions. Other training suggests you should start at the source and work outward.<br><br>Not everyone knows about the Material Safety Data Sheets. These contain critical information. | Novice would be likely to start at the source of the explosion. Starting at the source is a rule of thumb for most other kinds of incidents. | *Start* where you are most likely to find victims, keeping in mind safety considerations.<br><br>Refer to Material Safety Data Sheets to determine where dangerous chemicals are likely to be.<br><br>Consider the type of structure and where victims are likely to be.<br><br>Consider the likelihood of further explosions. Keep in mind the safety of your crew. |
| Finding victims in a burning building. | There are lots of distracting noises. If you are nervous or tired, your own breathing makes it hard to hear anything else. | Novices sometimes don't recognize their own breathing sounds; they mistakenly think they hear a victim breathing. | Both you and your partner stop, hold your breath, and listen.<br><br>Listen for crying, victims talking to themselves, victims knocking things over, etc. |

**Figure 4. Cognitive Demands Table example derived from Fireground Command interviews.**

# ACTA Workshops

Klein Associates conducted workshops throughout the course of this project in order to teach people the Applied Cognitive Task Analysis (ACTA) techniques and to obtain feedback that was used to refine the techniques. Many different forms of the workshop were developed based on who the participants were and how much time was available for the workshop presentation. A primary driver for developing formal workshops to teach the ACTA techniques was our need to evaluate the techniques. The workshops were used to teach graduate students to conduct interviews and create representations using the **ACTA** techniques, analyze the information gathered, and develop instructional materials for a potential course. This allowed us to evaluate the usability, validity, and reliability of the ACTA techniques.

In this section of the report we first describe in detail the workshops conducted as part of the Evaluation Study. Following the description of the workshops developed for the Evaluation Study, we briefly describe other workshops conducted **as** part of this project and also discuss what types of workshops **work** best for teaching people to use the ACTA techniques.

## Workshops for the Evaluation Study

The workshops developed for the Evaluation Study were the most intensive workshops developed during this project because our participants were graduate students who had little or no background in interviewing techniques or the preparation of training materials. We developed two different workshops for these students: an introductory workshop, which lasted approximately 2 hours, and an ACTA workshop, which lasted approximately *6* hours. Each of these workshops is described in turn.

### Introductory Workshop

The purpose of this workshop was fourfold:

- To provide the students with an overview of the Evaluation Study in which they were participating.
- To review basic interview skills.
- To introduce the students to Cognitive Task Analysis.
- To instruct the students in how to develop the training materials that would serve as the primary dependent measures for the Evaluation Study.

The Evaluation Study overview included background information on the purpose and sponsor for the project, a description of the requirements for participating in the project (e.g., each student would participate in interviews with two Subject Matter Experts **[SMEs]),** the timeline for the

Evaluation Study, and completion of an informed consent form. In addition, students were given a brief overview of the domain and the specific task they would be investigating.

The review of basic interviewing skills covered topics ranging from appropriate dress to fundamental good manners (e.g., be courteous at all times, thank the SME for his/her help, etc.). We discussed the need to establish rapport at the beginning of the interview before starting with their prepared questions. We conducted a role play exercise in which each student had the opportunity to practice introducing him/herself to an "SME." We also presented some background information on the domain in which the SMEs worked (i.e., firefighters or EW operators) to help acquaint the students with these domains prior to their first interviews.

The introduction to Cognitive Task Analysis started with an overview of the field of Cognitive Science. We emphasized that cognitive scientists are interested in the thinking underlying observable behaviors. We contrasted traditional laboratory methods that have been used to study cognitive processes with more applied methods such as field observations and interviews. We also contrasted traditional approaches to studying job performance, which focuses on behavioral aspects with Cognitive Task Analysis that attempts to identify the critical cognitive factors involved in a job.

The introductory workshop concluded with a detailed explanation of the materials the students needed to produce after conducting their interviews: a Cognitive Demands Table, learning objectives, and modifications to a course manual. After describing the types of information to be included in the different columns of the Cognitive Demands Table, a concrete example based on an interview with a car mechanic was reviewed (shown in Figure 5). Because the student participants had no prior experience developing learning objectives, we practiced this skill in the introductory workshop. Each student was given a copy of Figure 6 that lists potential action verbs to be included in learning objectives and was asked to develop learning objectives based on the information in the Cognitive Demands Table shown in Figure 5. The learning objectives written by the students were critiqued by the group in order to help the students learn what constitutes a good learning objective. In order to prepare the students to develop modifications to course manuals, an example involving modifications to an auto repair manual was reviewed.

Students investigating the size-up task of the Fireground Commander were given written materials describing the size-up task in the context of the Fireground Commander's job (refer to Appendix B). The instructor verbally introduced these topics, provided time for the students to read through the materials, and addressed the students' questions. Students investigating the signal threat analysis task of the Electronic Warfare (EW) supervisors were provided written materials describing the domain and the task, and a list of terms specific to the EW domain (refer to Appendix B). A videotape of an EW technician describing the signal threat analysis task was presented.

# Cognitive Demands **Table**

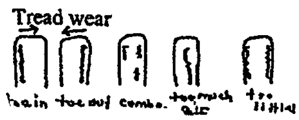
| **What is the difficult cognitive element?** | **Why is it difficult?** | **What cures does an experienced driver attend to?** | **What strategies does an experienced driver use?** |
|---|---|---|---|
| Detecting uneven wear. | Novices don't know what it is supposed to look like.<br>Novices don't realize the importance. | <br> | Glance at the tires on a regular basis. |
| Notice a shake while driving. | Novices don't notice until the shake is very pronounced. | Steering wheel shaking<br>Steering wheel pulling to one side<br>Rhythmic slapping noises coming from the tire. | Play with the steering, looking for other symptoms (i.e., does it shake only at certain speeds?).<br>Listen for noises from the tires. |
| Spinning tire and feeling for bumps on the tire. | Novices don't know to do it.<br>Tire is dirty and rough—hard to distinguish rough tire tread from real problem. | Look for wobble as you spin the tire—broken band.<br>Run hand along sidewall, feel for ridges—broken band.<br>Feel for bumps along the tread itself. | |
| Once a problem is detected, how to diagnose or correct it? | Novices don't understand the connection between the wear pattern and what is going on mechanically. | | Imagine the tire is going down the road—what would have to be happening for it to wear like this? |

**Figure 5. Car mechanic Cognitive Demands Table from introductory workshop.**

| Physical Skills | | Mental Skills | Communication Knowledge | Administrative Skills |
|---|---|---|---|---|
| Accomplish | Load | Achieve | Communicate | Administer |
| Adjust | Locate | Analyze | Define | Coordinate |
| Align | Manipulate | Calculate | Describe | Decide |
| Apply | Measure | Choose | Explain | Deliver |
| Balance | Move | Compare | Express | Draw |
| Calibrate | Operate | Compute | Identify | Fill out |
| Change | Perform | Condense | Illustrate | Instruct |
| Check | Plot | Decide | List | List |
| Clean | Position | Derive | Name | Manage |
| Complete | Remove | Determine | State | Report |
| Construct | Repair | Diagnose | Summarize | Submit |
| Correct | Replace | Distinguish | Tell | |
| Deenergize | Show | Evaluate | Write | |
| Demonstrate | Start | Interpret | | |
| Employ | stop | Monitor | | |
| Energize | Test | Observe | | |
| Enter | Trace | Recognize | | |
| Exchange | Troubleshoot | Select | | |
| Inspect | Use | Solve | | |
| Install | Utilize | Synthesize | | |
| Isolate | | | | |

**Figure 6. Learning objectives action verbs.**

**ACTA Workshop**

The purpose of the ACTA workshop was to describe the ACTA techniques to the students and

conducting

straight-forward behaviors. Following the presentation of the background material, each of the three ACTA techniques was taught as described in the following paragraphs. (The techniques themselves were described in detail earlier in this report.)

The Task Diagram was introduced as a technique that is used to obtain an overview of the task; it identifies the aspects of the task that require expertise and thus frames the rest of the Cognitive Task Analysis. The workshop leader distributed laminated job aids that described the steps involved in constructing a Task Diagram (Figure 7). She reviewed these steps while working through an example of a Task Diagram based on an interview she had conducted previously with an auto mechanic. Students were encouraged to ask questions throughout this demonstration. Next, the workshop leader instructed the students to follow the steps printed on the job aid while she conducted a Task Diagram interview with one of the workshop facilitators. Following the demonstration, the students were once again encouraged to ask questions. At this point, each student was paired with another student (or with a workshop facilitator when there were an odd number of students in the workshop) and instructed to interview their partners using the Task Diagram technique. In order to conduct these interviews, each student had to think of a domain in which s/he was an expert (e.g., cooking, jogging, etc.). Workshop facilitators circulated between interview pairs to answer questions and to determine whether or not the students were implementing the Task Diagram technique properly. After the students had completed their Task Diagrams, the workshop leader facilitated a discussion of what they had found to be most difficult about this process, and answered any additional questions raised by the students.

The Knowledge Audit was taught following the same general procedures described above for the Task Diagram. After a brief introduction in which the workshop leader reviewed the key aspect of expertise (e.g., perceptual skills, recognition of anomalies, improving, etc.), she distributed a laminated job aid for the Knowledge Audit as shown in Figure *8.* The workshop leader walked the students through an example of a Knowledge Audit conducted with an auto mechanic, and then demonstrated the Knowledge Audit using a different example with a workshop facilitator. In both of these examples, the workshop leader demonstrated the link between the Task Diagram and the Knowledge Audit. That is, the subtasks that had been circled (to indicate they involved expertise) when constructing the Task Diagram with these SMEs were then explored in more detail by using the Knowledge Audit probes. Following the demonstration of the Knowledge Audit, students practiced this technique with their partners while workshop facilitators circulated among the pairs. After having a chance to practice the Knowledge Audit, students discussed any difficulties they had and the workshop leader answered any remaining questions.

Applied Cognitive Task Analysis Interview Guide

# TD

## Task Diagram. Lists the procedures of a task in a linear fashion.

**Preparation** Go into this interview knowing which task you want to analyze. You will record the interviewee's responses on a whiteboard or large paper.

**Steps**

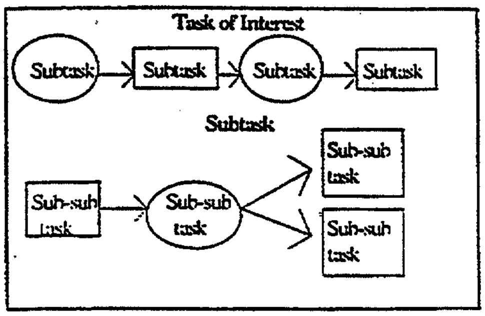
**TD-1** Record the Task of Interest at the top center of whiteboard.

**TD-2** Ask the interviewee, "Please decompose this task into subtasks. There should be at least three sub-tasks, but no more than six."

**TD-3** Record each Subtask from left to right across the whiteboard.

**TD-4** Ask the interviewee, "Which subtasks require the most expertise?"

**TD-5** Place circles around the tasks that require the most expertise and squares around the rest of the tasks.




**TD-6** Record the first Subtask that requires expertise on the whiteboard.

**TD-7** Ask the interviewee, "Please decompose this subtask into sub-sub tasks. Again, there should be at least three, but no more than six."

**TD-8** Record the Sub-sub tasks on the whiteboard.

**TD-9** Ask the interviewee, "Which of these sub-sub tasks require the most expertise?"

**TD-10** Circle those that require expertise and place squares around the rest.

**TD-11** Continue decomposing subtasks until you have a diagram for each one that requires expertise. DO NOT decompose sub-sub tasks.

**Application** Use this diagram when conducting the Knowledge Audit to limit the interview to those tasks that require expertise.



**Figure 7. ACTA Task Diagram Interview Guide, 1995.**

# Applied Cognitive **Task Analysis** Interview Guide

# KA

## Knowledge Audit. Contrasts what experts know and novices don't.

**Preparation**

In the *Task Diagram* you identified the sub- and sub-sub tasks that require the most expertise. Go into this interview knowing the sub-tasks you want to analyze.

**Steps**

**KA-1** Write the **Task of Interest** at top, center of whiteboard. Divide the remaining space into three columns with headings that match the illustration on the right.

| Task of interest | | |
|---|---|---|
| Example<br>1. Perceptual Skills<br>*Example of perceptual skills*<br>2. Anomaly<br>*Example of Anomaly*<br>3. Past & Future<br>*Example......* | Why Difficult | Cues & Strategies |

**KA-2** Use the probes listed below to elicit examples of the various aspects of expertise. Record the **first example** in column one. Ask questions KA-3 and KA-4 before moving on to the next probe.

**KA-3** For each example, ask, "Why is this task hard for novices or why don't novices know to do that?" Record answers in middle column under the heading **Why Difficult**.

**KA-4** For each example, ask, "What cues or strategies do you use in this situation?" Record answers in third column under **Cues and Strategies**.

| Expertise | Knowledge Audit Probes |
|---|---|
| **Perceptual Skills** | Experts detect cues and patterns and make discriminations that novices can't see. Can you think of any examples here? |
| **Anomaly** | Experts can notice when something unusual happens. They can quickly detect deviations. They also notice when something that should happen doesn't. Is this true here? Can you give me an example? |
| **Past & Future** | Experts can guess how the current situation arose and they can anticipate how the current situation will evolve. Can you think of any instance in which this happened, either where experts were successful or novices fell short? |
| **Big Picture** | If you were watching novices, how would you know that they don't have the big picture? |
| **Tricks of the Trade** | Are there tricks of the trade that you use? |
| **Improvising or Noticing opportunities** | Can you recall a situation when you noticed that following the standard procedure wouldn't work? What did you do? Can you think of an example where the procedure would have worked but you saw that you could get more from the situation by taking a different action? |
| **Self-monitoring & Adjustment** | Experts notice when their performance is sub-par, and can often figure out WHY that is happening (e.g., high workload, fatigue, boredom, distraction) in order to make adjustments. Can you think of any examples where you did this? |
| | Optional Probes |
| **Equipment** | Unless you're careful, the equipment can mislead you. Novices usually believe whatever the equipment says. Can you think of examples where you had to rely on experience to avoid being fooled by the equipment? |
| **Scenario from Hell** | If you, were going to give someone a scenario to teach someone humility--that this is a tough job--what would you put into that scenario? Did you ever have an experience that taught you humility in performing this job? |

**Figure 8. ACTA Knowledge Audit Interview Guide, 1995.**

The Simulation Interview was the final technique introduced to the students. After explaining that the Simulation Interview was used to highlight cognitive elements of a task within the context of a specific incident, the workshop leader distributed the job aid shown in Figure 9 and a one-page written simulation that had been given to an auto mechanic. She reviewed how to conduct a simulation interview using the auto mechanic example. Because it was not feasible to develop written simulations for each domain of expertise with which the students had conducted their Task Diagrams and Knowledge Audits, the workshop leader coached the students as they demonstrated the simulation interview with a workshop facilitator. For this demonstration, a one-page written simulation about baking cookies was distributed. The workshop leader facilitated a group discussion in which the decision points in the scenario were identified. Next, the workshop leader demonstrated how to use the Simulation Interview probes for the first decision point, and then she selected individual students to practice this technique for other decision points in the scenario. The workshop facilitators provided feedback to the students. Following the demonstration, the workshop leader answered any remaining questions about the Simulation Interview technique and any other questions the students had about the other ACTA techniques.

## Other Workshops Conducted

In addition to the workshops developed for training the participants in the Evaluation Study, additional workshops were conducted by Klein Associates as part of this research effort. Some of these workshops were presented at professional conferences, while others were presented to Navy personnel. These workshops are briefly summarized below.

### Professional Conferences

ACTA workshops were presented at the annual meetings of the Human Factors and Ergonomics Society in 1995 and 1996. At the 1995 meeting, we presented a half-day workshop that was so well received we decided to expand the workshop to a full-day format for the 1996 meeting. In both workshops, we introduced and demonstrated the three ACTA interview tools (i.e., the Task Diagram, the Knowledge Audit, and the Simulation Interview) and allowed a limited amount of time for participants to practice with these tools. In addition, these workshops included a review of other Cognitive Task Analysis techniques and concluded with a discussion of how to apply the ACTA tools to specific problem domains of interest to the workshop participants.

During the course of this research project, we also made several presentations to introduce the ACTA tools to professionals who might find them useful for their jobs. We gave a presentation in April, 1995, at the Southwestern Ohio Chapter of the American Society for Training and Development in which we described the ACTA tools and demonstrated them with the help of a local firefighter who served as the SME. We also gave a presentation to the San Diego Chapter of the International Society for Performance and Improvement in October, 1996.

# Applied Cognitive Task Analysis Interview Guide

SI

## Simulation Interview. Highlights the cognitive elements of a task

**Preparation** Obtain a simulation of the task. The simulation does not have to be high fidelity; it can be a paper and pencil simulation, video, or whatever is available.

**SI-1**

**SI-2** Divide a whiteboard into 6 columns with headings that match the illustration on the right.

| Events Decisions Judgments | Situation Assessment | Actions | Critical Cues | Alternatives | Potential Errors |
|---|---|---|---|---|---|
| *Event #1* | | | | | |
| *Evenl 12* | | | | | |
| *Event #3* | | | | | |

**SI-3** After the SME has reviewed the simulation, ask 'Think back over the scenario. Please list the major events/judgments/decision points that occurred during the incident. As you name them, I am going to list them in the left column on the board."

**SI-4** For each event in the left column, ask the questions listed below. Ask all five questions about a specific event before moving on to the next event. Record the answers to each question in the appropriate column,

- **Situation Assessment** What do you think is going on here.? What is your assessment of the situation at this point in time'?
- **Actions** What actions. if my, would you take at .this point in time?
- **critical cues** What pieces of information led you to this situation assessment/action?
- **Alternatives** Are there any alternative ways you could interpret this situation? Are there any alternative courses of action that you woutd consider at this point?
- **Potential Errors** What errors would an inexperienced person be likely to make? Are there cues they would miss'?

We asked the professionals attending both of these meetings to provide us with feedback about the relevance and usefulness of the ACTA tools.

### Navy Personnel

We conducted workshops with Navy personnel as part of our user analysis. Four different workshops were presented to Navy personnel to determine their reactions to the ACTA tools. In June, 1995, one workshop was presented to several different groups of Navy personnel; this workshop included researchers from the Navy Personnel Research and Development Center (NPRDC), instructors from the Antisubmarine Tactical Air Control School, and instructors from the EW School. Additional workshops were presented to instructors from the Physician Assistant School and the Air Intercept Controller School in March, 1995. Another workshop was given to personnel working at the Naval School of Health Sciences in San Diego in January, 1996. In each of these workshops we described and demonstrated the different ACTA tools and then allowed time for the participants to practice with the ACTA tools. We asked the participants to provide us with feedback about the usability of the tools and the relevance of the tools to their Navy job requirements.

Additionally, a workshop depicting an early version of the ACTA techniques was presented to representatives from the Chief of Navy Education and Training in Pensacola, FL in February, 1995. A follow-up presentation to describe a further refined set of ACTA tools was conducted in April, 1996, with representatives from both Chief of Naval Education and Training (CNET) and the Naval Education and Training Program Management Support Activity (NETPMSA).

### Lessons Learned

As part of this research project, Klein Associates conducted over a dozen workshops in which we trained a wide variety of individuals in how to use the ACTA tools. We continually modified and improved the workshops based on feedback from participants and on our own observations regarding the effectiveness of the training methods employed. The lessons we learned from conducting these workshops are summarized below.

It is important for the workshop participants to understand the purpose of using the ACTA tools. In order for them to understand what they will gain from using these particular interview tools, they must first understand something about the nature of expertise and the importance of the cognitive aspects of the task they are studying. Initially, we spent relatively little time in the workshops discussing the nature of expertise and the importance of cognition. We now believe this is a critical first step in training people how to use the ACTA tools.

We always recognized the need for participants to practice with the ACTA tools. However initially, we did not allocate very much time in the workshops for helping the participants select a task that they could use for this practice; we simply instructed the participants to think of any task for which they had some expertise. In several cases we noticed that the participants were struggling to apply the ACTA tools to tasks that were almost totally proceduralized and did not involve any significant amount of cognitive elements. It is much easier to practice the ACTA tools with tasks that involve more cognitive elements. We found that another benefit of spending more time discussing the nature of expertise and the importance of cognition at the beginning of the workshop was that this discussion helped participants select an appropriate task for practicing the ACTA tools.

We used very simplistic tasks (e.g., cookie baking) for demonstrating the ACTA tools to the workshop participants. We were careful to select simple tasks that involved a sufficient number of cognitive elements. This approach seemed to be very effective for training participants in how to use the ACTA tools. We were concerned that if we used a more complex task the participants would be struggling to understand an unfamiliar domain, and not be able to focus on the ACTA methods. The drawback to using simplistic tasks is that these tasks are not representative of the types of tasks that a professional would actually study using the ACTA tools. We believe the best way to conduct these workshops is to use simplistic tasks for demonstration purposes early in the workshop, and then to conclude the workshops with a discussion of the application of the ACTA tools to problem domains of interest to the participants. For these discussions, we would ask participants for examples of domains that they would like to study with the ACTA tools and then have the entire group discuss how to apply the tools to these particular domains. We found this technique to be very effective for helping participants learn how to use the ACTA tools with more complex tasks.

The workshops we conducted varied in many ways: some lasted 2 hours, some lasted 6 hours, the number of participants ranged from four to 50, some workshops included a very homogenous group of participants (e.g., all students, all physician assistants), whereas others included participants representing several different professions. Based on our experience, the most effective workshops lasted approximately 6 hours and were conducted with groups of 10-12 participants from a variety of different backgrounds. A heterogeneous group of participants provides the opportunity to learn about a wider variety of tasks to which the ACTA tools can be applied. A 6-hour format allows sufficient time for participants to practice the methods and receive feedback from the workshop facilitators who are experienced using the ACTA tools. Ideally, there would be a sufficient number of workshop facilitators so that each pair of participants could receive individualized feedback throughout the practice sessions. However, this typically is not feasible due to the cost involved, and the workshops can be run successfully with two facilitators who circulate among the pairs of participants while they practice using the ACTA tools.

After conducting ACTA workshops with a wide variety of participants it has become clear to us that there are large individual differences in the ease with which people learn how to use the ACTA tools. Some participants are able to quickly master these tools; whereas, others require a great deal of individualized feedback before they are able to use the tools effectively.

# Evaluation Study

The primary goal of the project was straightforward: develop efficient and effective Cognitive Task Analysis tools for use by Instructional Designers and others outside of the research community. How to test the ACTA tools in order to evaluate their usability, validity, and reliability was a more-complex issue, and one for which relatively little guidance exists within the current research literature. We found ourselves in the position of developing measures and methods of evaluation as part of the evaluation effort itself.

As Hoffman, Crandall, and Shadbolt (in preparation) point out, the question of how to empirically verify a knowledge base, and the methodologies used to articulate and represent that knowledge base, has received little attention from the research community. Many Cognitive Task Analysis methods are evaluated solely on the basis of subjective judgments of whether or not they seemed to work for a particular application or project. Exceptions include work by Crandall and her colleagues assessing the validity and reliability of data-gathering skills using the Critical Decision method (Crandall & Caldenvood, 1989; Crandall & Gamblian, 1991; Crandall & Getchell-Reiter, 1993; Taynor, Crandall & Wiggins, 1987), and method comparisons by Hoffman and colleagues (Hoffman, 1987; Hoffman, Shadbolt, Burton & Klein, 1995). The evaluation study described in this section not only attempts to address issues of validity and reliability for a specific set of Cognitive Task Analysis techniques, but also addresses a number of issues that surround the assessment of validity and reliability within the context of real-world tasks.

## Methods

An evaluation of the ACTA techniques was conducted to establish the validity and reliability of the data gathered using the methods, and to assess the usability of the techniques. In addition, a comparison of information gathered using ACTA techniques to data gathered using unstructured interview techniques was conducted.[2]

Parallel studies were conducted in two domains for this evaluation. Our intention was to test the ACTA techniques with a sample of naive users — people who lacked knowledge or experience with Cognitive Task Analysis or Instructional Design. A novice sample would allow a cleaner examination of the impact of the ACTA methods on the kind and quality of data produced. Therefore, students from graduate programs in clinical, human factors, or cognitive psychology were recruited via postings on college bulletin boards and email, to conduct interviews and generate instructional materials in either the firefighting domain or the Electronic Warfare (EW) domain. Volunteers were screened to make sure they had no previous knowledge of the domain they would be investigating, no previous experience conducting Cognitive Task Analysis, and no extensive experience or training in developing course materials. Each student was paid $250 for participation

[2] One set of Critical Decision method interviews was also conducted to be used as criterion data. See Appendix C, C.3 for a description of this procedure.

in the project. Twelve students conducted interviews in the firefighting domain and 11 in the EW domain.[3] The SMEs interviewed were experienced Fireground Commanders from the greater Dayton area in Dayton, Ohio, who had at least 10 years of experience including experience with fireground command and were recommended by the Fire Chief of each local fire department; and experienced EW technicians from Fleet Training Center Pacific in San Diego, California, who had at least 6 years of experience as EW technicians, including 4 years at sea and experience as an EW supervisor. (For a complete description of participant demographics, see Appendix C, C.1.)

Within each domain, students were placed in one of two groups. An attempt was made to match the groups on age, gender, and education level. After matching the students on these criteria, they were randomly assigned to groups. All students attended a 2-hour workshop introducing the concepts underlying Cognitive Task Analysis, describing the application of Cognitive Task Analysis to the development of instructional materials, and providing a brief overview of the domain and specific task they would be investigating. They also received instruction regarding the training materials they would be asked to develop following their interviews with SMEs. These materials included a Cognitive Demands Table, learning objectives, and modifications to a training manual. (Workshop materials are included in Appendix B.)

After the initial 2-hour workshop, the matched groups of students were separated for the remainder of the study. One group, referred to as the Unstructured group, was provided with instructions to conduct interviews with SMEs in whatever format they believed would be most useful for gathering cognitive information. They were told to spend time preparing questions, but were not given any direction regarding how to structure the interviews or specific types of questions to ask. The other group, referred to as the ACTA group, was provided with a 6-hour workshop on the ACTA techniques, including knowledge elicitation and knowledge representation. (Workshop materials are included in Appendix B.)

Students in both the Unstructured and ACTA groups then participated in two interviews with SMEs. Each student led one interview with an SME and observed an interview conducted by another student with another SME, and thus had access to data from two interviews. Students working in the firefighting domain were asked to focus on the size-up task. Students working in the EW domain were asked to focus on signal threat analysis. All interviews were scheduled for a 3-hour block of time.

[3] For the firefighter study, 13 graduate students in Dayton, Ohio were recruited. One student served as an alternate for the ACTA group. This student completed all the workshops, but did not actually conduct or attend any interviews. For the EW study, 11 graduate students in San Diego, California were recruited initially. Due to illness or school commitments, three of these students dropped out before completion of the workshops. To increase the number of participants, four additional students were recruited and another set of workshops was conducted. One of these students served as an alternate. The other three conducted interviews and generated instructional materials using the same format and procedures as those initially recruited.

Within a week of completing the two interviews, each student attended a 4-hour session to analyze the data and develop training materials. The students were instructed not to collaborate or do any additional work with their interview notes prior to the scheduled session. During the 4-hour session, they were required to structure and represent the information obtained in interviews. They were provided materials and instructions and asked to:

- Consolidate the data from the interview using the Cognitive Demands Table format.
- Develop at least 10 cognitive learning objectives for a hypothetical course in that domain.
- Revise or add to training manuals (these were provided), based on what they had learned in the interviews.
- Complete a questionnaire about participation in the study.

In addition, all students who had been exposed to the ACTA techniques were asked to fill out an ACTA usability questionnaire.

**Data Transformation**

In order to generate quantitative measure of utility and validity, the information generated by the ACTA tools required extensive data codification and transformation. All materials generated by the sample of graduate students were assessed by SMEs and/or cognitive psychologists. Wherever possible, data evaluation was carried out by multiple coders, so that inter-rater reliability could be assessed. In some cases, due to lack of availability or resource constraints, only one SME was available to code the data. Measures were devised to address two aspects of validity: (1) whether the ACTA tools produced information that was predominantly cognitive in nature, and (2) whether the information produced was domain-specific and relevant. Data transformation procedures and associated measures are described in detail in the following sections.

**Validity Indices: Cognitive Demands Table**

All items included in the Cognitive Demands Tables were coded by two Klein Associates researchers, Laura Militello and Dr. Rebecca Pliske, blind to treatment group (ACTA vs. Unstructured), for whether they contained cognitive content. The criterion for inclusion in the cognitive demand category was that the item addressed a cognitive skill or a cognitive challenge that a firefighter/EW operator encounters (e.g., "deciding whether or not water supply on the scene will be adequate," "devising a strategy to successfully remove people from a burning building"). Items in the Noncognitive demands category typically referred to declarative knowledge that the firefighter/EW operator should have (e.g., "know the initial command sequence") or behaviors (e.g., "return resources").

In order to establish whether students using the ACTA techniques could consistently elicit information across relevant cognitive categories (as opposed to task-based categories), we developed a coding scheme based on Rasmussen, Pejterson, and Goodstein's (1994) model of decision making. The categories included information collection, situation analysis, diagnosis, prediction, value judgment, choice, planning, and scheduling (see Appendix C, C.2, for category definitions). Two raters, blind to the students' interview group (ACTA vs. Unstructured), independently rated **30** percent of the data. The raters established acceptable inter-rater agreement (% agreement = 74%). The rest of the data were then divided among the two raters to complete the rating.

Evaluation of the domain-specific content of the Cognitive Demands Tables was based on the firefighting portion of the database. A task-based coding scheme specific to the firefighting domain was developed. Based on firefighting manuals made available to us by the National Fire Academy, Emmitsburg, MD, we established that there are three primary subtasks for which the Fireground Commander is responsible: size-up, strategy/tactics, and management. For the firefighter data, the coders independently assessed the content of each Cognitive Demands Table item and assigned it to one of these three categories. The coders established reliability (% agreement = 81%) on 40 percent of the data,[4] and one researcher then coded the remainder of the data.

We believed that it was also important to have the data evaluated by domain experts, in order to assess data quality and relevance. An assessment of the firefighter data was carried out by an instructor for the Incident Command course at the Ohio Fire Academy. He had more than 10 years of firefighting experience, had served as a Fireground Commander, and is currently involved in the development of course materials for the firefighter courses taught at the Ohio Fire Academy. The EW SME was a retired U.S. Navy Electronic Warfare technician who had extensive experience as an operator, a supervisor, and as an instructor. The SMEs were asked to indicate what percentage of the information contained in each Cognitive Demands Table would be likely to be known only by experienced personnel. In addition, the SMEs were asked to indicate the percentage of information contained in each Cognitive Demands Table that would be relevant for experienced, highly skilled personnel (Fireground Commander/EW supervisor) as opposed to a person with little experience on the job (firefighter/new EW operator). Given that one objective of the ACTA techniques is to elicit experience-based knowledge (as opposed to declarative knowledge, which is easily captured using other traditional techniques and disseminated via textbooks), we wanted to distinguish information that only an experienced person would know from that which people newly released from training would know. Both of these questions were intended to distinguish between information reflective of experience-based knowledge vs. classroom knowledge.

### Validity Indices: Instructional Materials

In addition to the firefighter **SME** described above, a second instructor from the Ohio Fire Academy was recruited to provide ratings of the instructional materials generated by the students in

[4] No standard for acceptable inter-rater agreement exists (Meister, 1985; Pedhazur & Schmelkin, 1991). However, agreement ratings exceeding 70 percent are generally accepted as adequate for this type of coding. Subsets of data were analyzed until an acceptable level of agreement was reached. The remaining data were then analyzed by one coder.

the firefighting domain. He also had more than 10 years experience as a firefighter, had served as a Fireground Commander, and is currently involved in the development of course materials at the Ohio Fire Academy. In addition, two EW instructors from the Electronic Warfare "A" School in Pensacola, Florida were recruited to rate the instructional materials generated by graduate students working in the EW domain. Both Electronic Warfare SMEs held a rank of E-6 or above, had served as an EW supervisor, and had experience as an instructor at the EW "A" School.

Working independently, the SMEs in each domain were asked to evaluate each learning objective and training manual modification for accuracy, importance, and whether or not it was currently included in the typical firefighter training/EW instructional program. In the firefighting domain, acceptable inter-rater agreement was obtained for the accuracy and importance ratings, but not for the rating of whether or not the information described in the learning objective was currently covered in the typical firefighter training course.[5] For the learning objectives, the percent agreement for the firefighter SMEs' accuracy judgments was **87.8** percent; the percent agreement for the firefighter SME's importance ratings was **71.4** percent. For the modifications to the student manual, percent agreement for accuracy was **90.1** percent and for importance was **76.1** percent. The accuracy and importance ratings made by the SME who had more extensive experience in developing training materials for Fireground Commanders were used in further analyses.

The SMEs in the EW domain were not able to reach acceptable inter rater agreement. For the learning objectives, percent agreement for importance was 58.5 percent and for accuracy it was **67.9** percent. For the modifications to the student manual, percent agreement for importance was **34.2** percent and for accuracy it was **61.7** percent. Discussion with the SMEs revealed that depending upon the type of ship one serves on, the EW job may be very different. Our two SMEs had served on different types of ships and were currently teaching very different courses (basic tactics vs. introductory course on equipment). As a result, they had quite different perspectives on what is important for an EW operator to learn in school to prepare him/her for the job. For all further analyses, we used the ratings from the SME with the most recent and most extensive sea experience.

## Results

The results section first presents our findings as they relate to the usability, validity, and reliability of the ACTA techniques, as these were the primary questions to be answered by our evaluation study. Thus the data presented in the following sections are based only on students who completed the ACTA workshops and used these methods to conduct an interview with a SME. The final portion of the results section discusses the data as it relates to differences between the materials generated by students who conducted interviews using ACTA vs. those students who

[5]Due to unacceptable reliability ratings, no further analyses were conducted on data relating to whether the information was currently covered in a course. Discussion with the firefighter SMEs revealed that they had experience teaching different courses and therefore had different perspectives on what was "typically" included in firefighter instruction.

conducted unstructured cognitive interviews. Although few group differences were found, a discussion of how large intra-group variability impacted this study is presented.

**Usability**

In evaluating the ACTA tools, we were interested in understanding the subjective experiences of both the interviewers and the interviewees. User acceptance is key to the success of this project. To assess user acceptance, three questionnaires were administered: a usability questionnaire focusing specifically on the ACTA techniques, an interviewee questionnaire eliciting information from the **SME's** perspective, and an interviewer questionnaire addressing the experience of participating in all aspects of the study. The findings from the questionnaire data are presented in this section.

**Usability Questionnaire. A** usability questionnaire was administered to all graduate students who used the ACTA techniques. Overall, ratings were very positive. All of the tools were rated as useful.[6] Mean ratings on all dimensions were above "3" on a 5-point scale, where "5" is the most positive rating and "1" is the least positive rating (see Table 1). These data indicate that graduate students found:

- The methods to be easy to use.
- The interview guides and job aids to be flexible.
- The output of the interviews to be clear.
- The knowledge representations to be useful.

**Interviewee Questionnaire.** Each **SME** was asked to fill out a brief questionnaire at the end of the interview. If the ACTA tools are to be accepted in an operational community, the impressions of the people who are interviewed will have considerable influence. If the **SMEs** find the interview process aversive, or do not find that they are given an opportunity to communicate the critical elements of the job, acceptance of the ACTA tools will be greatly compromised within an organization.

The questionnaire data indicate that the interviewees found the interview experience to be pleasant and worthwhile. Table 2 presents the means for each question for those **SMEs** who participated in ACTA interviews.[7]

[6] A three-way, mixed design ANOVA taking into account the domain (Firefighting, EW), the ACTA techniques (Task Diagram, Knowledge Audit, Simulation Interview), and the individual questions (Questions 2, 3, 4, and 5) on the usability questionnaire showed no difference in the usability of the three techniques, $F(2, 18) = 1.34, p = .29$, or in the usability of the techniques across domains, $F(1, 9), p < 1$.

[7] A three-way, mixed design ANOVA taking into account domain (Firefighting, EW), interview type (ACTA, Unstructured), and question (5 questions from questionnaire) showed no domain differences in the interviewees' responses, $F(1, 20) = .82, p < 1$.

## Table 1

**Usability Questionnaire Means for the Graduate Students who Conducted Interviews Using the ACTA Techniques**

| Question | Task Diagram | | Knowledge Audit | | Simulation Interview | | ACTA Overall | |
|---|---|---|---|---|---|---|---|---|
| | Firefighting $N = 6$ | Electronic Warfare $N = 5$ | Firefighting $N = 6$ | Electronic Warfare $N = 5$ | Firefighting $N = 6$ | Electronic Warfare $N = 5$ | Firefighting $N =$ [illegible] | Electronic Warfare $N = 5$ |
| Circle the amount of time you spent becoming familiar with the tool before using it.[a] | 1.00 (0.00) | 1.40 (0.55) | 1.17 (0.41) | 1.40 (0.55) | 1.00 (0.00) | 1.20 (0.45) | | |
| Rate the degree to which you found this technique easy to use. | 4.67 (0.52) | [illegible] | 3.67 (1.03) | [illegible] | 3.83 (1.60) | 4.40 (0.89) | 4.17 (0.75) | 4.20 (0.45) |
| Rate the degree to which you found the interview guide to be flexible. | 4.67 (0.52) | [illegible] | 3.67 (1.03) | 3.40 (0.55) | 3.83 (1.17) | 3.60 (1.14) | 3.67 (1.21) | 3.80 (0.45) |
| Rate the degree to which you found the output to be clear. | 4.67 (0.52) | 4.00 (1.00) | 4.00 (1.10) | 3.60 (0.55) | 3.83 (1.83) | 4.60 (0.55) | 4.00 (1.10) | 4.00 (0.00) |
| Rate the degree to which you found the knowledge representation to be useful. | 4.50 (0.55) | 4.00 (0.71) | .17 (1.174) | 3.80 (0.84) | 3.33 (1.21) | 4.00 (0.71) | 4.33 (1.21) | 4.40 (0.55) |

**Note.** All questions used a five point rating scale where 5 is the most positive rating and 1 is the least positive rating, unless otherwise stated. Standard deviations are included in parentheses.

[a] A three-point scale where 1 = 1 hour or less; 2 = 1 to 2 hours; and 3 = more than 2 hours was used for the questions concerning time required to prepare for each tool

## Table 2

| | Firefighting $N = 6$ | Electronic Warfare $N = 5$ | Mean Totals $N = 11$ |
|---|---|---|---|
| Overall, I found the interview to be a pleasant experience. | 4.33 (0.52) | 3.6 (1.14) | 3.97 (0.89) |
| The format of the interview allowed me to describe my expertise. | 4.50 (0.55) | 3.6 (1.14) | 4.05 (0.94) |
| I thought the interview lasted too long.“ (1 = strongly agree, 5 = strongly disagree) | 4.00 (0.63) | 4.00 (0.71) | 4.00 (0.63) |
| Participating in the interview gave me new insights into the cognitive aspects of my job. | 3.67 (1.03) | 3.20 (1.48) | 3.44 (1.21) |
| I think the cognitive aspects of my job that were discussed during the interview are important things for a novice to learn. | 4.33 (0.52) | 4.00 (1.22) | 4.17 (0.87) |

**Interviewer Questionnaire.** All graduate students filled out a questionnaire at the completion of their participation in the evaluation study. This questionnaire consisted of 10 questions intended to capture the interviewer's subjective experience, addressing issues such as confidence level, perceived difficulty or ease of the Cognitive Task Analysis process, etc. The means for each question from the ACTA group are presented in Table **3.**

These data indicate that graduate students in both domains found the interviews to be informative and to provide cognitive information about the job domain. Based on the information learned via ACTA interviews, the graduate students found the development of a Cognitive Demands Table and the generation of learning objectives to be easy. Participants indicated that they were able to make important revisions to the course materials provided. Surprisingly, participants responded negatively to the statement, "I want to conduct more interviews because **I** still want more information." Our only explanation for this is that because our participants were novices to Cognitive Task Analysis, they did not anticipate the breadth and depth of knowledge that can be gained via Cognitive Task Analysis techniques.

## Table 3

**Graduate Student Interviewer Questionnaire Means for the Graduate Students who Conducted Interviews Using the ACTA Techniques**

| | Firefighting $N = 6$ | Electronic Warfare $N = 5$ | Mean Totals $N = 11$ |
|---|---|---|---|
| I felt confident in my ability to lead an interview. | 4.33 (0.82) | 4.00 (0.00) | 4.17 (0.60) |
| I learned more information from the interview I observed, than from the one I led. | 2.00 (0.89) | 3.00 (1.23) | 2.50 (1.13) |
| I felt I had sufficient information to revise the course materials. | 4.00 (0.89) | 3.20 (1.30) | 3.60 (1.12) |
| The interviews provided me with important information about the cognitive skills involved in this job domain. | 4.33 (0.52) | 3.60 (1.14) | 3.97 (0.89) |
| I wanted to conduct more interviews because I still wanted more information. | 2.33 (0.82) | 3.20 (1.30) | 2.77 (1.10) |
| The Cognitive Demands Table was easy to fill out. | 4.00 (1.26) | 3.40 (0.89) | 3.70 (1.10) |
| It was easy to develop course objectives based on information specified in the Cognitive Demand Table. | 4.33 (0.52) | 3.20 (1.64) | 3.77 (1.25) |
| I was able to use the information to make important changes in the course material. | 3.50 (0.84) | 3.40 (1.14) | 3.45 (0.93) |
| Overall, I found the interviews to be informative. | 4.83 (0.41) | 4.60 (0.55) | 4.72 (0.47) |
| Given the information, I found the revision of course materials straightforward. | 3.67 (0.82) | 3.00 (1.23) | 3.34 (1.03) |

**Note.** All questions used a five point rating scale. Unless otherwise stated, 1 = strongly disagree, 5 = strongly agree. Standard deviations are included in parentheses.

### Validity

Table 4 presents data that addresses three central questions reg ding validity:

- Does the information gathered address cognitive issues?
- Does the infomation gathered deal with experience-based knowledge as opposed to declarative knowledge?
- Do the instructional materials generated contain accurate information that is important for novices to learn?

## Table 4

### Quality of Outputs for Graduate Students Who Conducted Interviews Using the ACTA Techniques

| Validity Indicator | Firefighter *N* = 6 | Electronic Warfare *N* = 5 |
|---|---|---|
| Percent of total Cognitive Demands Table items coded as cognitive. | 92% | 94% |
| Proportion of Cognitive Demands Table information experienced personnel likely to know, averaged across ACTA users. | 0.95 (.05) | 0.90 (.09) |
| Proportion of Cognitive Demands Table information relevant to a Fireground Commander/EW Supervisor, averaged across ACTA users. | 0.73 (.10) | 0.87 (0.10) |
| Proportion of student manual modifications rated as important or somewhat important, averaged across ACTA users. | 0.70 (.47) | 0.93 (0.26) |
| Proportion of learning objectives rated as important or somewhat important, averaged across ACTA users. | 0.95 (0.43) | 0.83 (0.38) |
| Proportion of student manual modifications rated as accurate, averaged across ACTA users. | 0.89 (0.31) | 0.65 (0.48) |
| Proportion of learning objectives rated as accurate, averaged across ACTA users. | 0.92 (0.24) | 0.54 (0.50) |

**Note.** Standard deviations are included in parentheses.

The extent to which the information elicited using ACTA was cognitive in nature was assessed by examining every item contained in the Cognitive Demands Tables for its cognitive content. The cognitive content codings indicate that fully 93 percent of the items generated address cognitive issues. More specifically, in the firefighter study, 92 percent of the items were rated as cognitive and in the EW study 94 percent of the cognitive demand items generated by the students using ACTA were rated as cognitive.

To address the issue of whether the ACTA tool provided a means to elicit experience-based knowledge, SMEs were asked to make a global assessment of each Cognitive Demand Table and to assign a percentage to each that reflected the proportion of information it contained that only highly experienced personnel would be likely to know. The inference here is that such information is reflective of experience-based, as opposed to declarative, knowledge. The information that newly-trained personnel possess is more likely to have been learned in a classroom setting and is likely to be predominantly declarative knowledge.

The findings offer strong support that the ACTA tools allowed students to elicit important and relevant domain information. In the firefighter study, the percentage of content of the Cognitive Demands Tables that was judged to be information that only highly experienced personnel would know averaged 95 percent. In the EW domain, the same assessment yielded an average of 90 percent across the ACTA group. In response to questions regarding information relevance, a substantial percentage of information in the Cognitive Demands Tables ($M$ = 73%) was rated as relevant for a Fireground Commander. Similar results were found in the EW domain where a mean of 87 percent of the information in the Cognitive Demands Tables was rated as relevant to an EW supervisor.

Our third validity question focused on the importance and accuracy of the instructional materials generated by ACTA users. Our measures included ratings of importance and accuracy by domain experts. The 3-point importance ratings were collapsed into a dichotomy, with "important" or "somewhat important" ratings combined into a single importance indicator. Accuracy had been assessed as a dichotomy (accurate vs. not). Findings indicate that in both domains, content of instructional materials generated by ACTA were viewed as important domain information for novices to learn. In the firefighting domain, an average of 70 percent of the instructional material modifications generated, and 95 percent of the learning objectives generated by each student were rated as important. In the EW domain, these averages were 93 percent and 83 percent, respectively.

Accuracy evaluations were also high, particularly for the firefighting data. In the firefighting domain an average 89 percent of the modifications to the student manuals were rated as accurate and 92 percent of the learning objectives were rated as accurate. In the EW domains, these averages were 65 percent (modifications to the student manual) and 54 percent (learning objectives). We suspect that the lower accuracy ratings in the EW domain were due to the more technical nature of the domain. The environment in which an EW operator/supervisor works was so foreign to the graduate students that understanding and using the terminology and acronyms that EW operators /supervisors use to describe the equipment and environment presented additional difficulty. There were a number of cases in which the EW SMEs rating the data indicated that they knew what the student must have meant, but that the wording used was incorrect.

**Reliability**

There is no well-established metric or method for assessing the reliability of Cognitive Task Analysis tools, and yet the issue is an important one. Briefly, the question is whether individuals using a particular technique are able to generate comparable information, so that the tools can be considered a source of consistent information, given the same (or similar) domain expert assessed at different points in time and/or by different knowledge engineers. This is a much simpler matter when one is dealing with highly-structured interview formats or scale items than when faced with textual knowledge representations. We sought to address the issue in several ways. One approach was to examine whether ACTA users consistently elicited the same types of cognitive information. Therefore, we examined the content of the cognitive demands generated by the students, to see whether they had generated similar information.

One set of analyses examined whether ACTA users had generated similar types or categories of cognitive information. This analysis utilized a coding scheme based on Rasmussen, et al., (1994) model of decision making (found in Appendix C, C.2). Each item in each Cognitive Demands Table was coded. In the firefighting domain, every Cognitive Demands Table (100%) generated by the ACTA group contained information that had to do with situation analysis and planning. All but one of the Cognitive Demands Tables (80%) contained data on information collection. Given that students were instructed to focus on the subtask of "size-up," which consists of gathering relevant information in order to accurately assess the situation and develop a plan of action, we concluded that students in this study were able to consistently elicit relevant cognitive information using the ACTA techniques. Students did not consistently elicit information in the remaining categories (diagnosis, prediction, value judgment, choice, and scheduling).

The same analysis was carried out for the EW study. All ACTA users generated cognitive demands that included information about situation analysis and all but one collected data in the information collection category. The signal threat analysis task consists primarily of gathering the necessary information to maintain an accurate, current assessment of the situation at all times. Again the data indicate that the students consistently elicited relevant cognitive information using the ACTA tools. Data across the two domains suggest that students were able to consistently elicit comparable cognitive information using the ACTA techniques.

A second coding scheme, specific to the firefighting data, also indicated that students consistently elicited similar information. The Fireground Commander task was divided into three subtasks: size-up, strategy and tactics, and management. All the ACTA users obtained information in each of these categories. The bulk of the information gathered focused on the size-up task (62%), which is where the students were asked to focus their interviews. Thus we conclude that, using ACTA, people were consistently able to get important cognitive information for the entire Fireground Commander task, with an emphasis on the size-up task.

We also attempted to assess the degree of overlap of specific items across the Cognitive Demands Tables generated by ACTA users. This proved extremely difficult, because users had not been constrained in level of detail, phrasing, or specificity. One student might list as a cognitive demand "look of the smoke" while another noted "color and movement of smoke." The levels of inference required by raters to judge the degree to which any two Cognitive Demands Table items matched were similar, or were different became unacceptable, and the analysis was abandoned.

However, our informal examination of the Cognitive Demands Tables suggests that the graduate students did not, in most cases, generate identical cognitive demands. This is not surprising given the design of this study. In order to reduce intra-subject variability, we excluded from the study graduate students who had any experience in the domain for which they would be conducting the Cognitive Task Analysis; which meant that all of the students were working at a disadvantage in conducting the Cognitive Task Analysis. When we describe the ACTA tools to professional audiences, we recommend that time is spent upfront becoming familiar with a domain before interviews are conducted. In this case, the students were given a brief overview of the domain and the task they would be studying. The limited time we had with the graduate students did not allow for the recommended level of familiarization with the domain. A second reason why the graduate students did not generate the same cognitive demands is that each student was exposed to only two interviews with **SMEs.** If SME availability had allowed each student access to three to five experts as we generally recommend, the students would have been more likely to have heard similar things in the interviews.

## Group Differences

One of the drawbacks of the evaluation study design was sample size. The intensive workshop preparation necessary to train subjects in ACTA methods, and the extensive coding and data transformation effort necessary to provide empirical evaluation data, and the limited number of available SMEs, made large samples simply beyond the time or resources available. Obviously, with the small group sizes we had, the effects associated with membership in the ACTA group were going to have to be very strong to be discernable as statistically significant. Nonetheless, we were surprised to find so few differences between the ACTA group and the unstructured interview group in our data. In addition to the small sample size, we found large intra-group differences that appear also to account for the lack of statistically significant results. Although an attempt was made to match the groups on age, gender, and education level, we found considerable individual differences in the students' comfort level and ease in conducting interviews (as observed by the investigators). This resulted in large standard deviations on nearly all the comparative measures, making those findings that were statistically significant difficult to interpret. For example, in rating the evaluation study experience, graduate students in the ACTA group for both the firefighter and the EW study agreed more strongly with the statement, "I felt confident in my ability to lead an interview" ($M$= 4.18, $SD$ = .60) than the graduate students who conducted unstructured interviews ($M$= 3.25, $SD$ = .87), $U$ = 28.5, $p$ =.02.[8]. In the firefighter study, the ACTA group agreed more strongly with the statement, "I felt I had sufficient information to revise the course materials" ($M$= 4.00, $SD$ = .89) than the Unstructured group ($M$ = 2.67, $SD$ = 1.03), $t$ (10) = 2.39, $p$ = .06. These statistical analyses indicate that students trained to use ACTA felt more confident in conducting the interviews and were more confident that they had gathered sufficient information to revise the course materials than the Unstructured group. However, in looking at the large standard deviations, it becomes clear that some students in each group were confident, whereas others were not.

In other cases, the means indicate very little difference between the groups, but the standard deviations indicate considerable variance within the groups. For example, the means for the two groups are nearly identical in response to the question, "Given the information, I found the revision of course materials to be straightforward." However, the large standard deviations indicate that some people in each group found the revision of the course materials straightforward, but others did not (see Table 5). Given the small sample sizes used in this study, it is clear that these group difference comparisons are not very robust.[9]

[8]A Mann Whitney U, which is free of variance assumptions, was used instead of a t-test because there was not variance in the responses from the ACTA students in the EW domain.

[9]An additional analyses that explored group differences are included in Appendix C, C.4.

**Table 5**

| | ACTA Group | | Unstructured Group | |
|---|---|---|---|---|
| | Firefighting Domain | Electronic Warfare Domain | Firefighting Domain | Electronic Warfare Domain |
| Given the information, I found the revision of course materials straightforward. | **3.67 (0.82)** | **3.83 (1.47)** | 3.00 **(1.23)** | **3.33 (1.03)** |

One potentially confounding factor in the design of our study was that during the introductory workshop, the Unstructured group was exposed to a lecture on cognitive elements, Cognitive Task Analysis, and how to fill out a Cognitive Demands Table before conducting interviews. Some of the students in the Unstructured group may have used the Cognitive Demands Table to structure their interviews, thus reducing the gap between the ACTA group and the Unstructured group. The implication for ACTA is that the Cognitive Demands Table is a valuable tool for framing the kinds of information that the interviewer intends to elicit from the **SME.**

Although we considered using a control group that would receive no introductory workshop on cognition, we found this to be impractical given that we wanted to compare both the amount of cognitive information elicited in the interviews and the quality of the training materials produced. In order to make these comparisons, it was necessary to provide training in how to create a Cognitive Demands Table and how to produce instructional materials to all of the participants in the study.

The high quality ratings (i.e., **SME** ratings of importance and accuracy) received by both interview groups indicate that an exposure to the concepts underlying Cognitive Task Analysis and a description of how cognitive task analytic data can be applied to instruction materials, may play a large role in learning to conduct Cognitive Task Analyses. Working only with this foundational material, in the absence of exposure to actual methodologies, some students in the Unstructured group were able to gather accurate, relevant cognitive information and develop useful instructional materials.

### Qualitative Analysis

In order to better understand the variability within the ACTA group, a qualitative analysis was conducted in which each graduate student's interview notes were examined. The combined output from each of the ACTA interviews was examined across participants by two researchers. The **goal** of this analysis **was** to look for commonalities and discrepancies across the data set, areas of confusion, and indicators that participants were having difficulty conducting the interviews. This analysis confirmed the variability suggested by the quantitative data, and provided us a better understanding of the sources of variability.

Our understanding of where participants may have struggled with the techniques (thus increasing the variability in their outputs) led to a revision of the tools. For example, we found that some graduate students using the Task Diagram Interview struggled to get the SME to describe the task globally in terms of a process, and would sometimes get lost in details. To ameliorate this problem, we reworded the initial probe from "Please decompose this task into subtasks...." to "Think about what you do when you (Task of Interest) . Can you break this down...." In addition, we found that the graduate students did not make use of the second level of decomposition recommended in the early version of the Task Diagram Interview, so we changed the instructions to say one should go to second level of decomposition only if the initial Task Diagram is too broad.

This analysis also informed us that students were having trouble changing perspectives in the Knowledge Audit Interview. The early versions of this interview instructed the interviewer to elicit an example (expert perspective), then ask why that activity is difficult (novice perspective), and finally ask the expert to describe hisher strategies (expert perspective). To reduce the confusion we reordered the questions, so that after eliciting an example (expert perspective), the interviewer asks the expert to describe his/her strategies (expert perspective), and then asks why the task would be difficult for an inexperienced person (novice perspective). The new order requires only one switch in perspective.

Analysis of the Simulation Interview notes indicated that students were having difficulty following the SME's narrative. This led us to simplify the Simulation Interview procedure. Early versions of this method included a probe regarding alternative courses of action/situation assessments and a probe about potential errors an inexperienced person might make. Graduate students had difficulty discriminating the types of information these two probes might elicit and thus ended up with considerable overlap. We eliminated the alternative courses of action/situation assessments probe to reduce redundancy and simplify the method. In addition, we rearranged the probes so that it would be easier for the SME to tell hisher story. Initially, the first probe after identifying the major decision points focused on situation assessment followed by a probe addressing courses of action. Although one typically assesses a situation before determining a course of action, in telling a story people tend to describe actions first and then fill in details about what led to that action. The order of the first two probes was reversed to accommodate the interviewees' story-telling tendencies.

**Discussion**

The findings presented here indicate that, after a 2-hour workshop defining Cognitive Task Analysis and a 6-hour workshop introducing the ACTA techniques, graduate students were able to conduct interviews with SMEs and elicit important, accurate cognitive information that was easily translated into instructional materials Furthermore, subjective reports from the graduate students indicate that the techniques are easy to use, flexible, and provide clear output. Our belief is that professional Instructional Designers and system designers will do even better than our graduate students, given that they will have more concrete goals for use of the cognitive information and more experience generating applications.

Although an attempt has been made here to establish the reliability and validity of the ACTA methods, we are aware that no well-established metrics exist. The need to test Cognitive Task Analysis methods in real-world settings with real-world tasks greatly reduces the level of control one has over the many sources of variability. Factors that are difficult to control include the fact that some people seem to be more predisposed to be good interviewers than others. In addition, some SMEs are more articulate and easier to focus than others. Given the variability among humans in both the interviewer and the SME roles, it will be important to answer such questions as: Does an SME report the same examples and the same details when asked the same question later in time? Do the Cognitive Task Analysis techniques elicit the same types of information when used by different interviewers? Do independent practitioners generate the same materials based on Cognitive Task Analysis interviews? The results of this evaluation study strongly suggest that the ACTA tools are reliable and valid, but further research is needed to establish meaningful metrics to assess the reliability and validity of Cognitive Task Analysis tools with experienced professionals.

Another point to consider is that although the ACTA methods have been shown to elicit important, accurate, cognitive information, we have yet to assess what is lost using these streamlined techniques. It is our belief that a tradeoff exists: the more streamlined and proceduralized Cognitive Task Analysis techniques become, the less powerful they are. Our suspicion is that the ACTA techniques gather less comprehensive information than more systematic techniques such as Hall et al.'s PARI method **(1994)** and Gordon and Gill's **(1992)** conceptual graph analysis, and that the information gathered is more superficial than that gathered using the Critical Decision method (Klein, Calderwood, & MacGregor, **1989)** or Rasmussen's **(1986)** cognitive analysis. In spite of the limitations of streamlined Cognitive Task Analysis procedures, the ACTA techniques provided graduate students sufficient tools to identify key cognitive elements and develop useful training materials. Until better metrics exist, however, it will be difficult to objectively assess what is lost and what is gained via different techniques.

It is also important to point out the potential impact of ignoring or minimizing cognitive issues in complex tasks requiring high degrees of cognitive skill. Despite the promise of automated and intelligent systems, the human decision maker will always play a role in systems where uncertainty and ambiguity exist. The consequences of not training operators to acquire the cognitive skills required, or not designing systems to support human problem solving and decision making can be dire, as illustrated by disasters such as Three Mile Island, the *USS Vincennes,* and Kings Cross Station, to name but a few (Reason, **1990).** Our results indicate that with minimal training, relatively inexperienced interviewers can be taught how to use the ACTA tools to obtain useful and important cognitive information in domains with which they are unfamiliar. This information will be useful in designing training and building systems to minimize errors.

The ACTA methodology was originally taught in a workshop format, which allowed the workshop presenters to tailor the methods to the audience and add personal anecdotes to the instruction. This also meant that no two ACTA workshops were the same. This made research into the reliability of the methods even more difficult to evaluate. However, more recently the ACTA training materials have been produced on a compact disk-based, multimedia training tool (Militello, Hutton, & Miller, 1996). This tool provides the learner with the reasons for undertaking a Cognitive Task Analysis, an introduction to cognition and expertise, a tutorial on the three ACTA techniques, an explanation of the Cognitive Demands Table, and sample applications. See the Stand-Alone Instruction for a detailed description of the software.

# Stand-Alone Instruction

This section describes the stand-alone instructional package intended to train Instructional Systems Specialists (ISSs) and other Instructional Designers in how to use the Applied Cognitive Task Analysis (ACTA) techniques and apply the information obtained via ACTA to training. In addition, this section includes a detailed discussion of the design rationale for the ACTA Instructional Software.

The ACTA instructional package includes the ACTA Instructional Software housed on a CD-ROM, a pamphlet outlining the content of the software, and three job aids corresponding to each of the ACTA tools. The pamphlet and job aids are included in Appendix D. The ACTA Instructional Software is described below.

## Software Description

The ACTA Instructional Software contains thorough audio and written descriptions of the three ACTA interview techniques along with visual displays that allows the participant to learn how to conduct interviews with Subject Matter Experts (SMEs). The ACTA Instructional Software is made up of three main sections. They are the Introduction, Interview Methods, and Applications sections.

The Introduction gives a brief overview of what is contained in the software. First, ACTA is defined and the essentials of the method are explained. Included in the essentials are:

- What ACTA helps you do.
- Understanding cognition and examples of cognitive elements.
- Novice vs. expert performance differences.
- The limitations of behavioral task analysis when compared with ACTA.

Secondly, the Introduction section presents an overview of the Task Diagram, the Knowledge Audit, and the Simulation Interview. And lastly, the Introduction concludes with a several tips on how to get started on conducting ACTA interviews. These include:

- Knowledge of the domain.
- Possible sources for obtaining this knowledge.

- Finding **SMEs,** and how many **SMEs** to interview.
- Interview supplies.
- Tape recording tips.
- Planning a timeline.

The Interview Methods section describes the three ACTA interview techniques (the Task Diagram, the Knowledge Audit, and the Simulation Interview), and also Tricks of the Trade for each. Each interview method is defined and describes steps on how to get started. An example of each interview method and tips for conducting these methods are described. Also included for each interview method is a practice session where the participant listens to a segment of a mock interview and then determines what the interviewer did right or wrong. Lastly, the software presents Tricks of the Trade, which pose things to remember when conducting the interviews. They include: the use of diagrams and drawings, method strengths, persistence, teaming, time issues, preparation, how to deal with conflicting information, controlling the interview, and a reminder to be flexible when using the ACTA techniques.

The Applications section includes a discussion and examples of the following:

- Advance Organizer.
- Cognitive Demands Table.
- Learning Objectives.
- Simulations and Scenarios.

The Advance Organizer is an instructional tool that serves as a bridge between known material and new material. Information gathered using the Task Diagram interview can feed directly into an Advance Organizer. Elements of an effective Advance Organizer are described. Steps to developing the Cognitive Demands Table as a tool for analyzing and consolidating data from interviews are included. Examples of cognitive learning objectives derived from a Cognitive Demands Table are presented. Lastly, in Simulations and Scenarios, guidelines and techniques are given for creating an instructor guide that emphasizes the use of simulations and scenarios to develop cognitive skills.

**Design Rationale for the ACTA Instructional Software**

The purpose of this section is to describe the goals and rationale for the design of the stand-alone instructional package. The section will describe the challenge of designing this product, the design goals, and the issues that impacted the final design. It will also describe the design process that occurred between Klein Associates and the instructional software developer.

## Goals of the Tool

The goal of this project was to develop a stand-alone instructional tool that would allow the learner to do four things:

- Understand the underlying concepts of cognition and expertise that drive the ACTA tools.
- Conduct Applied Cognitive Task Analysis (ACTA) interviews.
- Consolidate and represent the data from those interviews.
- Apply the data to training.

The intended audience is the Navy ISS community. It was anticipated that stand-alone instruction would be used on an individual basis as opposed to being used by several people at the same time. This meant that the interaction would be between a single learner and the instructional package as opposed to allowing for interaction between study partners to practice interview techniques.

## Challenges

There were several challenges posed by this effort. The first challenge was to expose the learner to key elements from the cognition and expertise literature that would help in implementing the ACTA techniques. Our experiences in the ACTA workshops indicated that people need an understanding of the types of information they are searching for if they are to use the ACTA techniques successfully. A further challenge was to teach the ACTA techniques, which included not only the knowledge elicitation interviews but also the consolidation and integration of this information into some sort of representation. Although teaching the learner basic interviewing skills was not a primary objective of the instructional software, it was important to provide some guidance regarding how to conduct a knowledge elicitation interview. A final challenge was to discuss and provide examples of how data gathered using ACTA could be used to provide improved training techniques that incorporate the cognitive skills and demands highlighted by the knowledge elicitation interviews.

**Cognition and Expertise.** One important lesson learned via the many workshops conducted is that people must have in mind what types of information they are looking for if they are to be successful in using the ACTA techniques. It was therefore critical that we identify key elements from the cognition and expertise literature, and provide examples of how those elements might play out in several domains. Although the ACTA techniques provide questions that begin to unlock the doors to expertise, the interviewer must recognize the cognitive elements and be able to make sense of them. Examples of cognitive elements in several domains are provided in the ACTA Instructional package so that the learner will have a better understanding of what types of information s/he is looking for.

In large part, the flow of the ACTA interviews is dictated by the interviewee and the responses s/he provides. This means that questioning is dependent on the previous response and no set of rigid rules or procedures will allow the interviewer to conduct these interviews successfully. The interviewer can rarely ask one question, which leads to a single response that can then be recorded allowing the interviewer to move on to the next question. The interviewer has to interpret the response based on an understanding of expert performance, and assess whether the response includes relevant cognitive information. Often the initial response will need clarification or more detail. The ACTA techniques require the interviewer to deepen beyond the initial response in most cases. The interviewer provides direction for the interview, including which portions of the task to deepen and how deeply to pursue each element. These judgments are based on an understanding of the **SME's** task and on an understanding of the clues that indicate expert performance and expert decision making. The interviewer must know what type of information s/he is looking for and whether the SME's response satisfies that requirement.

**The ACTA Techniques.** In the ACTA workshops each of the ACTA techniques was explained, followed by a demonstration of the technique, and an opportunity for the participants to practice the technique. Our intention was to follow a similar format in the stand-alone instructional package. Considerable time was spent investigating different potential media to understand the strengths and weaknesses of each, and to determine which would allow us to provide adequate explanations, demonstrations, and practice opportunities. Although the instructional content for teaching the ACTA technique had been well-rehearsed and refined, the transition to stand-alone instruction required a repackaging and condensing of the information.

Our experience teaching the ACTA techniques in workshops highlighted the fact that, in order for people to successfully use the ACTA techniques, they must have basic cognitive interviewing skills. Teaching the subtle skills of interviewing through any medium is difficult. An interview requires many interpersonal interaction skills as well as skills to elicit the required information. The ACTA interviews are not only demanding from the perspective of having to understand the individual's area of expertise, but also from the perspective of being able to get below a surface level of procedures and rules—to the level of understanding what it is that makes the individual an expert in that area of expertise.

There are many aspects of conducting an interview that require skill and confidence. For example, the interviewer must first establish rapport with the interviewee so that the interviewee feels comfortable talking about hisher job and helping the interviewer understand the job. Depending on the task being investigated, the interview may need to cover a large subject area in a limited amount of time. This requires interview time management **skills.** The interviewer must be able to listen for and understand the content, and at the same time listen for clues that will lead to the next question. While doing this the interviewer must try to document and record as much as possible from the interview.

**Data Analysis and Consolidation.** After conducting the ACTA techniques with a number of **SMEs,** the Instructional Designer must find a way to analyze the data, extracting that which will inform the development of a course and/or training materials, and consolidating it into a usable format. We recommend the use of a Cognitive Demands Table to frame this process. This process requires the Instructional Designer to have firmly in mind the type of course and/or materials s/he intends to build. In addition, the Instructional Designer must be able to recognize where the key cognitive elements of this task are, based upon what s/he has learned via the ACTA interviews. This process of data analysis and consolidation calls on the Instructional Designer's understanding of cognition and expertise, and his/her skills as an Instructional Designer.

**Applying the Data to Training.** The final step is to actually design the course or create the training materials. In the past, many of the training techniques used by the Navy have emphasized behavioral skills. It is critical in the environment in which the ISS works to be able to measure and evaluate each skill that is taught. Feedback we received from participants in our workshops indicated that a discussion of how to apply data gathered using ACTA to training would be needed for acceptance from our user community.

**Solutions**

Our first major decision was to decide on an instructional medium. We had found no analogues to teaching interviewing techniques. The closest candidates were customer service videos, which used a narrator "customer service expert" interspersed with short scenarios to illustrate points.

This led us to consider video instruction. Initially, this format was appealing because it would provide us the ability to demonstrate many of the interpersonal skills and the interviewing skills required for ACTA. It could be engaging, and would allow the use of text within the video to highlight key points and present more abstract ideas. However, further investigation into video technology and our increasing experience in teaching the ACTA techniques via workshops highlighted the limitations of video technology. Video is a very linear medium with little flexibility in terms of how the information is presented. It also does not give the learner control over the pace or presentation of the information. Video could be engaging for short periods, but allows for little variety in presentation techniques, so that over time it becomes less engaging. This technique worked well in the customer service videos we were using as an analog, but we did not believe it could accommodate the increased time requirements of our instructional package without becoming monotonous, and it did not provide the flexibility necessary to teach the ACTA techniques.

The next option we considered was the use of multimedia software. Computer-based technology allows the integration of computer text and graphics, with video and sound, as well as providing the learner with a large amount of control and flexibility in interacting with the material. Multimedia software would provide the ability to use video segments combined with the flexibility of non-linear, self-paced learning. This would mean that the learner would be able to choose his/her own path through the learning environment. Learners would be able to review portions of the instruction easily and flexibly, and would be able to quit and rejoin the instruction where they left off or at any other point in the program. It would allow for learner interaction with the material. This format also provided an added bonus of being very portable, and thus easily accessible to potential users throughout the Navy.

Our initial enthusiasm for this technology was soon tempered by the reality of technology limitations. The use of video requires a large amount of memory to implement, and without state-of-the-art equipment video quality quickly degrades. This meant that in order to illustrate the interview techniques using video, we could easily consume most of the memory on a single CD-ROM and still end up with low resolution, grainy images that would be difficult to interpret. Elements such as facial expressions and other nonverbal indicators of interpersonal skills related to interviewing would be lost. In addition, the programmers indicted that without state-of-the-art equipment to play the CD, sound-video synchronization would be degraded. Memory constraints would reduce the length of each video clip to between 20 and 30 seconds. This small amount of time would reduce our ability to convey the subtleties and difficulties of conducting these interviews.

Although technology limitations ruled out the use of video within the instructional software, the flexibility of the medium still qualified multimedia software as the most effective format for teaching the ACTA techniques. To replace the use of video, instructional programmers recommended the use of still photos accompanied by audio interview segments. The use of these is described below.

## The Software Design

In establishing the look and feel, architecture and functionality of the system, we worked very closely with instructional software designers from Multimedia Learning, Inc. Klein Associates provided the content and architectural framework for the system. The instructional developers provided much of the creative input and offered options for functionality. In designing the software, instructional principles as well as human factors design principles were taken into consideration.

Our primary design goals were for the instructional package to be:

- Appealing to the learner.
- Easy to navigate through.
- Consistent in its interactions and prompts.
- Logical in the progression of ideas, methods, and applications.
- Easy to understand, despite subtle concepts.
- Engaging.

### Appeal to the Learner

The instructional package had to generate immediate interest from the learner. The first aspect of this is the initial look and feel of the system—its visual appeal. We tried several different graphical looks for the package, with different styles of graphics and different color schemes. The goal was to produce a look that was engaging. The graphics had to be visually interesting, but not distracting.

Another critical aspect in appealing to the learner was to identify a need, and to demonstrate how ACTA could fill that need. The need in this case is to be able to extract information from experts about the cognitive skills needed to conduct a specific task, capture that expertise and cognitive skill, and then apply that information in the form of training. The first several frames and narrations of the package introduce the need and the benefits of ACTA in addressing that need.

### Easy to Navigate

The second key element in the design of the system was the ease of navigation throughout the system. This would support the usability of the system and allow for flexible use by learners. Critical to implementing a system that would be easy to navigate is designing a straightforward architecture. The software was divided into three primary modules: an introduction, the ACTA techniques, and the analysis and application of the data to training. Each of these three primary modules consisted of three to four lessons. This simple structure means that it is easy for the learner to navigate within the software. (See Figure 10.)

Navigation is aided not only by the shallow hierarchy, but also by the constant presence of a "side-bar" with several action buttons. The first is a "Quit" button, which takes you directly out of the program. A "Menu" button takes you directly back to the main menu screen. A "Forward" button allows you to skip a frame within a lesson. A "Back" button allows you to move back a frame within a lesson, and a "Repeat" button allows you to repeat the previous frame.

In addition to these navigation aids, there is also a "Help" button, which appears at the main menu screen. This help button introduces the basics of interacting with this type of interface and describes the function of each button on the "side-bar."

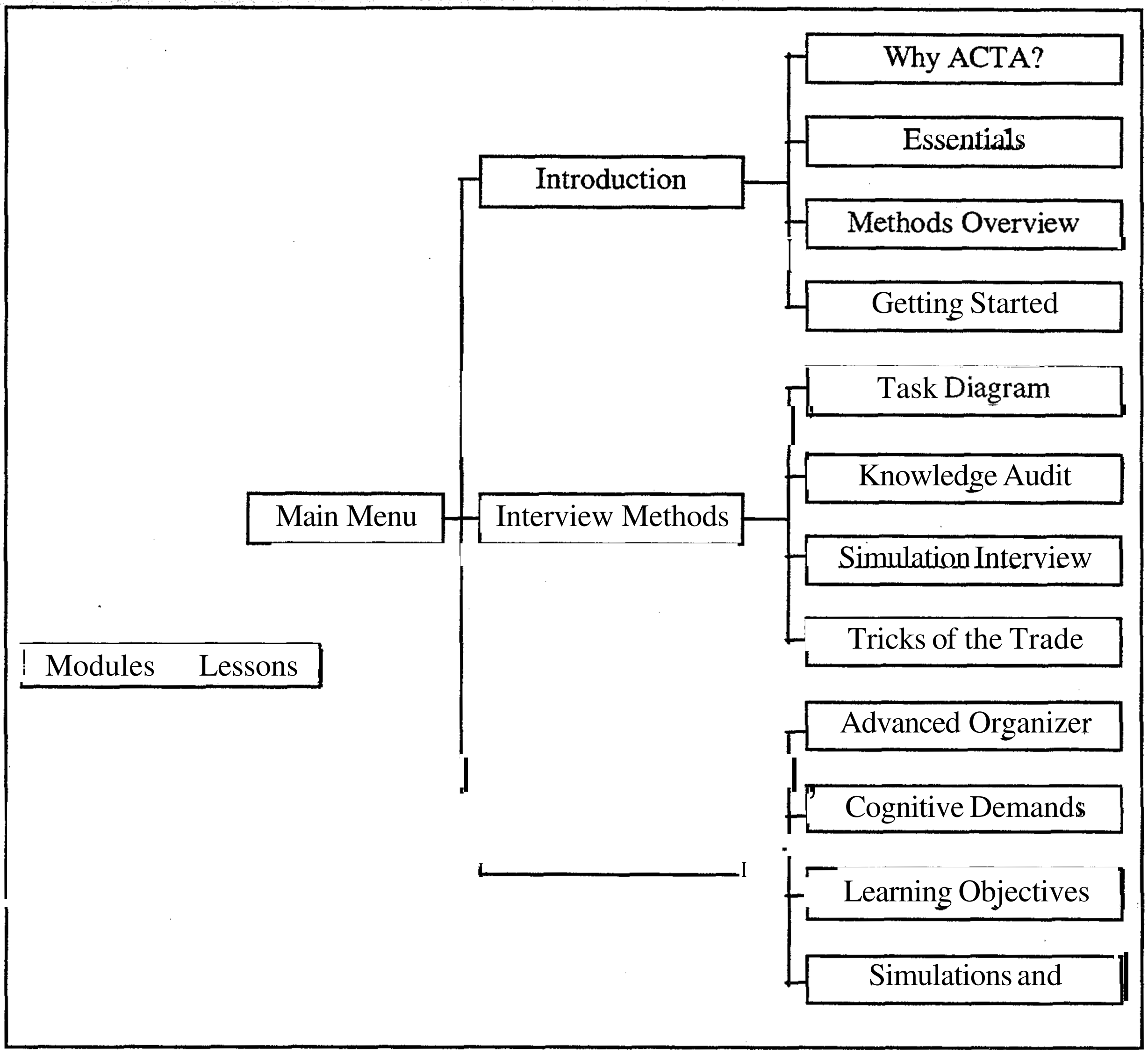



**Figure 10. ACTA software hierarchy.**

## Logical Progression

Navigation and usability are also improved by the logical flow and progression of lessons within the instructional package. The non-linear aspect of this form of computer-based training allows the learner to choose his or her own path through the modules and lessons. However, the layout of the module and lesson structure was designed to provide **a** logical progression through the introduction of concepts, the interview methods, and applications of the data to training. The learner will gain the most from **ACTA** by following this logical progression through the concepts, methods, and applications the first time through.

The heart of the package is the middle module, which presents the three interview tools and provides opportunity to see the interview in action through photo-snapshot demonstrations. The flexible format of ACTA will allow a learner to go straight to whichever section s/he is most interested in revisiting.

### Easy to Understand

A further goal of the software package was that it would be usable by ISSs and private sector Instructional Designers, who may have varying educational backgrounds and work in widely diverse domains. This meant that the flow had to be logical as explained above, and that the language and key concepts had to be defined up front. As has been explained earlier, an understanding of these key concepts and an integration of those key concepts into the interviewer's knowledge-base is important in conducting these types of interviews. Through the multiple workshops and evaluations we learned which terms and concepts were the most troublesome for people to learn. Our user analysis helped to identify terms that would be unfamiliar to our user population. As far as possible, we attempted to use words used in everyday language or words that could be understood within the context of the usage.

### Engaging

One big advantage of this form of instruction is that the multimedia format allows the use of animation, color, sound, graphics, etc. to create an engaging learning environment. This multimedia format also allows for interactions with the computer, which increase learner engagement. Our intention was to take advantage of the capability of multimedia technology to provide an interesting visual environment with meaningful graphics and text to represent the concepts, to provide an interesting audio account of the material, and to allow the learner to control and interact with the program. The goal was to avoid recreating a video-on-a-PC. In other words, to avoid having the learner sitting in front of a PC watching the instructional package play itself out much like sitting in front of a video. The next section describes our instructional approach for the instructional package, followed by the focal interactions that were intended to engage and instruct the learner in Cognitive Task Analysis.

### Instructional Approach

The basic instructional approach taken is one of encouraging the learner to model the behavior of an expert interviewer. A situation is presented, example interview questions and probes are asked by a model interviewer, the interviewee responds, and the interviewer records model notes of the responses into the appropriate table format. The learner is encouraged to watch the interaction and model the interviewer's behavior. After the appropriate interviewer behavior is modeled, exercises are provided in which the learner is asked to type in an answer or choose the correct response from a list. The learner's responses are then compared with model responses supplied by the software.

In the Introduction the learner is led though the instruction by a narrator. Contemporary, stylized graphics are used to represent the key concepts and how they are related along with text to further explain the concepts. The audio text and written text match closely but not exactly, thus providing two different presentations of the material.

In the Interviewing Methods section the narrator presents the basic procedure, probes, and data collection tools for conducting each interview. Each interview technique is illustrated with an example using an interviewer or Instructional Designer who is interviewing a Fireground Commander about firefighting. The interview process used in the example is mapped out for the learner as it progresses through each of the steps.

In the Interviewing in Action section, the learner is introduced to Lynn Thomas, a Navy ISS, and to Joe Harris, a Navy EW Technician. An example of each interview method is provided with Lynn interviewing EW1 Harris about EW operations. The interview setting is presented by multiple photograph snapshots of the interview situation, with Lynn sitting at the desk or standing at a whiteboard recording the responses, and EW Harris sitting at the desk answering Lynn's questions. Beneath the photographic representation of the interview, the table in which Lynn is recording EW Hams's responses is presented. Examples of the notes that Lynn is taking appear in the tables.

Following each clean run through an interview, the learner is then presented with a number of tough interview scenarios with tips on how to handle these situations. Some of these interview tips include exercises where the learner is required to type in his or her response to a question and then compare it to the correct answer.

The final section, Applications, reverts back to the narrator and the stylized graphics to present how to consolidate the information from multiple interviews, and how to convert that information into training materials.

### Interactions

There are four primary interactions in this program: interactions for navigation; interactions where the learner must click on a graphical object to get more information about that object; interactions where the learner must type a response to a question; and interactions where the learner must click on one or more choices in response to a question.

The purpose of these interactions is to allow the learner to progress through the learning environment and pick up the key concepts while remaining engaged with the presentation.

### Navigation

The learner can click on any of the "sidebar" buttons to go forward, skip through a frame, skip back a frame, or repeat a frame. The learner can also return directly to the main menu by clicking on the "Menu" button. These interactions are the basis of progressing through the instruction.

### Get More Information

The learner is sometimes given the option of clicking on an object on the screen (a tape recorder, a photograph, the simulation text) in order to obtain more information. This additional information is not presented in the body of the instruction as it is not critical to learning the skills of Cognitive Task Analysis.

### Type Response to a Question

During the Interviewing in Action segment of the instruction, the learner is provided with an interview scenario played out by an interviewer and interviewee, and the learner is asked to critique the interviewer's performance. The learner is asked to type in what the interviewer did well or did badly in handling the challenging interview situation. Once the learner has responded, the learner can click on an "ideal" response in order to compare their own answer to the model response.

### Multiple Choice

Following the presentation of a concept or concepts during the instruction, the learner is presented with a statement about the concept and a list of sentences, which are either related to the initial concept presented or are unrelated to the concept presented. The learner is asked to click on all the statements that are true about the initial statement. When the learner is finished, feedback is provided. After two attempts, if the learner has not identified the correct statements, the correct answers are provided.

## ACTA Software Review

The final phase of this project called for a review of the ACTA Instructional Software. Instructional design professionals were given the opportunity to review the ACTA Instructional Software. The purpose of the software review was for the instructional design professionals to evaluate the software to determine whether or not professionals in the instructional design field could learn how to use and implement the ACTA techniques from this stand-alone instructional material. For the software review, participants were instructed to review the instructional software to become familiar with three interview techniques (i.e., Task Diagram, Knowledge Audit, and Simulation Interview) and one technique for summarizing interview data (i.e., the Cognitive Demands Table), and to fill out a Software Review Questionnaire.[10]

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[10]After reviewing the software, one participant then utilized the techniques by conducting interviews with two SMEs and generating learning objectives for a potential course. The participant's subjective evaluation of the usability of the ACTA techniques was positive. Of the learning objectives that were developed based on her interviews, both SMEs rated the learning objectives as accurate and containing important information for learners.

## Method

**Participants.** Names of potential participants were provided through the Navy COTR, Dr. Josephine Randel, and through various contacts developed during the project. From the names provided, Klein Associates researchers contacted several instructional design professionals to ask if they would be interested in conducting a software review of the ACTA Instructional Software. A total of twelve participants (7 males and 5 females) evaluated the ACTA Instructional Software. Three of the participants were Navy ISSs (3 male) and six of the participants (3 males and 3 females) were commercial Instructional Designers. Three participants (2 male and 1 female) who were not Instructional Designers but were recommended because of their experience as instructors who provide input to courses in their own areas of expertise were also asked to review the ACTA Instructional Software.

**Materials.** Materials for the software review included a cover letter and instructions, which took each participant step by step through the materials and procedures. Other instructional materials included the following:

**ACTA Instructional Software.** The ACTA Instructional Software consists of a CD-ROM, which contains thorough descriptions, demonstrations, and practice opportunities for each of the three ACTA interview techniques. The software also contains instruction regarding analysis and application of data collected using the ACTA techniques.

**ACTA Instructional Pamphlet.** The ACTA Instructional Pamphlet contains an outline of the ACTA Instructional Software, incorporating graphics directly from the software. The pamphlet served as a guide to the software enabling quick reference to a particular area of interest. See Appendix D for a copy of the ACTA Instructional Pamphlet.

**ACTA Job Aids (3).** Laminated job aids listing steps for each knowledge elicitation technique, examples of knowledge representation, and interview tips were included in the instructional package. The job aids could be referred to at any time during the software review. Their primary function is for use during interviews with SMEs. See Appendix D for copies of the ACTA Job Aids.

**Software Reviewer Background Questionnaire.** The Software Reviewer Background Questionnaire was administered in order to obtain information about each participant's educational and professional background. The Software Reviewer Background Questionnaire is included in Appendix E.

**ACTA Software Review Questionnaire.** Participants were asked to complete a four-page questionnaire after reviewing the software. The purpose of this questionnaire was to get the participant's reactions to the ACTA Instructional Software. Participants were also asked to record how much time they spent in each of the three modules (i.e., Introduction, Interview Techniques, Applications). The Software Review Questionnaire included questions in which participants were asked to rate the ACTA Instructional Software based on its presentation (e.g., The concepts were clearly presented, The information was well organized), and open-end questions in which participants were asked to make recommendations for improving the software. Other questions focused on the usefulness of the techniques learned and the confidence level of the participant to conduct interviews with SMEs using the ACTA interview techniques. Response options ranged from a "1" (strongly disagree) to a "5" (strongly agree). See Appendix E for a copy of the ACTA Software Review Questionnaire.

**Procedures.** Software review packages were mailed to all of the participants. Participants could refer to the software review instructions to guide them through the steps of the evaluation. In addition, a meeting led by Dr. Josephine Randel was held for the San Diego participants to go over the instructions and answer any questions the participants might have. A similar session was held via telephone meetings with participants in other parts of the country. For the first step, participants were asked to review the ACTA Instructional Software. They were informed that this would take approximately 1.5 to 2 hours of their time. After reviewing the software, participants were then instructed to fill out the Software Reviewer Background Questionnaire and the ACTA Software Review Questionnaire. When the Instructional Designers had completed the software review, they were instructed to mail the two questionnaires back to Klein Associates. All of the participants were encouraged to contact Klein Associates researchers throughout the software review to ask any questions or voice any concerns.

## Results

**Software Review Quantitative Analysis.** Means for all of the quantitative questions were calculated[11] (see Table 6). These data show that in working through the software, Instructional Designers spent most of their time in the Interview Methods module ($M$ = 59.00 minutes), followed by the Introduction module ($M$ = **18.29** minutes), and the Applications module ($M$ = **15.86** minutes).

For each of the closed-end questions, participants reacted positively to the software. For example, participants reported that using the ACTA tools to conduct an interview with an SME would provide them with important information about the cognitive skills involved in the SME's job domain ($M$ = **4.43**). Overall, participants found the ACTA Instructional Software to be very informative ($M$ = 4.29). In addition, the Instructional Designers reported that the concepts were clearly presented ($M$ = 4.57) and the information was well organized ($M$ = 4.57).

**Table 6**

**Software Review Questionnaire Means**

| Software Review Questions | Mean (Standard Deviation) $N = 7$ |
|---|---|
| After working through the ACTA instructional software, I feel confident in my ability to use the ACTA tools to conduct an interview with a SME. | 4.00 (.58) |
| Using the ACTA tools to conduct an interview with a SME will provide me with the | 4.43 |

## Table 6

### Software Review Questionnaire Means

| Software Review Questions | Mean (Standard Deviation) $N = 7$ |
|---|---|
| After working through the ACTA instructional software, I feel confident in my ability to use the ACTA tools to conduct an interview with a **SME.** | 4.00 (.58) |
| Using the ACTA tools to conduct an interview with a **SME** will provide me with the important information about the cognitive skills involved in his or her job domain. | 4.43 (.79) |
| The Cognitive Demands Table will be a useful tool to help me organize information from the interviews I conduct with **SMEs.** | 4.00 (1.00) |
| The information in the Cognitive Demands Table will facilitate the development of course objectives. | 4.29 (.49) |
| Overall, I found the ACTA instructional software to be very informative | 4.29 (.76) |
| The ACTA tools described in the software are very similar to *the* interview techniques that I typically use when I interview **SMEs.** | 4.14 (.69) |
| Given your current position within your organization, rate how likely you would be to use the Task Diagram in an interview with a **SME.** | 3.86 (1.35) |
| Given your current position within your organization, rate how likely you would be to use the Knowledge Audit in an interview with a **SME.** | 4.00 (1.15) |
| Given your current position within your organization, rate how likely you would be to use the Simulation Interview in an interview with a **SME.** | 4.00 (1.00) |
| The concepts were clearly presented. | 4.57 (.53) |
| The information was well organized. | 4.57 (.53) |
| The examples provided were helpful. | Software Review Questions. |

**Note.** All questions used a 5-point scale where 5 is the most positive and 1 is the least positive. Standard deviations are included in parentheses.

**Software Review Qualitative Analysis.** Responses to open-ended questions were generally positive. One participant described the **ACTA** Instructional Package as "the best tutorial I have encountered on techniques for knowledge acquisition via interview." Another participant said that the instructional package was a "good start on a difficult concept for people to understand." Another participant said, "Techniques are all applicable—so much of our training is in cognitive tasks." Also, several participants briefly described relevant applications for the **ACTA** tools. Some participants offered courses for which the **ACTA** tools would be relevant (i.e., educational technical classes), while other participants noted jobs where the **ACTA** tools would be relevant (i.e., branch managers, helicopter pilots).

Requests for improvement focused on better instructions for getting started (i.e., "click on router to get started," "inform user that audio is needed"). Several participants also expressed a desire for additional practice opportunities and interactive elements in the software.

Although the quantitative data indicate that participants felt confident in their ability to use the ACTA tools to conduct an interview with an SME, responses to open-ended questions suggest that many participants intend to spend additional time reviewing the ACTA instructional materials. Others reported that they would like an opportunity to practice the interview techniques with a human before beginning a Cognitive Task Analysis. These comments suggest that although the instructional package clearly presents the concepts and procedures needed to conduct ACTA, many software reviewers believed they would benefit from additional preparation time and practice opportunities.

**Navy Instructional Systems Specialists**. As the ACTA tools were designed for use by Navy ISSs, we also examined their data separately. The ISSs responded favorably to the software. All indicated that they would recommend the ACTA software to colleagues. They all offered examples of courses they believed could benefit from Cognitive Task Analysis. One ISS commented that, "Cognitive Task Analysis is a major deficiency in our ISD (instructional system design) process. It needs to be done."

Suggestions from ISSs about improving the software included a request for stronger examples. One reviewer found the examples or tips sections in the software required a lot of concentration. Another ISS found navigation difficult and asked for a clearer statement of the purpose of the ACTA tools. One ISS found the graphics harsh and the background aesthetically unappealing.

**Workshop vs. Stand-Alone Instruction**. Responses to the question, "After working through the ACTA Instructional Software, I feel confident in my ability to use the ACTA tools to conduct an interview with an SME," varied little from people who learned the ACTA techniques via workshops ($M = 4.18$) and those who learned the ACTA techniques via stand-alone instruction ($M = 4.00$).[12] However, responses to open-ended questions indicate that people who learned the ACTA techniques via the stand-alone instruction believed they would benefit from additional practice opportunities such as those offered in the ACTA workshops.

## Conclusions and Future Research

The goal of this project was to begin to move Cognitive Task Analysis out of the research community into applied communities. We have made important progress in this direction. We have developed streamlined methods of Cognitive Task Analysis. Our evaluation study indicates that the methods are usable and aid in the development of important, accurate training materials addressing cognitive issues. In addition, we have developed a CD-based stand-alone instructional package

[12] Statistical analyses indicate these means do not differ significantly, ($t < 1$).

which will make the ACTA tools widely accessible. A review of the software conducted with both Navy ISSs and private sector Instructional Designers indicates that the software is successful in communicating the concepts behind the ACTA techniques and the procedures for conducting each technique. The ultimate success will be if these are adopted by Navy ISSs. A secondary measure of success would be adoption by Instructional Designers in the private sector.

The last 20-30 years have seen an exciting cognitive revolution in experimental psychology. Our hope is that this effort can help bring that revolution into the applied community in the form of training development that reflects cognitive as well as behavioral task requirements.

There are five key areas in which future research could expand on what we have accomplished with the current ACTA project. First, there is a need for team Cognitive Task Analysis methods. During the current project we developed the Team Schematic to capture the information flow between team members. Although development of this method was not pursued because team Cognitive Task Analysis methods are not as generally applicable as individual Cognitive Task Analysis methods, the need for such tools has been voiced in many domains. The preliminary feedback we received on these tools was generally positive, but additional research needs to be conducted to revise these tools and to develop additional methods for eliciting the knowledge and skills involved in team decision making for domains in which information flow between workers is critical.

Second, ACTA could provide valuable information for systems and interface design. Thus far, we have concentrated our efforts on developing streamlined Cognitive Task Analysis methods for use by training professions who develop instructional materials. The expert knowledge and skills elicited using the ACTA tools also have implications for systems and interface design. Future research could develop additional tools, or modify the existing ACTA tools, to facilitate their use for the Decision-Centered Design of systems and system interfaces.

Third, improved methods for designing cognitive skills training need to be developed. The ACTA interview techniques produce useful data that describe the critical judgment and decision-making skills involved in a particular domain. Additional research is needed to develop methods for translating this information into training. How does a training developer determine effective means to train novices so that they can rapidly acquire these skills? For example, some of the cognitive skills may be trained most effectively in the classroom, whereas other skills will have to be trained on-the-job. Future research efforts could develop new tools, or modify the existing ACTA tools, to facilitate the link between the expertise elicited from the SME and the optimal techniques for training these cognitive skills to novices.

In addition, future research should investigate whether effective knowledge elicitation and representation tools can be developed that reduce the role of the interviewer in this process. Although the ACTA tools are the most streamlined Cognitive Task Analysis tools available, they still require a significant time commitment on the part of the interviewer and SME. It typically takes 3 hours to use all three interview techniques with one SME. Future research could explore alternative techniques in which the SME is guided through a "self-Cognitive Task Analysis" process by using a structured questionnaire or interactive software. Although it is unlikely that this approach would result in as rich a set of cognitive demands as would be elicited by a trained interviewer, it may be possible to identify significant cognitive skills with this type of method.

A final direction for future research is to identify better metrics to assess the usability, validity, and reliability of Cognitive Task Analysis tools so that different methodologies can be compared. It will be helpful to know what is lost using streamlined techniques, and also what is gained. It would also be interesting to compare some of the more extensive Cognitive Task Analysis techniques to better understand the strengths and weaknesses of each.

This report has described a streamlined method of Cognitive Task Analysis, called ACTA—Applied Cognitive Task Analysis—that consists of three interview methods, which help practitioners extract and represent information about the cognitive demands and skills required for a task within a particular domain. Recent changes in the workplace have resulted in jobs that place increased cognitive demands on many workers. Knowledge elicitation and representation methods like ACTA will allow organizations to quickly identify the key cognitive skills involved in particular tasks and will facilitate the development of cognitively-based training for new employees.

The current effort may have moved the field two steps into the future in developing streamlined Cognitive Task Analysis techniques and creating a means to disseminate the ACTA techniques via stand-alone instruction. Cognitive Task Analysis and other cognitive technologies will never develop into widespread use as long as they are designed and developed solely for use by the research community. By trying to make these methods more accessible, we hope that we have contributed to the growth of the field of cognitive instruction and cognitive engineering

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# Appendix A

## Expertise Literature:
### Characteristics *of* Expert Performance

# Expertise Literature: Characteristics of Expert Performance

It is important to consider the nature of expertise if one is to conduct a successful Cognitive Task Analysis. In developing Cognitive Task Analysis techniques, it is important to consider what types of information are being sought and how they are likely to be stored. This section contains excerpts from the expertise literature which have influenced our thinking in developing the ACTA techniques.

<u>Nature of expertise</u>. Shanteau (1985) has distinguished between perceptual expertise (e.g., soil judgments, wine tasting) and conceptual expertise (e.g., bridge playing). This distinction seems to work fairly well. If a domain does not require any expertise, then it is not an appropriate subject for Cognitive Task Analysis. That is, if skill does not continue to grow for a period of several years, sometimes as long as 10 years, sometimes throughout a Subject Matter Expert's **(SMEs)** entire career, then the task is primarily procedural and the cost of Cognitive Task Analysis is not warranted.

<u>Expertise is domain suecific.</u> Experts tend to be experts only in their own domains of expertise. The reason for excellence in their own domains is vast domain-specific knowledge. This has been found in studies of medical diagnosis (Johnson et al., 1981), and taxi drivers' route knowledge (Chase, 1983).

<u>Experts perceive patterns.</u> Experts perceive large meaningful patterns, or chunks of information, rather than individual pieces of information. This is proposed to be a reflection on the organization of the knowledge base from a refined sense of typicality through experience. For example, the "perceptual" advantage in this view is proposed not to reside in a difference in knowledge base, per se, between the expert and the novice, but in the expert's ability to "see the invisible," or perceive when something that is expected to be there is missing.

<u>Experts are faster and make fewer errors.</u> Experts are also proposed to be able to perform more efficiently, consistently, and with committing fewer errors than novice performers. This is demonstrated in the ability of chess players while playing "lightening chess" with tight time constraints per move (Caldenvood, Klein, & Crandall, 1988). This ability is proposed to be due to the skill being learned to automaticity, where the expert does not have to analyze a situation to perform well. For example, while driving a car one is able to do so very proficiently with adequate mental resources to carry on a conversation and listen to the radio, because the skill of driving is automatic. A further possible reason is that the expert does not have to conduct extensive search for response options due to a vast library of learned responses to typical conditions (condition-action rules).

<u>Experts have superior memory in their domain.</u> Another finding is that experts have superior long- and short-term memory in their areas of expertise (Chase & Ericsson, 1982). This

advantage has been ascribed to various mechanisms. One is chunking. The information is said to be stored in meaningful patterns or chunks rather than in terms of individual pieces of information. This means that the expert can recall more than the novice. Also, the chunks of information are integrated into a richer more meaningful knowledge base which aids recall in both the long- and short-term. A further theory puts the power of the expert's memory not in the head of the expert but in the environmental constraints imposed by the task domain, in terms of the physical environment and the rules that govern it. The expert is attuned to the goal-relevant constraints in the environment and thus the information can be recalled according to, or with respect to, those constraints (Vicente & Wang, in press). This provides a mechanism for recall that allows the expert to store and retrieve the information in meaningful chunks based on the rules and constraints that govern the task. The environmental conditions are an external aid to recall.

Experts see and represent a problem at a deeper level. Novices in a domain tend to represent problems at a more superficial level, based on surface features of a problem, and on learned rules, as opposed to thinking about a problem at a deeper level. Experience provides the experts with the domain knowledge, patterns, and context that make the world meaningful to them at a causal level. For example, when asked to sort physics problems into categories, novices used literal objects stated in the problem description to sort the problems; whereas, experts used principles of mechanics to organize the problems (Chi, Feltovich, & Glaser, 1981).

Experts spend more time trying to understand the problem. This process involves building a mental representation of the problem from which relations that define the situation can be inferred. Constraints to the problem can then be added, defining the boundaries on action. This is in contrast to the novice who jumps right in and begins to manipulate the surface features of the problem. An understanding of the problem often leads to a more efficient path to the solution without being sidetracked by irrelevant information and without following fruitless courses of action. The importance of situation awareness and problem definition is a central theme for understanding expert decision making in real-world contexts.

Experts have strong self-monitoring skills. Experts have an ability to catch themselves when they make errors. They know why they cannot understand a problem, and they know when to check their solution. Novices, on the other hand, do not have the ability to realize their own limitations, and do not have a refined enough sense of what a typical solution looks like to be able to check themselves before pursuing a false line of action or reasoning.

Experts have refined perceptual abilities. This perceptual advantage that the expert has developed exists at three levels according to Klein and Hoffman (1993): the ability to see typicality, the ability to see distinctions, and the ability to see antecedents and consequences (through story building and mental simulation). It is assumed that in order for these abilities to work for the expert, an extensive knowledge base has accrued through years of experience. The assertion is not that the less experienced, journeyman performer does not attempt to use these abilities, it is more that, in the expert, these abilities are more finely attuned based on a greater number of past experiences on which to draw.

The ability to see typicality. There is no way for a novice to judge what is normal and what is an exception (Chi, Hutchinson, & Robin, 1988). In studies with expert firefighters, Klein, Calderwood, and Clinton-Cirocco (1986) found that the rapid size-up of a situation is facilitated by judging typicality of the situation which evokes several types of knowledge: recognizing relevant cues, recognizing events that are expected, recognizing plausible goals, and recognizing feasible courses of action. This ability allows the expert decision makers to direct their actions and avoid wasting efforts by seeing which goals are feasible given the situation. They are able to avoid being overwhelmed by a flood of information by focusing on the relevant cues. They are able to recognize when a situation assessment or course of action was incorrect based on their anticipation of expected events and a recognition of when those expectancies are violated. They are also able to respond rapidly based on a recognition of the typical course of action, which also means that experts are able to perform proficiently under intense time pressure (Calderwood, Klein, & Crandall, 1988).

The ability to see distinctions. Experts are particularly good at making fine discriminations, compared to the performance of the novice or journeyman. Good examples of this occur particularly in competitions where expert judges are either required to judge performance at a task, such as high diving or gymnastics, or judge some attribute of a particular item, such as prize bulls, show dogs, or watermelons. The inexperienced audience member is left wondering what it was about the winning dive A, bull X, or watermelon Z that distinguished them from the rest of the competition. This ability to distinguish subtle, but functionally important and relevant, differences between two or more similar cues or pieces of information is a skill that is acquired through active participation in a domain for many years. For more on this topic the reader is referred to the work of Shanteau (Shanteau, 1985; Phelps & Shanteau, 1978).

The ability to see antecedents and conseauences. Experts are able to build a story to explain how a situation arose and to mentally simulate how the situation will develop, or how a course of action may be played through. This ability is based on the ability to perceive typicality and resemblances to many past experiences. It also relies on the subsequent ability to generate expectancies in terms of what will happen if one chooses to follow a particular course of action. In terms of playing through a particular course of action, the experts may predict whether the course of action will have a satisfactory outcome. If the outcome is not satisfactory, the experts can see where they might trip up. This may occur because of a realization that the initial assessment was incorrect in some way, which will be highlighted by the mental simulation, or because the course of action will have consequences for the development of the situation, which may call for an alternate subsequent course of action.

This mental simulation of a course of action has been likened to the idea of "progressive deepening" used by chess masters to play out a sequence of moves and the opponents' likely responses (de Groot, 1946/1978). For more about the functions of mental simulation in skilled performance see Klein and Crandall (1995).

With specific reference to characteristics of expertise in decision-making, Shanteau (1987) presented fourteen characteristics that differentiated the decision making abilities of experts from those of novices. Briefly these include: highly developed perceptual and attentional abilities; a sense of what is relevant versus irrelevant; the ability to simplify complex problems, or "make sense out of chaos;" a superior pattern-recognition ability; the ability to communicate their expertise effectively; an ability to identify and react to exceptions to strategies; a strong sense of responsibility in backing their decisions; an ability to pick solvable problems; strong outward confidence; a strong belief in their ability; adaptability and flexibility in their response to situations; extensive and up-to-date content knowledge; automaticity in cognitive processing; a greater tolerance to stress; creativity in finding new decision-making strategies when presented with atypical situations; and an inability to articulate their decision-making processes.

These findings have been found to be robust and generalizable across many varied domains (Glaser, 1987). The fact that the research has studied individuals within a rich context, and that individuals only display expertise within their own domains, suggests the importance of the environmental or situational factors and constraints on expertise.

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# Appendix B

# Workshop on Interviewing and Training Applications

# WORKSHOP ON INTERVIEWING AND TRAINING APPLICATIONS

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# AGENDA

- Overview of project
- Discussion of cognitive skills and job performance
- General interviewing skills
- Description of learning materials to be produced by participants
- Review of research plan

# PROJECT OVERVIEW
# BACKGROUND INFORMATION

- SPONSOR: The Navy Personnel Research and Development Center

- PURPOSE: To evaluate alternative interview methods for use by Navy course **de**velopers

- PRODUCT: Improved techniques for the development of course materials for training Navy personnel

# PROJECT OVERVIEW
# RESEARCH PLAN

- Participants will attend one or more workshops to develop interviewing skills
- Pairs of participants will conduct interviews with Electronic Warfare Supervisors (EWs)
- Each participant will lead one interview with an EW Supervisor
- Each participant will observe another interview with an EW Supervisor
- Interviews will be conducted at Point Loma or Coronado
- Each interview is scheduled for a four-hour block of time

PROJECT OVERVIEW RESEARCH PLAN (continued)

- Participants will develop instructional materials

- Each participant will schedule a four-hour block of time to work

- Three types of materials will be developed

  — a cognitive demands table
  — learning objectives
  — revisions to a section of a course manual

- Participants will also be asked to complete a questionnaire to provide us with feedback on this research project

# PROJECT OVERVIEW
# BENEFITS TO PARTICIPANTS

- Participants will learn about interviewing, cognitive skills, and how to develop course materials
- Participants will be paid $250 for their time

IT IS ESSENTIAL THAT YOU DO NOT DISCUSS THIS PROJECT WITH OTHER PARTICIPANTS UNTIL THE PROJECT IS COMPLETED!!

# COGNITION

- What is cognition?

  — mental activity
  — what goes on in your head

- Cognition refers to the processing of information

  — acquisition
  — storage
  — retrieval
  — use
  — transformation
  — communication

# COMPONENT COGNITIVE PROCESSES

- ATTENTION: mentally focusing on a particular stimulus

- PERCEPTION: interpreting sensory information to make it meaningful

- PATTERN RECOGNITION: classifying sensory information to make it meaningful

- MEMORY: storage and retrieval processes

- HIGHER ORDER PROCESSES: judgments, decision making, problem solving, and reasoning

# COGNITIVE SCIENCE

- Interdisciplinary field of study that includes
  — psychology
  — philosophy
  — anthropology
  — linguistics
  — computer science
  — neuroscience

- Cognitive scientists assume that thinking involves the manipulation of internal representations of the external world

- Cognitive research focuses on these internal representations —
  — not on behaviors
  — not on emotions

# COGNITIVE RESEARCH METHODS

- Laboratory methods
  - — Response time
  - — Patterns of correct or incorrect responses
- Field methods
  - — observations
  - — interviews

# COGNITIVE FACTORS IN JOB PERFORMANCE

- Traditional approaches to the development of job training focused on behavioral aspects of the job

  — Researchers decomposed tasks into component procedures
  — This approach neglects the cognitive factors that influence job performance

- Cognitive Task Analysis

  — More recent approach to the development of training materials
  — Interviewers identify the critical cognitive factors involved in a task
  — Training materials emphasize the cognitive as well as the behavioral aspects of the job

# CONDUCTING INTERVIEWS WITH ELECTRONIC WARFARE SUPERVISORS

- Dress appropriately
- Be prepared for a three-hour interview
  - — Pencils/pens and paper
  - — Lots of questions
- Be courteous at all times
- Establish rapport
  - — Make sure interviewee is comfortable
  - — Introduce yourself and explain why you are there
- Thank the participant for his/her help.

ELECTRONIC WARFARE (EW) SUPERVISORS TASK DESCRIPTION

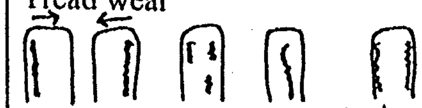
- You will be interviewing Electronic Warfare Technicians with at least seven years of experience
- They will have some experience as an Electronic Warfare Supervisor
  - They have supervised other Electronic Warfare Technicians during real-world missions
  - They make many judgments and decisions while serving as an EW Supervisor
- For the purposes of this project
  - Focus your interview questions on the cognitive factors involved in the EW's task of "signal threat analysis"

# INSTRUCTIONAL MATERIALS COGNITIVE DEMANDS TABLE

- Based on the information obtained from your interviews, develop a table that contains:

  — Difficult cognitive demands in the job
  — Why these demands are difficult
  — The important cues in the environment that the experienced EW attends to in this situation
  — What strategies the experienced EW Supervisor uses in this situation

# COGNITIVE DEMANDS TABLE

| What is the difficult cognitive element? | Why is it difficult? | What cues does an experienced driver attend to? | What strategies does an experienced driver use? |
|---|---|---|---|
| Detecting uneven wear | - Novices don't know what it is supposed to look like<br>- Novices don't realize the importance | Tread wear<br><br> | Glance at the tires on a regular basis |
| Notice a shake while driving | - Novices don't notice until the shake is very pronounced | - Steering wheel shaking<br>- Steering wheel pulling to one side<br>- Rhythmic slapping noises coming from the tire | - Play with the steering, looking for other symptoms (i.e. does it shake only at certain speeds?<br>- Listen for noises from the tires |
| Spinning tire and feeling for bumps on the tire | - Novices don't know to do it<br>- Tire is dirty and rough--hard to distinguish rough tire tread from real problem | - Look for wobble as you spin the tire--broken band<br>- Run hand along sidewall, feel for ridges--broken band<br>- Feel for bumps along the tread itself | |
| Once a problem is detected, how to diagnose or correct it? | - Novices don't understand the connection between the wear pattern and what is going on mechanically | | Imagine the tire is going down the road—what would have to be happening for it to wear like this? |

Cognitive Demands Table continued

| What is the difficult cognitive element? | Why is it difficult? | What cues does an experienced driver attend to? | What strategies does an experienced driver use? |
|---|---|---|---|
| Recognizing a tire with combination problems | Combination disguises the causes | - Small wavy bumps indicate a front end alignment is needed<br>- If the tire is no longer symmetrical, a new tire is needed (the band is broken) | Check for all possible causes: tires, alignment, mechanical problems |
| Knowing when to replace a tire | Competing forces:<br>1) customer doesn't want to spend money, 2) you want to sell tires, 3) safety/legal issues | - Tread depth | - Legal issues always take priority<br>- If the tire is marginal, exaggerate flaws--try to make it clear-cut for the customer |
| Determining if there is too much play in the tires by aggressively moving the tire sideways and up & down | May not know how much play is acceptable | - Sideways movement indicates a problem with the ball joint or steering box, or a loose bearing<br>- Up and down movement indicates a problem with the steering joint | |

# INSTRUCTIONAL'MATERIALS COGNITIVE DEMANDS TABLE

Purpose: To organize ALL the information you gathered from the interviews with the two EWs

Remember: The focus of the interviews is on the cognitive aspects of the signal threat analysis task

Common questions:

- How much detail should you include in the cognitive demands table?
- How many cognitive demands should you identify?

# INSTRUCTIONAL MATERIALS LEARNING OBJECTIVES

- Course developers specify learning objectives that guide their design of course materials

a After you complete your interviews, you will be asked to develop learning objectives based on the cognitive factors you have found to be important

- A learning objective is a statement of what the trainee can do after training (completing the course or part of the course)

- A learning objective should include the following two elements:
  — Behavior
  — Conditions

# INSTRUCTIONAL MATERIALS LEARNING OBJECTIVES BEHAVIOR ELEMENT

- A BEHAVIOR usually has three elements

  — the subject (which is always the trainee and may be implied or explicitly stated)
  — an action verb describing what the trainee is expected to do
  — an object describing what the action verb acts upon

EXAMPLE: The student will administer the Standford-Binet Intelligence Test.

# LEARNING OBJECTIVES
# ACTION VERBS

| PHYSICAL SKILLS | | MENTAL SKILLS | KNOWLEDGE COMMUNICATION | ADMINISTRATIVE SKILLS |
|---|---|---|---|---|
| accomplish | load | achieve | communicate | administer |
| adjust | locate | analyze | define | coordinate |
| align | manipulate | calculate | describe | decide |
| apply | measure | choose | explain | deliver |
| balance | move | compare | express | draw |
| calibrate | operate | compute | identify | fill out |
| change | perform | condense | illustrate | instruct |
| check | plot | decide | list | list |
| clean | position | derive | name | manage |
| complete | remove | determine | state | report |
| construct | repair | diagnose | summarize | submit |
| correct | replace | distinguish | tell | |
| deenergize | show | evaluate | write | |
| demonstrate | start | interpret | | |
| employ | stop | monitor | | |
| energize | test | observe | | |
| enter | trace | recognize | | |
| exchange | troubleshoot | select | | |
| inspect | use | solve | | |
| install | utilize | synthesize | | |
| isolate | | | | |

# INSTRUCTIONAL MATERIALS LEARNING OBJECTIVES CONDITION ELEMENT

- The CONDITION(S) or circumstances under which the behavior will be performed

  — conditions can set limits or restrictions on performing the behavior
  — conditions can describe the help or assistance given the trainee
  — more than one condition can apply to a learning objective

EXAMPLE 1: The student will administer the Standford-Binet Intelligence Test to children without severe emotional problems.

EXAMPLE 2: With his or her supervisor's assistance, the student will administer the Standford-Binet Intelligence Test to children with severe emotional problems.

# INSTRUCTIONAL MATERIALS LEARNING OBJECTIVES

- The learning objectives should correspond to the cognitive demands listed in the cognitive demands table

- Typically, participants generate at least as many learning objectives as cognitive demands and they often generate more learning objectives than cognitive demands

- Do not combine multiple learning objectives within one statement

# INSTRUCTIONAL MATERIALS REVISIONS TO COURSE MANUAL

- After you have completed your interviews, you will be given a few pages from an instructional manual for EW Supervisors
- The manual describes behavioral factors that are important, but not the cognitive factors
- You will make suggested changes or additions to the manual based on the cognitive factors you have identified as being important
- These additions to the manual must be written in complete sentences

EXAMPLE
Additions to existing auto repair manual

## Tire rotation

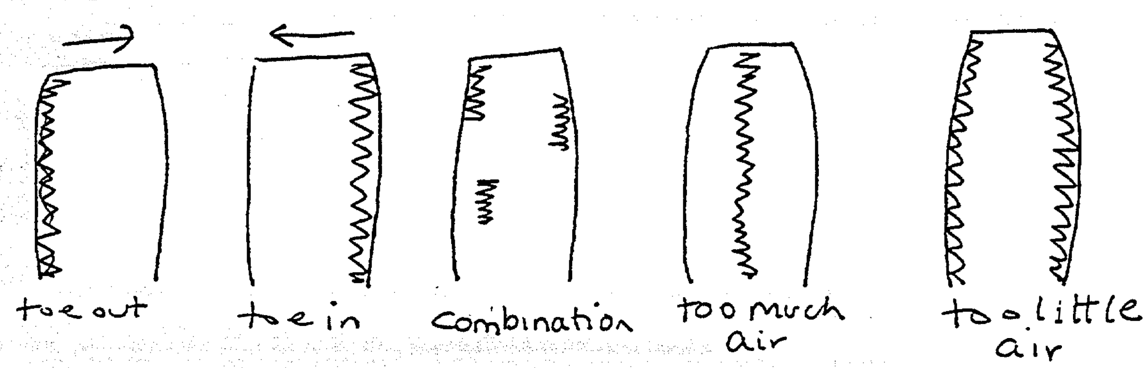
1. The tires should be rotated at the specified intervals and whenever uneven wear is noticed. Since the vehicle will be raised and the tires removed anyway, check the brakes (see Section **28)** at this time.

*It is a good idea to develop a habit of checking your tread periodically, so that you can notice changes in the tires. Other indicators of irregular tire wear occur when driving. If you notice the steering wheel pulling to one side or shaking as you drive, you should check for uneven wear on the tires. Also, if you hear a rhythmic, slapping sound as you drive, uneven tire wear is likely to be the problem.*

*When visually inspecting the tires for wear patterns, you are specifically looking for places where one part of the tire is worn differently from the rest of the tire. Some examples are provided below. Imagine the tire going down the road in order to visualize what must be going wrong in order for the tire to wear in the pattern you are seeing.*

*An additional diagnostic procedure is to manually spin the tire and watch the rotation. If you see a wobble as the tire spins or it appears to be asymmetrical, this indicates a broken band and the tire should be replaced. Also, run your hand along the sidewall as the tire spins, feeling for ridges. Ridges in the sidewall also indicate a broken band. Next, run your hand along the tread itself: If you feel small wavy bumps, a front end alignment is needed.*

*Finally, grip the tire and aggressively try to move the tire sideways and up and down. Some play in the tire is to be expected. If you can easily move the tire sideways, there is likely to be a problem with the balljoint or steering box, or a loss bearing. Excessive up and down movement indicates a problem with the steering joint.*




2. Radial tires must be rotated in a specific pattern (**see illustration**).

3. Refer to the information in Jacking and Towing at the front of this manual for the proper procedures to follow when raising the vehicle and changing a tire. If the brakes are to be checked, do not apply the parking brake as stated. Make sure the tires are blocked to prevent the vehicle from rolling.

4. Preferably, the entire vehicle should be raised at the same time. This can be done on a hoist or by jacking up each corner and then lowering the vehicle onto jackstands placed under the frame rails. Always use four jackstands and make sure the vehicle is firmly supported.

5. After rotation, check and adjust the tire pressures as necessary and be sure to check the lug bolt tightness.

*6. Make any necessary mechanical repairs. If necessary, have an alignment done.*

**7.** For further information on the Wheels and Tires, refer to Chapter 10.

## Size-Up Task Description

The *size-up* task is critical to each incident a firefighter confronts. The firefighter must combine preincident information (environmental conditions, water supply, area knowledge, departmental resources, etc.) with what s/he sees and hears from the time of dispatch to arrival on the scene. This information is combined into an initial assessment or size-up of the situation, and is used to communicate information about the situation to other firefighters and to develop a plan for a course of action. In addition to the *initial size-up*, information is gather throughout the incident so that continual updates are made to the *ongoing size-up*.

We believe that the size-up task requires considerable cognitive effort and skill. Your task is to interview experienced firefighters about this task, so that the cognitive elements can be documented and included in course materials.

Signal Threat Analysis Task Description

## Combat Information Center and
## the Electronic Warfare (EW)Technician

### General Background[1]

Combat Information Center (CIC) is the technical center for all U.S. Navy ships. This room is where all the ship's sensors (radars, sonars, radio communications, EW equipment) are controlled, all weapons systems (guns, missiles, torpedoes) are fired, and where all tactical decisions, both offensive and defensive, are made. The atmosphere in CIC is cold and dark with only blue lights and the sounds of computer equipment, and radio communications nets playing over speakers; there are no windows and one door. CIC is wall-to-wall consoles. The Tactical Action Officer (TAO) is in charge. He is the officer responsible to the ship's Captain (the Commanding Officer or CO) for using the ship's weapons in combat. If you have seen the movie *Huntfor **Red** October,* you know what it's like. During the ship's highest state of alert, general quarters (GQ), all consoles will be used (manned-up, battle stations). When GQ is set, no one leaves his position, no breaks, no quitting. Everyone is serious and tensions are usually high. Most of the people who operate the consoles (on watch) are on an eight hour on — eight hour off schedule. This means they work on a console in the dark for 16 hours of the day, and most never see daylight until the ship reaches port. They eat — stand watch — sleep — stand watch, and the cycle continues. This is where EWs spend most of their time . . . on watch in CIC.

The job of an EW in CIC is to find enemy radars by listening to the sound that a radar makes when it scans the ship. They use antennas mounted outside the ship to pick up these radar signals. The main objective for the EW is to keep an enemy from being able to use radar to target a US. Navy ship and thus fire weapons (missiles). EWs do this by intercepting radar signals that are used to guide missiles to targets. If they know the enemy is using radar to target them, they will not be taken by surprise by an enemy attack. If missiles are launched, they can counter the missile by jamming the enemy radar. Jamming the enemy missile, or enemy ship's radar is also controlled by the EW. Jamming can be accomplished electronically, or by launching decoys to fool the missile or enemy radar operator. These decoys are called CHAFF. They provide false targets that appear on radar scans and confuse the missile and enemy radar operators to prevent them from successfully targeting U.S. ships.

Intercepting the enemy's radar gives another advantage. It gives the EW the tactical location of the enemy or the enemy's bearing. This bearing information allows the launching of U.S. missiles in a counter attack if it is deemed necessary by the Captain or TAO. If an attack is not made, the bearing and radar (EW) information, along with the ship's other sensor information, is used to keep an overall tactical picture (the big picture). Then senior ship personnel will try to determine the enemy's intentions and develop tactics in case of an attack.

---

[1]Summarized from notes provided by EWI Beltran, FCTCPAC.

## The EW

The EW operator uses the equipment to actually look and listen for the enemy radar signals. Once he intercepts a signal he makes an initial evaluation of the signal (friend or foe). This evaluation is then reported to the EW Supervisor, along with the bearing, and the EW operator moves on searching for other signals. The EW Supervisor puts these data into his console and using the big picture, makes the ultimate signal evaluation and reports this to other stations on his ship (like the TAO) and to other ships in the area. Once a signal has been reported to the other ships it is referred to as a RACKET.

If the signal was determined to be an immediate threat (Emergency Racket) the Supervisor has the option of launching decoys — in the case of an enemy missile — or setting GQ, or simply reporting the signal and monitoring it to maintain the tactical picture. If the EW operator misidentifies a signal, and the EW Supervisor doesn't catch the mistake, U.S. ships or aircraft may be destroyed by enemy missiles, friendly ships or aircraft may fire at other friendly units (blue-on-blue engagements), or U.S. units may fire at the wrong target.

In May 1987 the USS Stark was hit by an enemy missile, the EWs saw the enemy targeting radar and heard the enemy lock-on. What happened?

In April 1988 the USS Vincennes fired a missile and destroyed an unarmed airbus, before the captain gave the order to fire he waited as long as he could for an EW signal — none was received.

## Electronic Warfare

EWs as a rate or job in the U.S. Navy perform the following: Monitor the electromagnetic spectrum with the purpose of ANTI-SHIP MISSILE DEFENSE **(ASMD).** EWs operate and maintain the ship's electronic support (ES) and electronic attack (EA) equipment. Watch standing at the EW OPERATOR level involves operating computer equipment, making appropriate voice reports, and keeping a written log of intercepted signals. The EW SUPERVISOR oversees the EW operations and makes threat analysis decisions.

The step between EW operator and EW supervisor is usually a jump of 5-8 years of job experience. The EW rate is of a high stress nature. Recently, this rate was opened to allow females to hold this position.

Other points of interest:

— EWs support both combat and non-combat roles (EW-derived information can be used for targeting data to launch an attack, although their primary job is defensive).

— EWs maintain and launch the ship's only SOFTKILL weapons systems (electronic "jamming" or decoy of an enemy by "chaff").

— EWs operate and repair their own equipment (most other technical rates in the Navy include two separate jobs, one to operate and one to fix).

— EWs must have access to classified information (most of the job is classified SECRET by the Department of Defense).

— The written logs kept by EWs on watch are considered official documents and can be used in legal proceedings.

## Terms

| | |
|---|---|
| Bearing: | Location of an enemy signal |
| EA: | Electronic Attack — actions to degrade enemy operations (jamming/decoys) |
| Emitter: | An enemy signal |
| EP: | Electronic Protection — actions taken to prevent the enemy from denying EWs the use of their sensors (don't let enemy jam us). |
| ES: | Electronic Support — actions in support of friendly operations |
| Eval: | Evaluation of intercepted signal |
| Freq: | Frequency of an intercepted signal |
| NSG: | NATO Sea Gnat (a chaff decoy) |
| Torch: | A decoy for infra-red (heat seeking) missiles |
| Zulu Time: | A 24-hour clock used by the military for precise timing operations. This avoids confusions from different time zones. Expressed after the time, (i.e., 2300Z is the same as 11:00 pm). |

# APPLIED COGNITIVE TASK ANALYSIS

**Presented by:**

**LAURA MILITELLO, M.A.**

**REBECCA PLISKE, Ph.D.**

**ROSEMARY OLSZEWSKI, B.A.**

**November, 1995**

# AGENDA

- Background Information
- Task Diagram Interview
- Knowledge Audit Interview
- Simulation Interview
- Summary

# BACKGROUND

- Project sponsored by Navy Personnel Research and Development Center

- Develop ACTA tools for use by curriculum developers

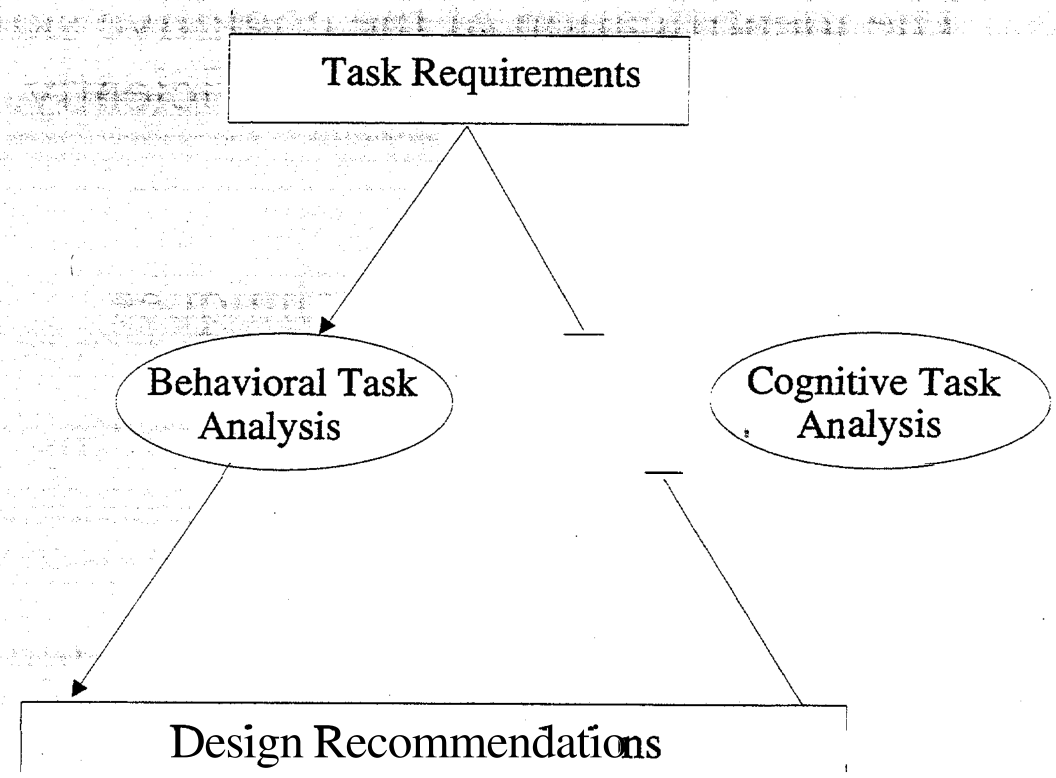
- Incorporate cognitive elements of the job into course curriculum

# Definition of Cognitive Task Analysis

CTA is:

The identification of the cognitive skills needed to perform a task proficiently.

- Includes interview techniques
- Includes methods of representing information
- Most valuable for tasks that require cognitive skills
- Focuses on key decisions and how they are made


Task Requirements
Behavioral Task Analysis
Cognitive Task Analysis
Design Recommendations

# BEHAVIORAL TASK ANALYSIS

- The attempt to decompose a task into its component operations

- Strengths: Flexible, general, logical, linked to training interventions

- Limits: Emphasis on procedures, not on judgments and decisions

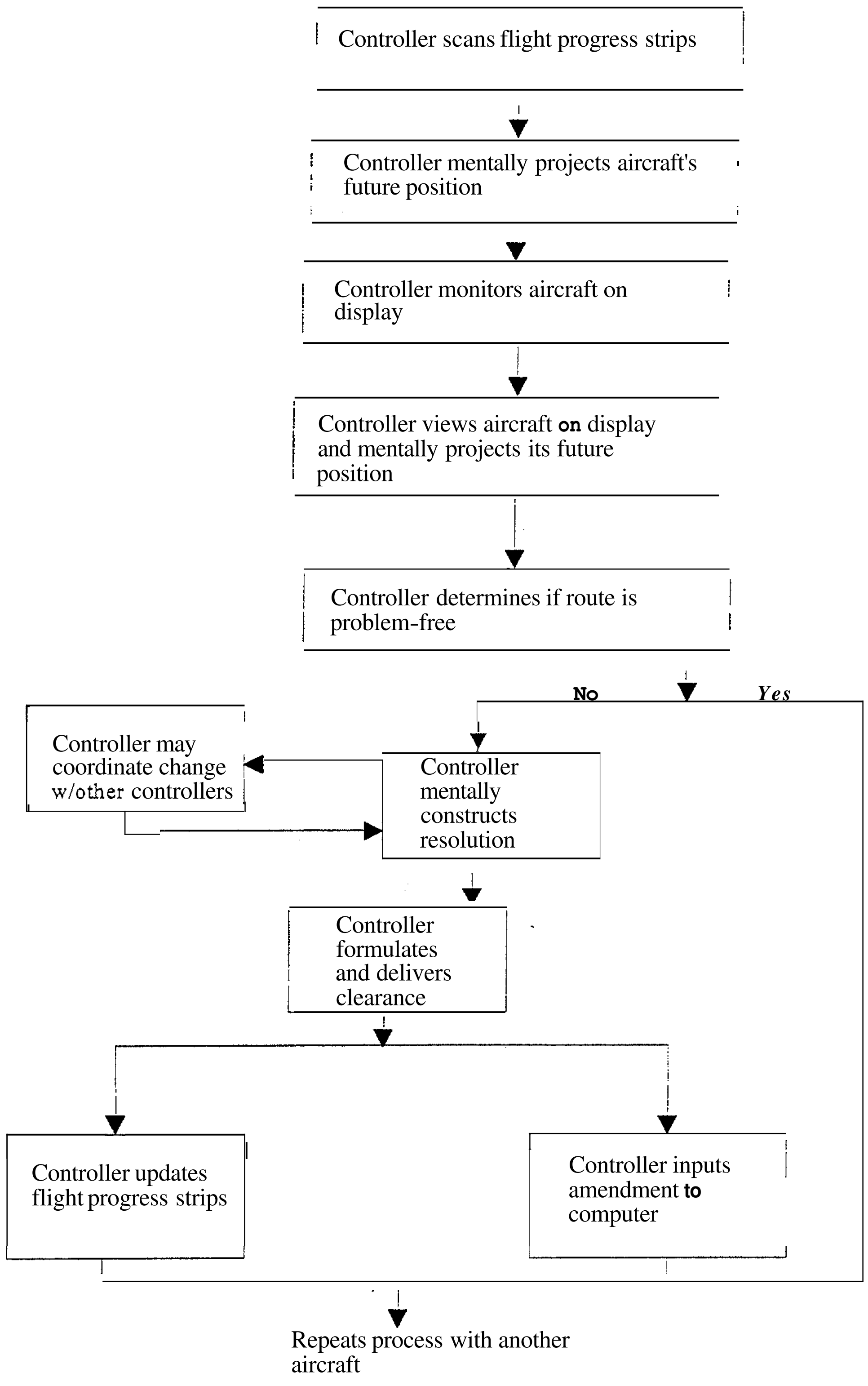
# Example of Behavioral Task Analysis

2.1 Perform Normal Takeoff Operations

2.1.2 Perform Takeoff Roll Procedures

- 2.1.2.1 Position aircraft on runway centerline and stop
- 2.1.2.2 If required, transfer control of aircraft
- 2.1.2.3 If required, comply with Standard Policy for Transfer of Aircraft Control
- 2.1.2.4 Select HDG HLD on MCP
- 2.1.2.5 Set WX radar for takeoff
- 2.1.2.6 Release brakes and set takeoff thrust
- 2.1.2.7 Advance power on both engines
- 2.1.2.8 PF call for EPR
- 2.1.2.9 PNF select EPR on MCP
- 2.1.2.10 Engage autothrottle in EPR mode as engines are accelerating through 1.1 EPR
- 2.1.2.11 Comply with Standard Policy for Takeoff and Go/No Go Decision
- 2.1.2.12 Maintain directional control
- 2.1.2.13 Monitor engine and flight instruments
  - 2.1.2.13.1 If abnormality exists, **Captain decides** and initiates rejected takeoff
- 2.1.2.14 Complete standard callouts for takeoff conditions
- 2.1.2.15 Comply with Standard Policy for Takeoff Flight Path Control Techniques
- 2.1.2.15.1 **Recognize** unstable flight path condition and be prepared to execute immediate recovery

## Behavioral Task Analysis of Air Traffic Control



# GOALS OF ACTA

- Provide interview format that allows the interviewer to elicit cognitive elements of the job
- Provide representation format that presents the data in a readily usable form
- Can be incorporated into other methods to provide a more complete picture of performance
- Easy to learn
- Easy to use

# ACTA TOOLS

- TASKDIAGRAM
- KNOWLEDGE AUDIT
- SIMULATION

# TASK DIAGRAM

- Purpose is to obtain an overview of the task
- Purpose is to identify the aspects of the task requiring expertise
- Purpose is to frame the rest of the CTA

# Applied Cognitive Task Analysis Interview Guide

# TD

## Task Diagram. Lists the procedures of a task in a linear Fashion.

**Preparation** Go into this interview knowing which task you want to analyze. You will record the interviewee's responses on a whiteboard or large paper.

**Steps**

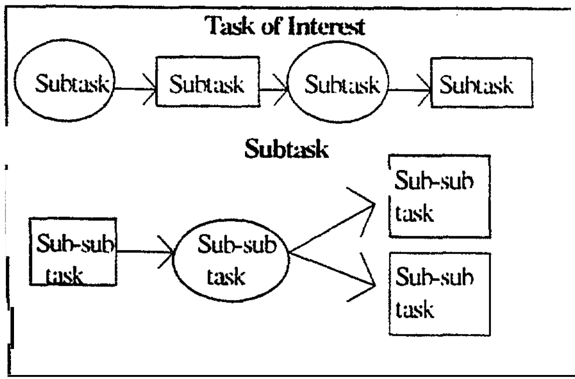
**TD-1** Record the **Task of Interest** at the top, center of whiteboard.

**TD-2** Ask the interviewee, "”Please decompose this task into subtasks. There should be at least three sub-tasks, but no more than six."

**TD-3** Record each Subtask from left to right across the whiteboard.

**TD-4** Ask the interviewee, "Which subtasks require the most expertise?"

**TD-5** Place circles around the tasks that require the most expertise and squares around the rest of the tasks.




**TD-6** Record the first **Subtask** that requires expertise on the whiteboard.

**TD-7** Ask the interviewee, "Please decompose this subtask into sub-.sub tasks. Again, there should be at least three, but no more than six."

**TD-8** Record the Sub-sub tasks on the whiteboard.

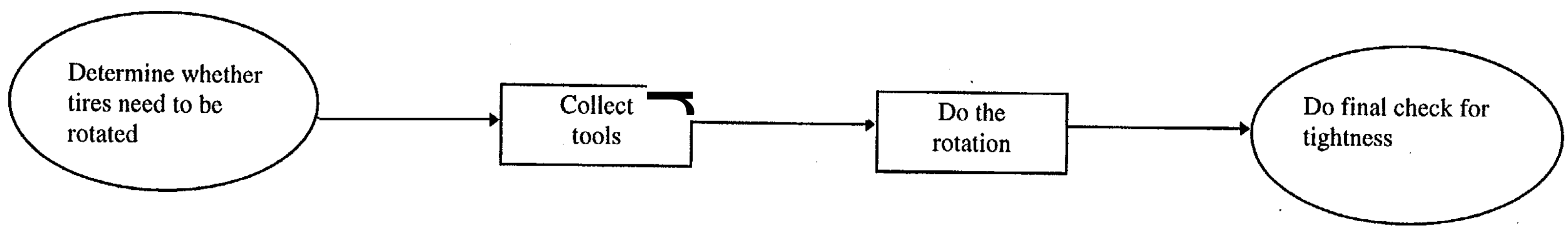
**TD-9** Ask the interviewee, "Which of these sub sub tasks require the most expertise?'

**TD-10** Circle those that require expertise and place squares around the rest.

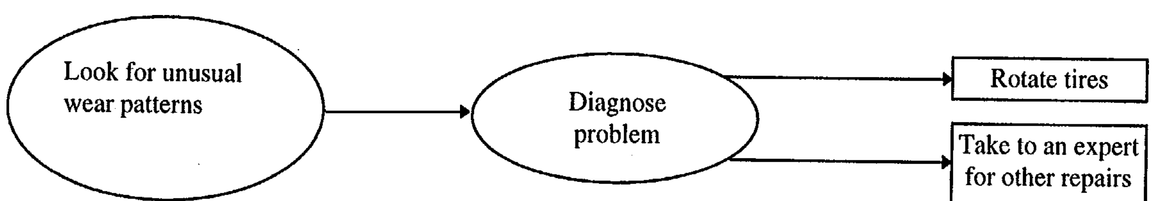
**TD-11** Continue decomposing subtasks until you have a diagram for each one that requires expertise. DO NOT decompose sub-sub tasks.

**Application** Use this diagram when conducting the **Knowledge Audit** to limit the interview to those **tasks** that require expertise.

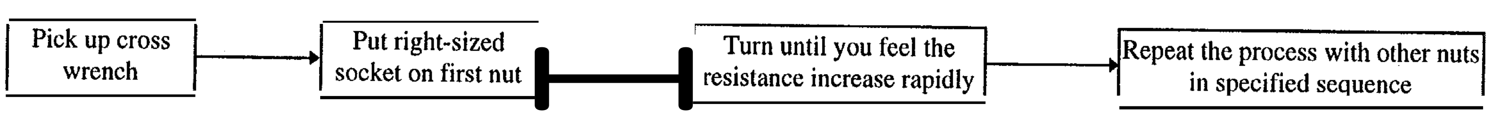
# TASK DIAGRAM: ROTATING TIRES




Determine whether tires need to be rotated




Do final check for tightness



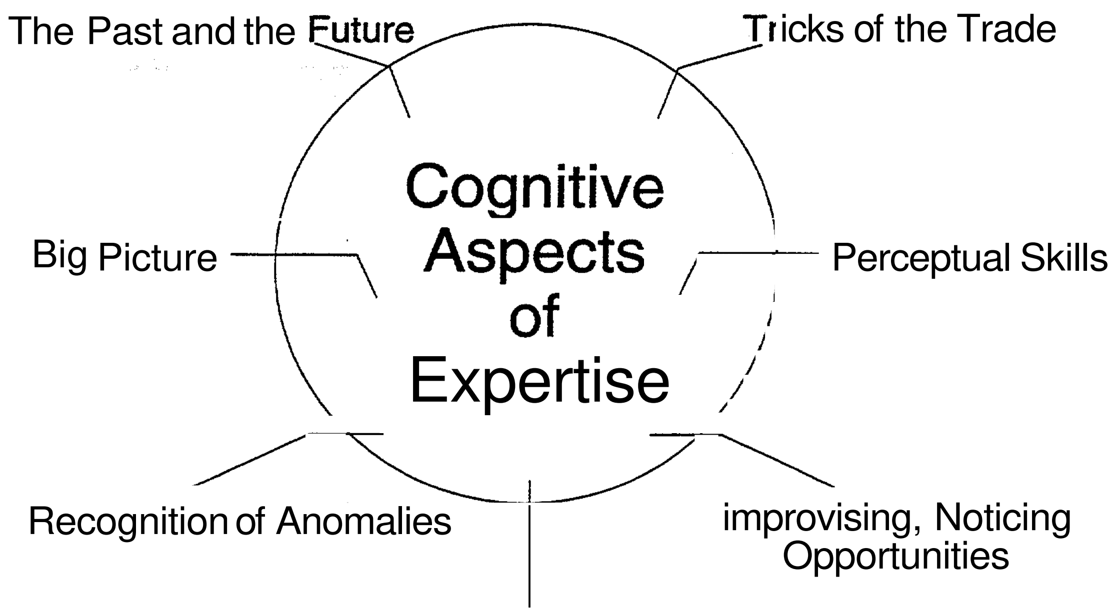
# KNOWLEDGE AUDIT

- Method for surveying key aspects of expertise

- Contrasts things that experts know and novices don't know

- Often a source of interesting incidents

# CTA Attempts to Identify the Cognitive Skills Needed to Perform a Task Well



# Applied Cognitive Task Analysis Interview Guide

KA

## Knowledge Audit. Contrasts what experts know and novices don't.

**Preparation**

In the *Task Diagram* you identified the sub- and sub-sub tasks that require the most expertise. Go into this interview knowing the sub-tasks you want to analyze.

**Steps**

**KA-1** Write the Task of **Interest** at top. center of whiteboard. Divide the remaining space into three columns with headings that match the illustration on the right.

| Task of interest | | |
|---|---|---|
| Example | **Why** Difficult | Cues & Strategies |
| 1. Perceptual Skills<br>*Example of perceptual skills* | | |
| 2. Anomaly<br>*Example of Anomaly* | | |
| 3. Past & Future<br>*Example...* | | |

**KA-2** Use the probes listed below to elicit examples of the various aspects of expertise. Record the first **example** in column one. Ask questions KA-3 and KA-4 before moving on to the next probe.

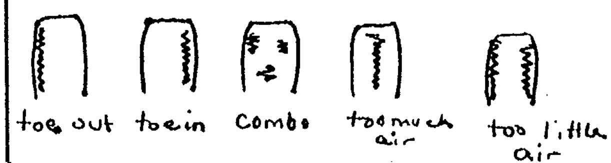
**KA-3** For each example, ask, "Why is this task hard for novices or **why** don't novices know to do **that?**" Record answers in middle column under the heading Why **Difficult.**

**KA-4** For each example, ask, "What cues or strategies do you use in this situation?" Record answers in third column under **Cues and Strategies.**

| **Expertise** | Knowledge Audit Probes |
|---|---|
| **Perceptual Skills** | Experts detect cues and patterns and make discriminations that novices can't see. Can you think of any examples here? |
| **Anomaly** | Experts can notice when something unusual happens. They can quickly detect deviations. They also notice when something that should happen doesn't. Is **this true** here? Can you give me an example? |
| **Past & Future** | Experts can guess how the current situation arose and they can anticipate how the current situation will evolve. Can you think of any instance in which this happened, either where experts were successful or novices fell short? |
| **Big Picture** | If you were watching novices. how would you know that they don-t have the big picture:' |
| **Tricks of the Trade** | Arc there tricks of the trade that you use? |
| **Improvising or Noticing Opportunities** | Can you recall a situation when you noticed that following the standard procedure wouldn't work? What did you do? Can you think of an example where the procedure would have worked but you saw that you could get more from the situation by taking a different action? |
| **Self-monitoring & Adjustment** | Experts notice when their performance is sub-par, and can often figure out WHY that is happening (e.g., high workload. fatigue. boredom, distraction) in order to make adjustments. Can you think of any examples where you did this? |
| | Optional Probes |
| **Equipment** | Unless you're careful. the equipment can mislead you. Novices usually believe whatever the equipment says. Can you think of examples where you had to rely on experience to avoid being fooled by the equipment? |
| **Scenario from Hell** | If you were going to give someone a scenario to teach someone humility--that this is a tough job-what would you put into that scenario? Did you ever have an experience that taught you humility in performing this job'? |

# KNOWLEDGE AUDIT OF AUTO REPAIR

Determining whether tires need to be rotated

| Aspect of Expertise | Why difficult | Cues & Strategies |
|---|---|---|
| Perceptual Skills<br>Detecting uneven wear | - Novices don't know what it is supposed to look like.<br>- Novices don't realize the importance. | - I know what cues to look for<br> |
| Notice a shake while driving | - Novices don't notice until the shake is very pronounced | - I glance at the tires on a regular basis. I watch them wear.<br>- Does it feel like the steering wheel is shaking or the car is pulling to one side?<br>- Rhythmic, slapping noises coming from the tire<br>- Combination of noise and shaking is a dead give-away |
| Spinning tire and feeling for bumps on tire | - Novices don't know to do it.<br>- Tire is dirty and rough. It is hard to discriminate rough tire tread from real problem | - Look for wobble as you spin the tire—indicates a broken band.<br>- Run hand along sidewall, feel for ridges—indicates a broken band.<br>- Feel for bumps along the tread itself |
| Big Picture<br>Novices can detect problem, don't know how to diagnose it or correct it. | - Novices don't understand the connection between the wear pattern and what is going on mechanically | - Imagine the tire is going down the road--what would have to be happening for it to wear like this? |
| Scenario from Hell<br>Tire with combination problems | - Combination disguises the causes, have to check for them all | |

| Aspects of Expertise | Why Difficult? | Cues and Strategies |
|---|---|---|
| | | |

# SIMULATION INTERVIEW

- Highlight cognitive elements of the task within the context of a specific incident

- Provide access to an expert's thought processes

- Identify potential errors **a** novice would be likely to make

# Applied Cognitive Task Analysis Interview Guide

# SI

## Simulation Interview. Highlights the cognitive elements of a task.

**Preparation** Obtain a simulation of the task. The simulation does not have to be high fidelity; it can be a paper and pencil simulation, video. or whatever is available.

**SI-1** Ask the **SME,** "Please review the simulation keeping in mind that I will be asking you about the decisions and judgments you would have made in this situation." Offer the SME pencil and paper on which to keep notes.

**SI-2** Divide a whiteboard into 6 columns with headings that match the illustration on the right.

| Events Decisions Judgments | Situation Assessment | Actions | Critical Cues | Alternatives | Potential Errors |
|---|---|---|---|---|---|
| *Event #1* | | | | | |
| *Event #2* | | | | | |
| *Event #3* | | | | | |

**SI-3** After the SME has reviewed the simulation, ask: "Think back over the scenario. Please list the major events/judgments/decision points that occurred during the incident. As you name them, I am going to list them in the left column on the board."

**SI-4**
**SI-** For each event in the left column, ask the questions listed below. Ask all five questions about a specific event before moving on to the next event. Record the answers to each question in the appropriate column.

- **Situation Assessment** What do you think is going on here? What is your assessment of the situation at this point in time?
- **Actions** What actions, if any, would you take at this point in time?
- **Critical Cues** What pieces of information led you to this situation assessment/action?
- **Alternatives** Are there any alternative ways you could interpret this situation? Are there any alternative courses of action that you would consider at this point'?
- **Potential Errors** What errors would an inexperienced person be likely to make? Are there cues they would miss?

# WORN TIRES SIMULATION

Worn Tires Simulation

| Events, Decisions, Judgments | Situation Assessment | Actions | Critical Cues | Alternatives | Potential Errors |
|---|---|---|---|---|---|
| Detect Problem—steering wheel shaking | Steering problem—could be anything related to steering | • Play with steering, look for other symptoms<br>• See when shaking is present and when it is not | • Shaking<br>• At what speeds does it shake?<br>• Strange noises coming from the tire—slapping noise indicates strange wear | • Wheel weight could have flown off<br>• Ball joint failure<br>• Front end out of alignment has caused the wheel to wear unevenly<br>• Wheel bearing could fail (unlikely)<br>• Steering bar could be worn or broken (unlikely)<br>• Wheel could be loose | |
| Visual inspection—uneven wear on front tires—concern | • Front end is out of alignment<br>• Rear tires are low on air | • Investigate front tires further<br>• Pump up rear tires and not worry about them<br>• Run hands along rear tires | • Appearance of the tires and the feel | The alternatives above still apply | • May not recognize the wear on the tread as a symptom of the shaking<br>• Ignore the problem |

| Events, Judgments | Situation Assessment | Actions | Critical Cues | Alternatives | Potential Errors |
|---|---|---|---|---|---|
| Take a closer look—jack up the car | Three possibilities: 1) alignment problem, 2) mechanical problem, 3) problem with the tire itself<br><br>Fluid is either brake fluid, leaky shock, wheel bearing grease, or ran over something nasty | • Spinning tire, looking to see if symmetrical<br>• Rubbing hand on sidewall and tread<br>• Aggressively trying to move tire sideways and up & down (if sideways, ball joint or steering box or loose bearing; if up & down, problem is steering joint) | • Fluid<br>• What types of bumps (small, wavy bumps—alignment or mechanical; tire isn't symmetrical—broken band)<br>• Wear on tires<br>• Looking for symmetry and play in the tire<br>• Look for leak | | • Making the wrong diagnosis<br>• May not take the fluid lead seriously<br>• May not discriminate between the two types of tire damage<br>• May not know how much play in the tire is acceptable |
| Decide what to do | It is a mechanical problem | • Fix mechanical problems<br>• Rotate tires<br>• Have front end aligned | • small wavy bumps<br>• wear pattern on tires<br>• brake fluid | | Make the wrong diagnosis |

| E ıts, Decisi udgments | Situation Assessment | Actions | Critical Cues | Alternatives | Potential Errors |
|---|---|---|---|---|---|
| | | | | | |

# Appendix C

## Additional Evaluation Study Information

This appendix contains additional information about the evaluation of the **ACTA** techniques described in Section **V.** The first section provides additional detail about the participants in the study. The second section contains the definitions of the coding categories used for coding cognitive demands. The third describes additional interviews conducted using the Critical Decision method and explains why these data were not included in our analyses. The fourth section provides an in-depth look at the group difference data and a discussion of the reasons for the large intra-group variability found in this study.

## C.1 STUDY PARTICIPANT DEMOGRAPHICS

*Firefighter Study (Dayton)*

Participants: Twelve students participated in the study, six in each group. Eight female. and four male participants (two males in each group). **All** participants were recruited from graduate psychology programs in the Dayton, OH area. The schools represented were University **of** Dayton and Wright State University.

Undergraduate Degree: Ten of the **I2** participants completed their undergraduate degrees since **1993** (ail psychology majors}. One from the **ACTA** group compieted a degree in Religious Studies in 1986. one from the Unstructured group completed a degree in elementary education in 1982.

Graduate Demee: All participants were in a graduate psychology program. In the **ACTA** group, there were three first year students, one second year, and two third-year (Ph.D.) students. In the Unstructured group there were four first-year students and two second-year students.

Work Experience**:** In the **ACTA** group, five participants had had one year or less of work experience. one had five years of work experience. In the Unstructured group, three had one year or less of work experience. three had more than a year's work experience (four years. five years. and 25 years).

Related Exuerience:

Course design: In the **ACTA** group, one person had some course design experience. the rest had none. The Unstructured group had no one with course design experience.

Teaching: In the **ACTA** group, three people had teaching experience (graduate teaching assistants); in the Unstructured group. four people had teaching experience (three grad-TAs. one elementary school teacher).

Writing Learning Objectives: One person in the **ACTA** group had had some experience. No one else had any experience.

Instructional System Design: No one had any experience with Instructional System Design.

Interviewing Experience: One person in each group had some experience.

Formal Interviewing Training: Three from each group had some experience (in an Introduction to Clinical Psych class).

| | | |
|---|---|---|
| Mean time to complete the materials development: | ACTA: | 193.5 mins |
| | Non-ACTA: | 210.67 mins |

*Electronic Warfare Study (San Diego)*

Participants: Eleven people participated (five in the ACTA group. six in the Unstructured group). Nine females and two males (one male in each group). All students were from psychology graduate programs in the San Diego area. The schools included California School of Professional Psychology. San Diego State University, and University of California at San Diego.

Undergraduate Decree: Three of the ACTA group received their degrees since 1992, one in 1985. one in 1989. All of the ACTA group held undergraduate degrees majoring in psychology. In the Unstructured group, three received their degrees since 1990, one in 1984. one in 1987, one in 1988. Four majored in psychology, one in organizational psychology, one in social ecology.

Graduate Decree: In the ACTA group. two students were in their fourth year. two in their second year. and one in the first year of a graduate psychology course. In the Unstructured group, there were three first-year students, one third-year. and two fourth-year students in psychology graduate programs.

Work Experience: Three ACTA group participants had no work experience. one had four years. one had eleven years. Two Unstructured group participants had no work experience, the remainder had five, nine. ten, and thirteen years of work experience.

Related Experience:

Course Design: One participant in the Unstructured group reported any experience with course design.

Teaching experience: Two ACTA participants had graduate Teaching Assistant experience. four Unstructured group participants had graduate Teaching Assistant experience.

Writing Learning Objectives: No one had any experience.

Instructional System Design: None.

Interviewing Experience: Three of five in the ACTA group had had various interviewing experience. Three of six in the Unstructured group had interviewing experience.

Formal Interviewing Training: Three ACTA participants had some formal (mostly clinical) interviewing training. Two of the Unstructured group had training (clinical).

| | | |
|---|---|---|
| Mean time to complete the materials development: | ACTA: | 194.5 mins |
| | Non-ACTA: | 216.17 mins |

## C.2 DEFINITIONS OF COGNITIVE CATEGORIES FOR CODING COGNITIVE DEMANDS

(adapted from Rasmussen et al., 1994, *Cognitive Systems Engineering,* p. 64)

Identify state of the environment

1) Information collection: searching for, detecting, and/or recognizing cues or patterns of cues in the environment that will be used in situation analysis.

2) Situation analysis: interpreting and/or integrating information collected from the environment (i.e., assessing, determining).

3) Diagnosis: explaining the current state of the environment by linking observed events to causal factors.

Evaluation of current state relative to current objective

4) Prediction: consideration of future conditions relevant to the current situation.

5) Value judgment: consideration of personal or cultural values relevant to the current situation.

6) Choice: evaluating (in order to select from) a set of two or more alternative strategies or courses of actions to determine the "best" one.

Selection of course of action

7) Planning: determining the set of actions required for implementing an effective response to the present objective.

8) Scheduling: determining the timing for implementation of planned actions.

## C.3 CRITICAL DECISION METHOD INTERVIEWS

Two experienced Klein Associates researchers conducted Critical Decision method interviews with three experienced Electronic Warfare (EW) supervisors in San Diego in November. 1995 and with two experienced firefighters in Dayton in January, 1996. The Critical Decision method interviewers attended the initial workshop given for students in the firefighter study in October, 1995 to learn about the types of training materials they would be required to develop. They watched the videotape of the EW supervisor used in the initial workshops provided for students in the EW study prior to conducting their Critical Decision method interviews with EWs. The Critical Decision method interviewers spent four hours developing Cognitive Demands Tables, learning objectives, and modifications to the student manual based on their interviews with the EWs. They spent an additional four hours developing Cognitive Demands Tables, learning objectives, and modifications to the student manual based on their interviews with firefighters.

The goal of gathering Critical Decision method data was to have a set of criterion data with which to compare data gathered using other techniques. Unfortunately, a lack of available Subject Matter Experts (SMEs) prevented the completion of a full-scale Critical Decision method Cognitive Task Analysis. A typical Cognitive Task Analysis conducted using the Critical Decision method includes at least six interviews with SMEs. The materials generated from the Critical Decision method interviews with two (firefighter) and three (EW) SMEs did not turn out to be comprehensive. and thus could not be used as a criterion with which to compare the data collected using other techniques. Qualitative analysis of these data indicate that the Cognitive Demands Tables generated based on Critical Decision method data tended to include higher-level, broader-based cognitive demands with much more depth to fill out each demand than the Cognitive Demands Tables generated based on ACTA data or unstructured interview data.

Although it would be interesting to explore the question of what is lost using streamlined Cognitive Task Analysis techniques as opposed to an in-depth method such as the Critical Decision method. that was beyond the scope of this evaluation of the ACTA tools.

## C.4 ADDITIONAL GROUP DIFFERENCE DATA

This section includes differences observed in the questionnaire data, followed by a table depicting the means and analyses conducted in examining the validity of the data gathered using the ACTA techniques and unstructured interviews. Interpretation of these findings is not included because of the large intra-group differences and small sample sizes in our data. This combination of factors makes interpretation of group differences difficult.

Interviewee Questionnaire. A three-way, mixed design **ANOVA** taking into account Domain (Firefighting, EW), Interview Type (ACTA. Unstructured), and Question (4 questions from the Interviewee Questionnaire) showed significant main effects for interview type ($F$ (1, 20) = *3.60*, $p$

= .07) and question ($F$ (3, 60) = **6.13,** $p$ = .001). The main effect of Question is of little interest to this study, suggesting that the responses to each question on the questionnaire varied significantly. The main effect for Interview Type indicates that the experience of the interviewee in an **ACTA** interview and an unstructured interview **is** not the same.

Interviewer Ouestionnaire. **A** three way, mixed design **ANOVA** taking into account Domain (Firefighting. EW), Interview Type (**ACTA.** Unstructured). and Question (9 questions from the Interviewer questionnaire) showed a significant main effect for Question. This main effect is of little interest in this study as it merely indicates that responses varied between the questions asked. In addition to this main effect, a three-way interaction between Domain. Interview Type, and Question was revealed.

Question 8 demonstrated a significant main effect for Domain. Participants in the EW study agreed more strongly with the statement, "I **was** able to use the information to make important changes in the course materials." (**$M$ = 3.82, $SD$** = .98) than participants in the Firefighter study (**$M$ = 2.92, $SD$ = 1.08), $F$** (1, 19) = **4.84, $p$** = .04. We hypothesize that this difference may be due to the nature of the materials presented to the two groups for revision. The sample student manual used in the Firefighter study contained more detail than the sample manuai used in the EW study due to differences in the ways in which the two skills are taught and the classification level of much of the EW task. This provided considerably more opportunity to add information to the EW manual.

Table **7** depicts the groups means and analyses conducted examining group differences for each of the validity measures. The data transformation is described in detail in Section V of this report.

**As** discussed in Section V, **we** attribute the lack of group differences in this study to large intra-group differences. In examining the data. the large standard deviations throughout stand out as an indicator that we were not successful in reducing intra-group variability sufficiently. The difficulty associated with interpreting data with large intra-group variability was intensified by the small sample sizes used in our study. Although an attempt was made to match the groups on age. gender. and education level, we found considerable difference in the students' comfort level and ease in conducting interviews (as observed by investigators).

Table 7

Validity Measures and Analyses Exploring Group Differences

| Validity Measure | Firefighter | | Electronic Warfare | |
|---|---|---|---|---|
| | ACTA N= 6 | Unstructured N=6 | ACTA N=5 | Unstructured N=6 |
| 1) Does the information gathered address cognitive issues? | | | | |
| Percent of items in Cognitive Demands Tables rated as cognitive. | 92% | 93% | 94% | 80% |
| 2) Does the information gathered deal with experience-based knowledge as opposed to declarative knowledge? | | | | |
| Proportion of information in the Cognitive Demands Table experienced personnel likely to know. averaged across users. | .95 (0.05) | .93 (0.03) | .90 (0.09) | .79 (0.18) |
| Proportion of information in the Cognitive Demands Table that is relevant for a Fireground Commander/Electronic Warfare Supervisor. averaged across users. | .73 (0.10) | .88 (0.07) | .87 (0.10) | .93 (0.07) |
| 3) Do the instructional materials generated contain accurate information that is important for novices to learn'? | | | | |
| Mean important ratings for modifications to the student manual. Ratings on a 3-point scale. where 1 = Not important. 2 = Somewhat important. and 3 = Very important. | 2.06 (.63) | 2.35 (.42) | 2.50 (.18) | 2.10 (.44) |
| Mean important ratings for learning objectives. Ratings on a 3-point scale. where 1 = Not important. 2 = Somewhat important. and 3 = Very important. | 2.68 (.21) | 2.67 (.36) | 2.30 (.21) | 2.44 (.28) |

Table 7 (Continued)

| Validity Measure | Firefighter | | Electronic Warfare | |
|---|---|---|---|---|
| | ACTA N= 6 | Unstructured N=6 | ACTA N=5 | Unstructured N=6 |
| Mean accuracy ratings for modifications to the student manual. Ratings on a 2-point scale. where 0 = Not accurate. 1 = Accurate. | .90 (.09) | .90 (.15) | .12 (.13) | .16 (.14) |
| Mean accuracy ratings for learning objectives. Ratings on a 2-point scale. where 0 = Not accurate, 1 =Accurate. | .94 (.08) | .91 (.09) | .51 (.18) | .58 (.12) |

Note. *Standard deviations are included in parentheses.*

# Appendix D

# Applied Cognitive Task Analysis (ACTA) Software Pamphlet and Job Aids

# APPENDIX D

## APPLIED COGNITIVE, TASK ANALYSIS (ACTA)

## SOFTWARE PAMPHLET

## AND

## JOB AIDS

# APPLIED

# COGNITIVE

# TASK

# ANALYSIS

# ACTA

Klein Associates Inc.
582 E. Dayton-Yellow Springs Road
Fairborn, OH 45324
(937) 873-8166

The accompanying disk contains a tutorial describing the concepts underlying Cognitive Task Analysis, how to conduct the ACTA techniques, and a discussion of how data collected using ACTA can be applied to instruction. Access to these powerful techniques will allow you to identify and articulate the difficult cognitive elements of a job, so that they can be incorporated into your courses.

This pamphlet provides an overview of the information contained in the ACTA instructional software.

## System Specifications

- 486DX2-66 MHz, PCI or SCSI-2 device bus
- 16 bit Soundblaster compatible sound card with speakers
- Video card with at least 2 MB of RAM, 64-bit data path
- Quad Speed CD-ROM
- Windows 3.1 or Window 95
- Standard screen size of 640 X 480
- Resolution setting for thousands of colors

## ACTA Instructional Software
## Start-Up Instructions

**To run the program from the CD-ROM drive using Windows 95 or Windows 3.1:**

1. **Insert the ACTA CD-ROM disk into your CD-ROM disk drive.**

2. **Windows 95 users select Run from the Start menu on the task bar. Windows 3.1 users select Run from the File menu in your Windows Program Manager.**

3. **a. Type: D:\ACTA.exe in the Command Link text and select "OK" (if your CD-ROM drive is not D then make sure you've indicated the appropriate drive)**
   **b. Or, select "Browse," locate your CD-ROM drive, select the icon "ACTA.exe," and select "OK".**



## Table of Contents

# INTRODUCTION

**Why ACTA?**
**Essentials**
**Methods Overview**
**Getting Started**

1

Why ACTA?

## Applied Cognitive Task Analysis
## ACTA

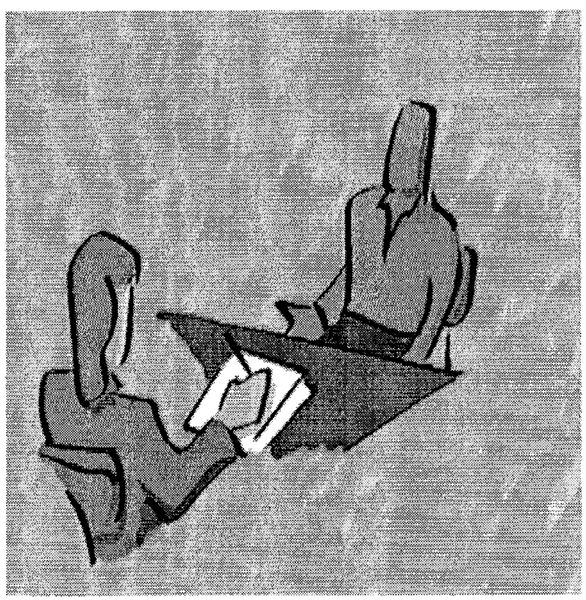
- Uses three interview techniques
- Elicits information about the task
- Provides tools for representing knowledge

2

Essentials

## ACTA Helps You

- Discover difficult job elements
- Understand expert strategies for effective performance
- Iden ify errors that novices would [illegible]

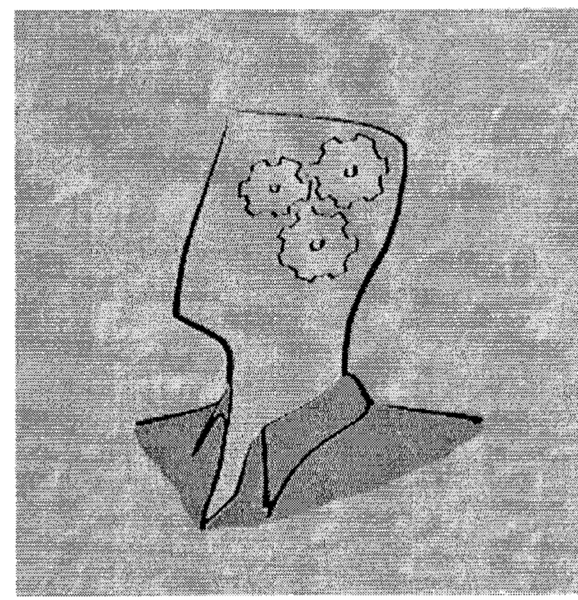


3

Essentials

## Understanding Cognition

- Cognition relates to mental activities or things that go on inside your head.
- Cognitive tasks require the use of mental processes that cannot be observed.



4

Essentials

## Examples of Cognitive Elements

- Decide
- Judge
- Notice
- Assess
- Recognize
- Interpret
- Prioritize
- Anticipate

5

Essentials

## Novice vs. Expert Performance

### Novice

- Basic job / task knowledge
- Limited experience

### Expert

- In-depth job / task knowledge
- Wealth of experience

6

Essentials

## Performance Comparison

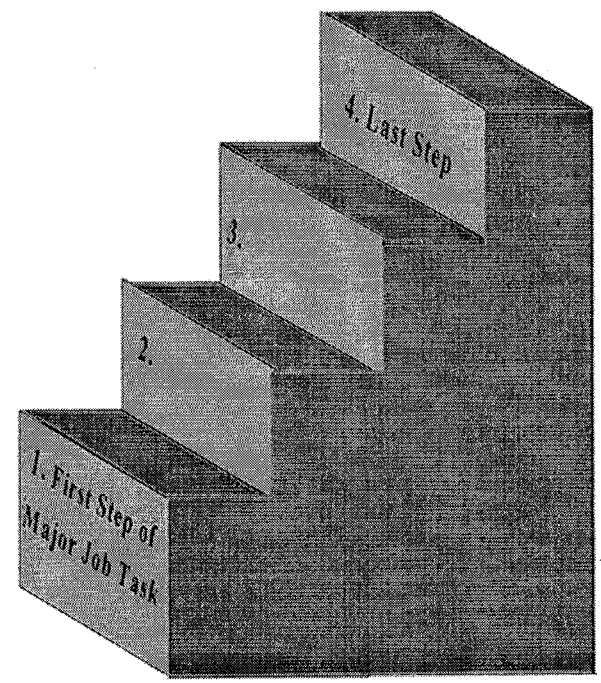
| Novice | Expert |
| --- | --- |
| ■ Inflexible — bound by rules | ■ Flexible — adapts to circumstances |
| ■ Rigid, inefficient | ■ Confident, efficient, fluid |
| ■ Reverts to trial & error quickly | ■ Assesses situation & develops strategy |
| ■ Focuses on parts of the problem | ■ Focuses on the entire problem |

7

Essentials

## Behavioral Task Analysis

- Reliable, objective method
- Used to develop training
- Breaks task or job into procedural steps

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Essentials

## Behavioral Task Analysis

| Strengths | Limitations |
| --- | --- |
| ■ Flexible | ■ May overlook the hidden, cognitive aspects of a task |
| ■ General | ■ May oversimplify a complex task |
| ■ Logical | ■ Less valuable for highly complex cognitive tasks with few observable behaviors |

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Essentials

## Air Traffic Controller: A Highly Cognitive Task

- Detecting potential conflicts
- Mentally projecting an aircraft's future position
- Identifying when to tell an aircraft to change its altitude or direction in order to keep it away from other aircraft
- Deciding which action would be most effective
- Prioritizing the multiple problems of this kind that must be handled quickly, while continuing to monitor other situations

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Methods Overview

## Applied Cognitive Task Analysis ACTA

- Is most valuable for tasks that depend on thinking skills
- Completes picture begun with behavioral task analysis
- Provides a process for describing cognitive skills

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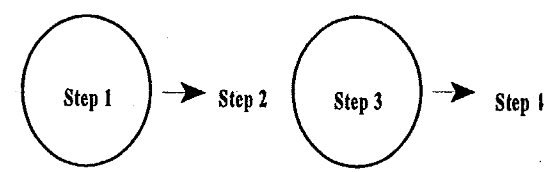
Methods Overview

## Task Diagram

- Provides a broad overview of task
- Identifies which parts of the job or task require complex cognitive skills
- Serves as a road map for the rest of your interviews




12

Methods Overview

## Knowledge Audit

- Elicits examples of cognitive skills
- Elicits detailed information about selected task
- Contrasts expert and novice performance

| Examples | Cues & Strategies | Why Difficult? |
|---|---|---|
| | | |

13

Methods Overview

## Simulation Interview

- Focuses on a specific scenario
- Provides view of task in context
- Identifies

<u>cues</u> used in assessment
<u>strategies</u> implemented
<u>errors</u> novices make

| Events | Actions | Situation Assessment | Critical Cues | Potential Errors |
|---|---|---|---|---|
| | | | | |

14

Getting Started

## Knowledge of the Field

- Vocabulary —
  jargon & acronyms
- Equipment
- Environment

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Getting Started

## Possible Sources

- Student / instructor manuals
- Task analysis data
- Movies, novels, documentaries
- Observing on-the-job performance

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## Finding Subject Matter Experts (SMEs)

- To find the experts you want to interview, ask a few high-level, experienced people in the field how many years it takes to become "seasoned" or "expert" at the job.
- Use this as one of your criteria, and ask managers to recommend people who have at least that many years of experience and who the manager would describe as highly skilled.
- As you recruit people, keep in mind that your interviews will work best if participation is voluntary. It is difficult to conduct a successful interview with a reluctant interviewee.





## How Many Experts to Interview?

**Interview 3 to 5 experts because...**

- Interviewer knowledge increases
- Information is verified among experts
- Buffer is provided for unsuccessful interviews

## Interview Supplies

- Whiteboard
- Tape recorder
- Paper and pencils
- Simulation





## Tape Recording Tips

- Ask permission
- Test the recorder to be sure you know how it works
- Use clip-on microphones, if possible
- Use quality tape
- Test the recording at the beginning of the session to adjust for ambient noise levels

Getting Started

## Why Use Whiteboard or Flip Chart?

- Provides shared image of the task and what has been said
- Prompts the SME to offer valuable corrections
- Stimulates additional comments

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Getting Started

## Planning Your Timeline

- Become familiar with new field
- Allow three hours for each set of ACTA interviews —

  20 minutes for Task Diagram
  60 minutes for Knowledge Audit
  90 minutes for Simulation Interview

- Contact S early
- Allow time for data analysis

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## INTERVIEW METHO

**Task Diagram**
**Knowledge Audit**
**Simulation Interview**
**Tricks of the Trade**

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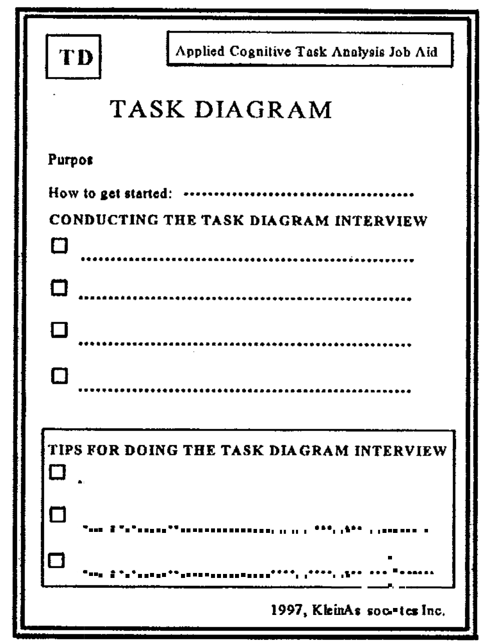
Task Diagram

## Task Diagram

- **Provides a broad overview of task**
- **Directs focus of ACTA process**
- **Serves as a road map of the task**
- **Identifies which parts of the job or task may require complex cognitive skills**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Applied Cognitive Task Analysis Job Aid

TASK DIAGRAM

Purpos

How to get started:

CONDUCTING THE TASK DIAGRAM INTERVIEW

TIPS FOR DOING THE TASK DIAGRAM INTERVIEW

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Task Diagram

## Before You Begin

- Have clearly in mind the task you want to investigate
- Discuss with SME the purpose of the interview
- Discuss with SME that you are looking for a broad overview

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Task Diagram

## Task Diagram Example

**Can you break this task down into steps — between three and six?**

**Getting the call** → **Pre-assessment of the situation** →

**On-scene assessment** → **Assign tasks**

**Continued on next page**

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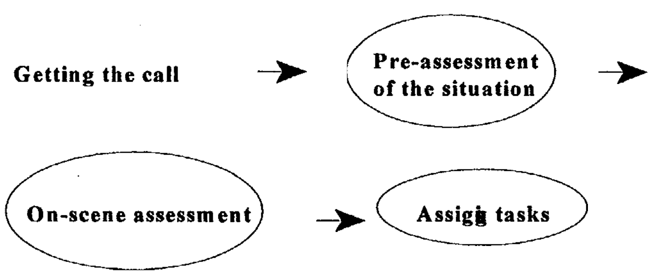
Task Diagram

## Task Diagram Example

Of these steps, which ones require cognitive skills? By cognitive skills I mean complex thinking skills such as judgments, assessments, or problem solving.

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Task Diagram

## Tips for Task Diagram

If SME talks at fine level of detail, redirect him or her to get broad steps.

Give the SME time to think; you may need to repeat or rephrase the question.

Reframe question if SME lists things to consider rather than tasks.

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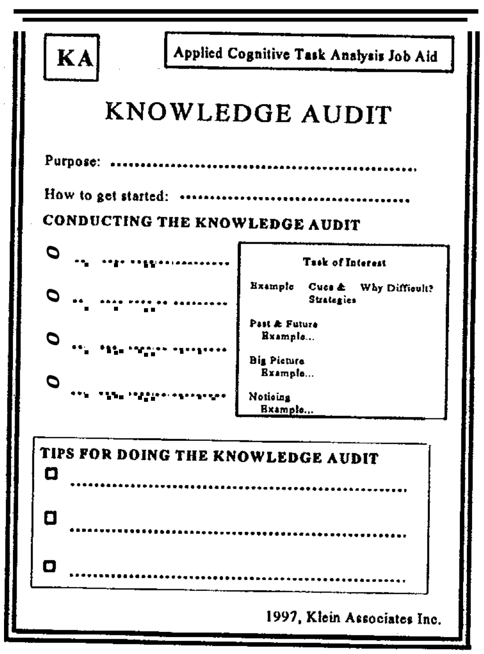
Knowledge Audit

## Knowledge Audit

- Uses probes that address different aspects of expertise
- Uncovers difficult elements of the task
- Contrasts experts and novices






Knowledge Audit

## Knowledge Audit Table

| Examples | Cues & Strategies | Why Difficult? |
|---|---|---|
| | | |

What's the big picture for this?

In this situation how would you know this?

What cues and strategies did you rely on?

In what ways would this be difficult for a novice?

Knowledge Audit

## Knowledge Audit Probes

- Investigate cognitive elements of expertise
- Illuminate different aspects of cognitive skills
- Apply to different domains

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KKnowledge Audit

## Basic Probes

**Past and Future**: Experts know how the situation developed and know where the situation is going.

**Big Picture**: Experts understand the whole situation and understand how the elements fit together.

**Noticing**: Experts can detect cues and see meaningful patterns.

**Job Smarts**: Experts can combine procedures and do not waste time and resources.

**Improvising/Opportunities**: Experts can see beyond standard operating procedures and take advantage of opportunities.

**Self-monitoring**: Experts are aware of their own performance and notice when performance is not what it should be and adjust to get the job done.

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## Optional Probes

**Anomalies**: Experts can spot the unusual and detect deviations from the norm.

**Equipment Difficulties**: Experts know equipment can mislead and don't implicitly trust equipment.





## Knowledge Audit Example

**Can you give me an example of the big picture for this task? What are the major elements you have to know and keep track of?**

| Examples | Cues & Strategies | Why Difficult? |
|---|---|---|
| **<u>Big Picture</u>** **contacts: 2 air, [illegible] surface; watch them because don't know which will strike first** | | |

**Continued on next page**

Knowledge Audit

## Knowledge Audit Example

**In this situation, how would you know this? What cues and strategics are you relying on?**

| Examples | Cues & Strategies | Why Difficult? |
|---|---|---|
| **<u>Big Picture</u> contacts: 2 air, 1 surface; watch them because don't know which will strike first** | **Observe if they're setting up for an attack and know what changes in the signal to look for** | |

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Knowledge Audit

## Knowledge Audit Example

**In what ways would this be difficult for a less-experienced person? What makes it hard to do?**

| Examples | Cues & Strategies | Why Difficult? |
|---|---|---|
| **<u>Big Picture</u> contacts: 2 air, ω surface; watch them because don't know which will strike first** | **Observe if they're setting up for an attack and know what changes in the signal to look for** | **Don't know indicators of attack** |

Knowledge Audit

## Knowledge Audit Tips

- Repeat or rephrase the question if the SME doesn't understand it.
- Use an example from a familiar domain to help the SME understand.
- Reword the probe into the language of the expert to get a good example.
- Sometimes the SME starts with generalities; help him or her get specific by asking for examples.

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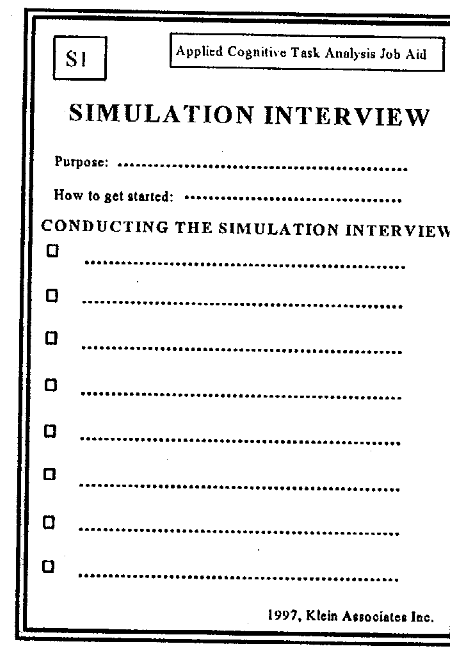
Simulation Interview

## Simulation Interview

- Discovers additional cognitive elements required by the task
- Focuses on a specific scenario to provide view of task in context



| Events | Actions | Situation Assessment | Critical Cues | Potential Errors |
|---|---|---|---|---|
| On-scene arrival | | | | |
| Initial attack | | | | |

Continued on next page





## Simulation Interview Example

**Actions: As the fireground commander in this scenario, what actions, if any, would you take at this point in time?**

| Events | Actions | Situation Assessment | Critical Cues | Potential Errors |
|---|---|---|---|---|
| On-scene arrival | Accounts for people, asking neighbors and knocking on doors | | | |
| Initial attack | | | | |

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Simulation Interview

## Simulation Interview Example

**Situation Assessment: What do you think is going on here? What is your assessment of the situation at this point in time?**

| Events | Actions | Situation Assessment | Critical Cues | Potential Errors |
|---|---|---|---|---|
| On-scene arrival | Accounts for people, asking neighbors and knocking on doors | It's a cold night; need to find place for the people who've been evacuated | | |
| Initial attack | | | | |

**Continued on next page**

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Simulation Interview

## Simulation Interview Example

**Critical Cues: What pieces of information led you to this assessment and these actions?**

| Events | Actions | Situation Assessment | Critical Cues | Potential Errors |
|---|---|---|---|---|
| On-scene arrival | Accounts for people, asking neighbors and knocking on doors | It's a cold night; need to find place for the people who've been evacuated | It's night-time; it's cold | |
| Initial attack | | | | |

**Continued on next page**

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## Simulation Interview Example

**Potential Errors: What errors would an inexperienced person be likely to make in this situation?**

| Events | Actions | Situation Assessment | Critical Cues | Potential Errors |
|---|---|---|---|---|
| On-scene arrival | Accounts for people, asking neighbors and knocking on doors | It's a cold night; need to find place for the people who've been evacuated | It's night-time; it's cold | Not keeping track of people or could be looking for people who are not there |
| Initial attack | | | | |





## Simulation Interview Tips

- **Eliciting major events is crucial. You do not want a recount of the entire scenario.**
- **If SME critiques the scenario, tell him or her you'd like to work with the scenario as it's presented.**
- **If you are confused about what to write in which column, you may need to restate or rephrase.**
- **Try not to write everything but write enough so you will know later what was said and meant.**

Tricks of the Trade

## Diagrams / Drawings

**Be prepared with extra paper and writing utensils so that you can use diagrams to clarify or explain difficult points.**

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Tricks of the Trade

## Method Strengths

**In an ideal situation, the three ACTA interviews would be used together in the following way:**

- **Task Diagram serves as road map to the interview process by identifying which parts of the task or subtasks require the most complex cognitive skills.**
- **Knowledge Audit produces detailed information about the task and contrasts expert and novice performance.**
- **Simulation Interview produces detailed cognitive information by looking at the task in a specific context.**

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Tricks of the Trade

## Persistence

Don't be put off if the first question draws a blank.

Be persistent and rephrase the question or provide an example of what you are looking for.

Prompt the SMEs to talk about the tough parts of their job, and the cognitive skills required to do a task. It is important that you follow your curiosity and ask follow-up questions until you understand. If you don't understand what the SME is telling you, keep asking questions until you do understand.



Tricks of the Trade

## Teaming

Interviewing in pairs has several advantages. First, one person can concentrate on leading the interview while the other person takes notes. Second, the flow and direction of the interview can be guided by the lead but monitored by the team member, bringing up key points that have been overlooked or helping to get the interview back on track.

General guidelines for interviewing as a team include the following:

- Decide what role each will play before the interview
- Agree on interview format and goals
- Determine tactic or style for interjecting comments or suggestions in a way that doesn't interrupt the flow of the interview

## Time Iss m

**Be aware of the energy levels of all participants so that you can initiate breaks at the most appropriate times. However, always consider the stage of the interview process when selecting a time to break. Be aware of the time and communicate anticipated time frames for each portion of the interview.**

**Don't be afraid to step back and:**

- **refocus everyone to evaluate your progress**
- **take a breather**
- **check your notes**
- **think about the next line of questions**

**You may find it easier to break up the interviews. If so, conduct a Task Diagram and Knowledge Audit in one session, and conduct the Simulation Interview the next day. Be flexible and don't wear out your SMEs.**





## Preparation

**Be prepared. It is important that you understand how the ACTA techniques work and what types of information you can expect to obtain. Be sure to take some time to become familiar with the domain before you begin interviews. This knowledge and confidence will allow you to guide the interviewee.**

**You will evolve as an interviewer. Depending upon your familiarity with the job you are investigating, it may require a couple of interviews before you are confident that you understand the types of tasks involved and have a clear idea of what information you are looking for.**

## Conflicting Information

**Points of conflict among interviews are always worth investigating, even with just a phone call.**

**Follow up by starting with the expert who provided the unusual response and explain how other opinions differed.**

**If the interview subject is no longer available, consult another expert. Remember to focus on the response, not the individual.**

**The "conflict" may be a misunderstanding, or the expert may provide additional insight omitted by the others. In fact, there may be more than one "expert" approach.**





## Control

**Interviews are not conversations, and it is important that you stay on track. Have goals for your interview and stick with them.**

**You need to guide the interview. If you don't understand an example that the interviewee relates, ask questions until you do understand. If the interviewee is getting drawn into a discussion of aspects of the task not relevant to your goals, redirect the interviewee so that he or she knows what you are after.**

**Based on your training goals, you have to decide how much time is available and how to concentrate your resources.**

Tricks of the Trade

## Flexibility

**One of ACTA's major strengths is its ability to be adapted to your own training goals.**

**Remember that your goal is to get useful information. As you become more experienced with these tools, you may discover ways to adapt them so that they are more useful to you in the context of your work setting.**

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## APPLICATIONS

**Advance Organizer**
**Cognitive Demands Table**
**Learning Objectives**
**Simulations and Scenarios**

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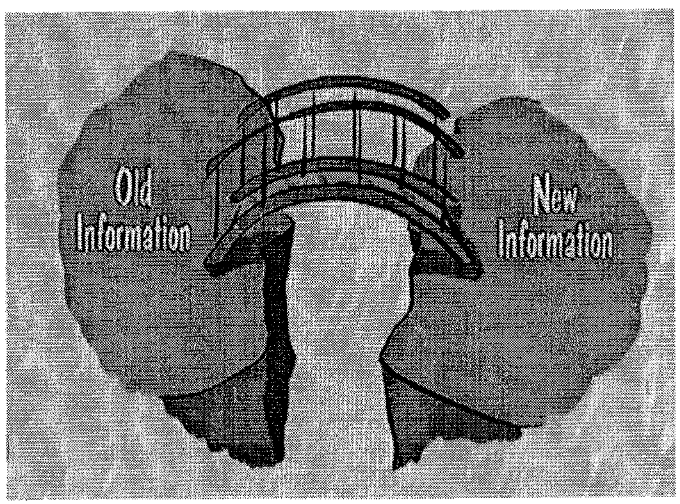
Advance Organizer

## Advance Organizer

- Serves as bridge between known material and new material






Advance Organizer

## Elements of an Effective Advance Organizer

- Brief paragraph showing how new content and previous knowledge are related
- Outline of new content
- Graphic of new content base on task Diagram

Cognitive Demands Table

## Cognitive Demands Table

- Select and prioritize information most useful for your training goals
- Analyze and interpret interview data
- Look for common themes

| Cognitive Demand | Why Difficult? | Cues | Strategies | Potential Errors |
|---|---|---|---|---|
| | | | | |

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Learning Objectives

## Learning Objectives

- ACTA provides raw materials for writing learning objectives that target cognitive skills.
- Cognitive Demands Table provides basic information about thinking skills.
- Information includes which skills should be taught, as well as specific performance conditions.

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## Simulations and Scenarios

- Learners compare their responses to those of experts.
- Scenarios can shape and reinforce expert performance.
- Scenarios can help evaluate how well learners understand.
- ACTA generates a wealth of detail about complex thinking skills.





## Create an Instructor Guide

The Instructor Guide should contain:

- Questions for learners that stimulate thinking about how information is used to make decisions and judgments
- Answers from experts, recorded in the Cognitive Demands Table and other interview data

## Instructor Guide Examples

**Stimulate the learner to:**

- **Seek information**
- **Integrate the information into understanding the situation**
- **Make effective decisions**





## Instructor Guide Technique #1

1. **Provide description of scenario**
2. **Ask questions for each major event**
3. **Check that points from Guide are covered**
4. **Compare answers with expert responses**

## Example Questions

- **What are the critical cues in this incident?**
- **What are the implications of these cues?**
- **What strategies could you use in this situation and why?**
- **What actions should be implemented and why?**

## Instructor Guide Technique #2

1. Present an event
2. Ask learners for an assessment and action
3. Compare answers with expert responses

## Work Though Each Event

- 1st Event
- 2nd Event
- 3rd Event
- 4th Event



**If you have questions about the information presented in this CD, please contact:**

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In cooperation with the
Navy Personnel Research and Development Center

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# TASKDIAGRAM

**Purpose:** The **Task Diagram** is intended to serve as a road map to the rest of the CTA. The **Task Diagram** acts as an advance organizer, providing an overview of the task and identifying the cognitively complex elements of the task.

**How to get start.** Before you begin, have clearly in mind what the task is you intend to investigate. In this interview, you want to find out about the interviewee's processes as s/he performs the task of interest.

## CONDUCTING THE TASK DIAGRAM INTERVIEW

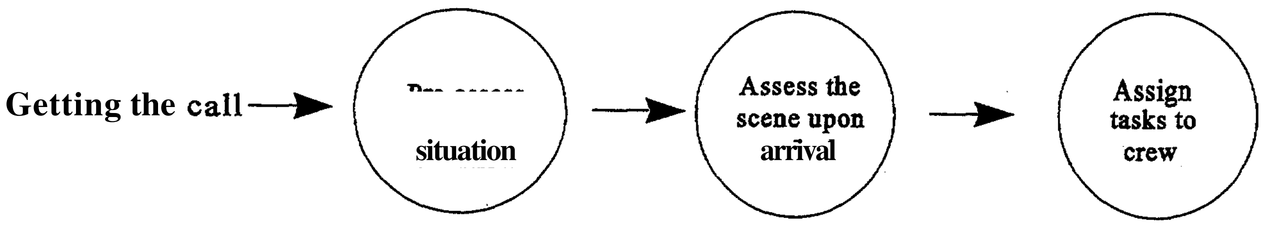
- ☐ Write the **Task of Interest** at top of whiteboard.
- ☐ Elicit the steps required to do the **task.** Record them across the board from left to right in chronological order. Use arrows to indicate the order in which the steps occur. (See back)
  - — Ask your SME, ***"Think about what you do when you*** <u>*(Task of Interest)*</u>. ***Can you break this task down into between three and six steps?"***
- ☐ Elicit information regarding which of the steps require cognitive skills. Circle the elements that require cognitive skills.
  - — Ask your **SME,** ***"Of the steps you have just identified which require difficult cognitive skills? By cognitive skills I mean judgments, assessments, problem solving—thinking skills."***

At this point, you should have a very broad overview of the task, with an indication of where the complex cognitive skills lie. If the task seems too big or the steps you have identified are too broad for further investigation, you may choose to focus on one or two of the subtasks you have identified as requiring cognitive **skills.** In **this** case, you should complete a **Task** Diagram on the step(s) you have chosen to focus the rest of the Cognitive Task Analysis.

## TIPS FOR DOING THE TASK DIAGRAM INTERVIEW

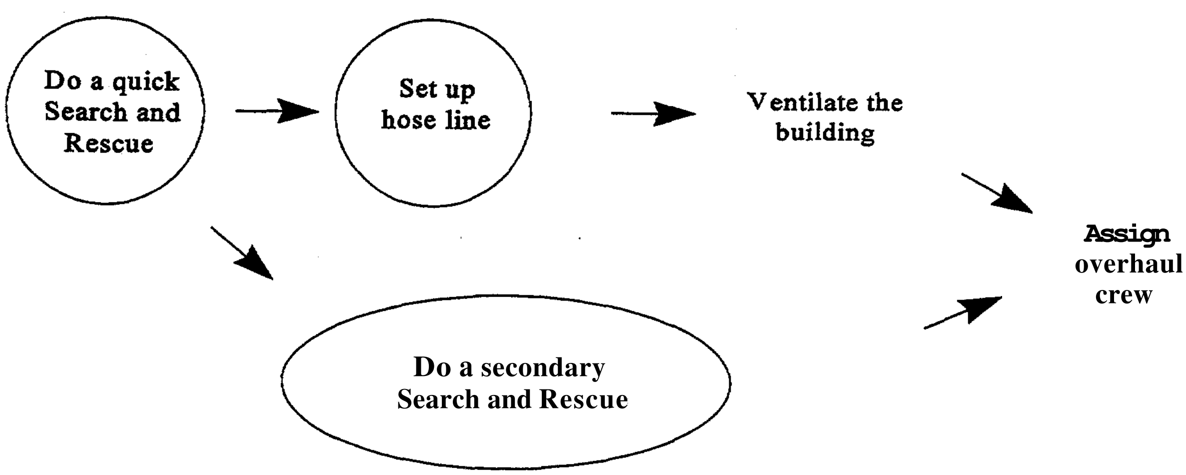
- ☐ Your interviewee may immediately start talking at a very fine level of detail. Make it clear early on that you are looking for a very broad overview with this interview. You will be interested in hearing lots of stories and details later in the session (with the **Knowledge Audit** and the **Simulation Interview).**
- ☐ If your interviewee begins listing **things** to consider rather than the steps of the task, help reframe the topic for him/her. ***"What do <u>you</u> do when you*** <u>*(Task of Interest)*</u>***?"***
- ☐ This may be a new way for the interviewee to think about the job. Give him/her time to think. You may need to repeat or rephrase the question.
- ☐ The Task Diagram serves as a road map to the rest of the Cognitive Task Analysis. You are not trying to elicit detailed, specific cognitive information with this interview. **You** are trying to get a sense of which parts of the task require complex cognitive skills.

**EXAMPLE:** **Task Diagram of Fireground Commander's Job in Commanding Crew**




**The interviewer decides this is too broad — really wants to focus on the assignment of tasks during an incident.**

**EXAMPLE:** **Task Diagram of Assign Tasks**



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# KNOWLEDGE AUDIT

**Purpose:** The **Knowledge Audit** provides details and examples of cognitive elements of expertise; it contrasts what experts know and novices don't.

**How to get started:** You used the **Task Diagram** to identify parts of the job that require skilled judgment, decision making and evaluation. In the **Knowledge Audit** you will elicit the expertise necessary to do each of those tasks. Use the Task Diagram to help you decide which tasks and subtasks you want to explore with the Knowledge Audit. Go into the Knowledge Audit interview knowing what you want to analyze.

| Task of Interest | | |
|---|---|---|
| **Example** | **cues & strategies** | **Why Difficult?** |
| Past & Future Example | | |
| Big Picture Example | | |
| Noticing Example | | |

## CONDUCTING THE KNOWLEDGE AUDIT

- Write the **Task of Interest** at top, center of whiteboard.
- Divide the space below into three columns; label as shown.
- Elicit an example of one element of expertise, using the definitions and probes provided. **Start** with the first probe, (e.g., "Is there a time when you walked into the middle of a situation and knew exactly how things got there and where they were headed?)
- Elicit information for the remaining two columns before proceeding to another element:
  - Ask your **SME,** ***"In this situation, how would you know this? What cues and strategies are you relying on?"*** Record answers in middle column under **"Cues and Strategies."**
  - Ask your **SME,** ***"In what way would this be difficult for a less-experienced person?" What makes it hard to do?"*** Record answers in final column under **"Why Difficult**?"
- It is important that you cover the six basic Knowledge Audit probes; you may also want to use some or all of the optional probes.

## TIPS FOR DOING THE KNOWLEDGE AUDIT

- Examples allow you to get at specifics and help you understand the task better. Ask for an example for each element of expertise.
- Don't try to write everything; but write enough so you will know later what was said and meant. With practice you will develop a sense of the level of detail you need.
- Some of the questions may take a few minutes for the **SME** to answer thoughtfully; don't rush; give the SME time to think over what you are asking about.
- Confusion about what to write and in which columns may be a signal that your **SME** has misunderstood your question; the information you are getting is not what you expect. You may want to take a timeout, restate the question, and check that your SME understands what you are trying to get at.

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**ELICITING INFORMATION WITH THE KNOWLEDGE AUDIT**

Provide an explanation of the type of information you want; then ask the probe questions. You can read the definitions below or paraphrase them.

***BASIC PROBES:***

- **Past & Future** Experts can figure out how a situation developed, and they can think into the future to see where the situation is going. Among other things, this can allow experts to head off problems before they develop.
  *Is there a time when you walked into the middle of a situation and knew exactly how things got there and where they were headed?*

- **Big Picture** Novices may only see bits and pieces. Experts are able to quickly build an understanding of the whole situation—the Big Picture view. This allows the expert to think about how different elements fit together and affect each other.
  *Can you give me an example of what is important about the Big Picture for this task? What are the major elements you have to know and keep track of?*

- **Noticing** Experts are able to detect cues and see meaningful patterns that less-experienced personnel may miss altogether.
  *Have you had experiences where part of a situation just "popped" out at you; where you noticed things going on that others didn't catch? What is an example?*

- **Job Smarts** Experts learn how to combine procedures and work the task in the most efficient way possible. They don't cut corners, but they don't waste time and resources either.
  *When you do this task, are there ways of working smart or accomplishing more with less—that you have found especially useful?*

- **Opportunities/ Improvising** Experts are comfortable improvising—seeing what will work in this particular situation; they are able to shift directions to take advantage of opportunities.
  *Can you think of an example when you have improvised in this task or noticed an opportunity to do something better?*

- **Self Monitoring** Experts are aware of their performance; they check how they are doing and make adjustments. Experts notice when their performance is not what it should be (this could be due to stress, fatigue, **high** workload, etc.) and are able to adjust so that the job gets done.
  *Can you think of a time when you realized that you would need to change the way you were performing in order to get the job done?*

**OPTIONAL PROBES:**

- **Anomalies** Novices don't know what is typical, so they have a hard time identifying what is atypical. Experts can quickly spot unusual events and detect deviations. And, they are able to notice when something that ought to happen, doesn't.
  *Can you describe an instance when you spotted a deviation from the norm, or knew something was amiss?*

- **Equipment Difficulties** Equipment can sometimes mislead. Novices usually believe whatever the equipment tells them; they don't know when to be skeptical.
  *Have there been times when the equipment pointed in one direction, but your own judgment told you to do something else? Or when you had to rely on experience to avoid being led astray by the equipment?*

# SI SIMULATION INTERVIEW

**Purpose:** The **Simulation Interview** provides a view of the expert's problem solving processes in context. **This** interview will provide you with specific detailed information about an expert's cognitive processes.

**How to get started:** You will need to obtain a simulation of the task. The simulation you choose should address difficult, challenging elements of the job. It does not have to be **high** fidelity; it can be a paper and pencil simulation, a video depicting a scenario, or whatever is available. It is important that the simulation you choose presents a challenging scenario.

## CONDUCTING THE SIMULATION INTERVIEW

- ☐ Divide **a** whiteboard into five columns; label as shown on the back.

- ☐ Have the SME experience (**i.e.** read, watch, interact with) the simulation.

  — Tell the **SME,** *"As you experience this simulation, imagine you are the (Job You are investigating) in the incident. Afterwards, I am going to ask you a series of questions about how you would approach this situation."*

- ☐ Elicit a list of the major events in the simulated incident and record in the first column.

  — Ask your **SME,** *"Think back over the scenario. Please list the major events that occurred during the incident. These events could include judgments or decision points. As you name them, I am going to list them in the left column of the board."*

- ☐ Begin with the first major event and elicit information for the remaining four columns before proceeding to the next major event.

  — Ask your **SME,** *"As the (Job You are investigating) in this scenario, what actions, if any, would you take at this point in time?"* Record answers in the second column under **Actions.**

  — Ask your **SME,** *"What do you think is going on here? What is your assessment of the situation at this point in time?'* Record answers in the third column under **Situation Assessment.**

  — Ask your **SME,** *"What pieces of information led you to this situation assessment and these actions?"* Record answers in the fourth column under **Critical Cues.**

  — Ask your **SME,** *"What errors would an inexperienced person be likely to make in this situation?"* Record answers in the fifth column under **Potential Errors.**

## TIPS FOR DOING THE SIMULATION INTERVIEW

- Eliciting major events is critical to this interview. The major events should be turning points or segments of the story. You do NOT want a recount of the entire scenario.

- People often want to critique the simulation. Assure your interviewee that you are interested in his/her critique, but that for the first part of the interview, you would like to work with the scenario as it has been presented. Be sure to follow up and ask for a critique at the end. The critique can yield interesting additional insight and is worth the time.

- Don't try to write everything; but write enough so you will know later what was said and meant. With practice you will develop a sense of the level of detail you need.

- Confusion about what to write and in which columns may be a signal that your SME has misunderstood your question; the information you are getting is not what you expect. You may want to take a timeout, restate the question, and check that your SME understands what you are trying to get at.

## EXAMPLE: EXCERPT FROM A FIREGROUND SIMULATION

| Events | Actions | Situation Assessment | Critical Cues | Potential Errors |
|---|---|---|---|---|
| On-scene arrival | Account for people (names)<br>Ask neighbors (but don't take their word for it, check it out yourself)<br>Must knock on doors or knock it in to make sure people aren't there | - It's a cold night, need to find place for people who have been evacuated | - Night (time)<br>- Cold — 15 degrees<br>- Deadspace<br>- Addon floor<br>- Poor materials (wood) punk board metal girders — buckle and break under fire<br>- Common attic in whole building | - Not keeping track of people (could be looking for people who are not there) |
| Initial attack | Watch for signs of building collapse<br>If signs of building collapse, evacuate and throw water on it from the outside | - Faulty construction: building may collapse | - Signs of building collapse include: what walls are doing, cracks (building ready to collapse), floor groans (floor ready to cave in), metal girders (click—coming out of wall—popping), cable in old buildings holds wall together, fire collapses walls | - Ventilating the attic, this draws the fire up and spreads it through the pipes and electrical system |

# APPENDIX E

## SOFTWARE REVIEW INSTRUCTIONS

Thanks for participating in the software review of our Applied Cognitive Task Analysis (ACTA) software. Your feedback will be of great value to us.

**Software Review**

- Work through the ***ACTA*** *software* to learn about the ACTA techniques. You will learn about three techniques (the Task Diagram, the Knowledge Audit, and the Simulation Interview), as well as a tool to help you analyze data collected using the ACTA techniques (the Cognitive Demands Table). We predict that this will take 1.5 to 2 hours of your time.

- When you are finished, please return to the **main menu** before exiting. The system will tell you how long you spent in each module of the software. Please record these times on the first page of the *Software Review Questionnaire.* These times will give us a realistic measure of how long an experienced professional spends using the software.

- Fill out the *Software Review Questionnaire* provided, describing your reactions to the instructional software and to the ACTA techniques.

- Fill out the Software Reviewer Background form.

Return the Software Reviewer Background form and the Software Review Questionnaire in the envelope provided no later than March 21, 1997.

Our goal is to have all the software review data collected by March 21, 1997. If it looks as if this will not work with your schedule, please let us know at this time.

## SOFTWARE REVIEWER BACKGROUND INFORMATION

Please answer the following questions so we can get a better understanding of your educational and professional background.

Name:

Phone Number:

E-mail address:

Current position title:

Number of years at this position:

Briefly describe your previous professional experience in the instructional design field:

What kinds of instructional materials do you typically develop?

Have you ever conducted a Cognitive Task Analysis?
Yes____ No____

If yes, what methods have you used to conduct a Cognitive Task Analysis?

If yes, how frequently do you conduct a Cognitive Task Analysis?

Briefly describe your educational background.

## SOFTWARE REVIEW QUESTIONNAIRE

Name______________________________

Date______________________________

Fill out this questionnaire AFTER you have reviewed the ACTA instructional software.

Thank you for reviewing the ACTA Instructional Software. Now we would like you to give us your reactions to the software by answering the questions below. Before you answer the questions, please record the amount of time you spend in each module of the software in the blanks provided below. (If you returned to the main menu before exiting from the program, these times should be displayed on the screen; if you exited before returning to the main menu, just skip to the Question 2.)

1. Time spent viewing the different modules in the ACTA Instructional Software:

| | |
|---|---|
| Introduction | minutes |
| Interview Methods | minutes |
| Applications | minutes |

2. Please rate the extent you agree or disagree with the following statements by circling a number on the scale below each statement.

a. After working through the ACTA instructional software, I feel confident in my ability to use the ACTA tools to conduct an interview with a Subject Matter Expert (SME).

| **Strongly Disagree** | | | | **Strongly Agree** |
|---|---|---|---|---|
| **1** | **2** | **3** | **4** | **5** |

b. Using the ACTA tools to conduct an interview with a SME will provide me with important information about the cognitive skills involved in his or her job domain.

| Strongly Disagree | | | | Strongly Agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

c. The Cognitive Demands Table will be a useful tool to help me organize information from the interviews I conduct with SMEs.

| Strongly Disagree | | | | Strongly Agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

d. The information in the Cognitive Demands Table will facilitate the development of course objectives.

| Strongly Disagree | | | | Strongly Agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

e. Overall, I found the ACTA instructional software to be very informative.

| Strongly Disagree | | | | Strongly Agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

f. The ACTA tools described in the software are very similar to the interview techniques that I typically use when I interview SMEs.

| Strongly Disagree | | | | Strongly Agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

3. Given your current position within your organization, rate how likely you would be to use each of the ACTA tools in an interview with a SME.

a. Task Diagram

| Not At All Likely | | | | Extremely Likely |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

b. Knowledge Audit

| Not At All Likely | | | | Extremely Likely |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

c. Simulation Interview

| Not At All Likely | | | | Extremely Likely |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

4. Please rate the extent you agree or disagree with the following statements about the ACTA instructional software.

a. The concepts were clearly presented.

| Strongly Disagree | | | | Strongly Agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

b. The information was well organized.

| Strongly Disagree | | | | Strongly Agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

c. The examples provided were helpful.

| Strongly Disagree | | | | Strongly Agree |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

5. What suggestions do you have for how we can improve the ACTA instructional software?

6. Would you recommend the ACTA instructional software to other colleagues?_______

If yes, please briefly describe the relevant applications you see for the ACTA tools.

If no, why not?

# Distribution List

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