

One Work Analysis, Two Domains: A Display Information Requirements Case Study

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Work domain analyses can be time consuming, requiring extensive interviews, documentation review, and observations, among other techniques. Given the time and resources required, we examine how to generalize a work domain analysis technique, namely the hybrid Cognitive Task Analysis (hCTA) method across two domains in order to generate a common set of display information requirements. The two domains of interest are field workers troubleshooting low voltage distribution networks and telecommunication problems. Results show that there is a high degree of similarity between the two domains due to their service call nature, particularly in tasking and decision-making. While the primary differences were due to communication protocols and equipment requirements, the basic overall mission goals, functions, phases of operation, decision processes, and situation requirements were very similar. A final design for both domains is proposed based on the joint requirements.

INTRODUCTION

Developing information requirements for a decision support display is a critical step in the design process both to ensure the display can actually support operators in their work, but also to communicate these requirements to the development of underlying hardware and infrastructure. Unfortunately, how to develop such critical requirements is still very much an art more than science, often reliant upon the skill and knowledge base of the individual practitioner. Few formalized processes exist to take the practitioner from a work domain or cognitive task analysis to the generation of display requirements with clear requirement traceability to some lower-level analysis. To this end, the hybrid Cognitive Task Analysis (hCTA) was developed to bridge the gap between domain and task analysis and requirements generation (Nehme, Scott, Cummings, & Furusho, 2006).

The hCTA approach combines more traditional cognitive task analysis methods (Schraagen, Chipman, & Shalin, 2000) with work domain analysis methods (Vicente, 1999) and the need to explicitly design for situation awareness (Endsley, Bolte, & Jones, 2003). As will be detailed in the next section, the hCTA method results in a list of display information requirements that can be grouped functionally or temporally and that present the designer with options for both levels of automation and the presentation of information across different channels, i.e., haptic, visual or aural.

The hCTA method has been used across a number of domains to generate design requirements and ultimately actual designs, including the development of a high speed rail scheduling display (Tappan, Pitman, Cummings, & Miglianico, 2011), an aircraft carrier deck scheduling display (Ryan, Cummings, Roy, Banerjee, & Schulte, 2011), a display to predict unmanned aerial vehicle operator performance (Castonia, Boussemart, & Cummings, 2010), and a display for single operator control of multiple unmanned vehicles (Massie, Nehme, & Cummings, 2007).

As with most cognitive task or work domain analysis methods, performing an hCTA can be very time consuming

and labor intensive. While it is important for any display design effort to account for different operational conditions that could be encountered, it would also be very helpful in terms of time and monetary resources if parts of an hCTA could be perhaps duplicated and adapted for domains with similarities. To this end, this work presents an attempt to take an hCTA for field workers in the utility domain and determine what level of adaptation was needed in order to use the same hCTA for field workers in telecommunication settings for the purpose of developing a handheld decision support system.

BACKGROUND

The hCTA method was developed in order to link work domain and task analysis techniques to the generation of display requirements in a traceable manner (Nehme et al., 2006). The primary goal of the hCTA process is to generate requirements for an interface design within a complex system, and consists of the following steps: 1) Scenario Task Overview, 2) Event Flow Diagrams, 3) Situation Awareness Requirements, 4) Decision Ladders (and jointly, display requirements and automation levels), and finally, 5) Functional and Information Requirements (Figure 1).

The details of how to perform each individual phase can be found elsewhere (Nehme et al., 2006), but the primary deliverable of such an effort is a list of information requirements for a display either categorized by functional requirements or phase of operation. Table 1 illustrates a partial list of information requirements generated from an hCTA for the function of scheduling an assignment for a field troubleshooter in a utility domain. Each information requirement is tied to its original source, either a decision ladder or a situation awareness requirement.

Like most work domain analysis methods, the hCTA can be time consuming, requiring extensive interviews, documentation review, operation observations, etc. Given the time and resources required, we decided to investigate just how generalizable an hCTA in one domain could be for another, and the practical limitations for doing so.

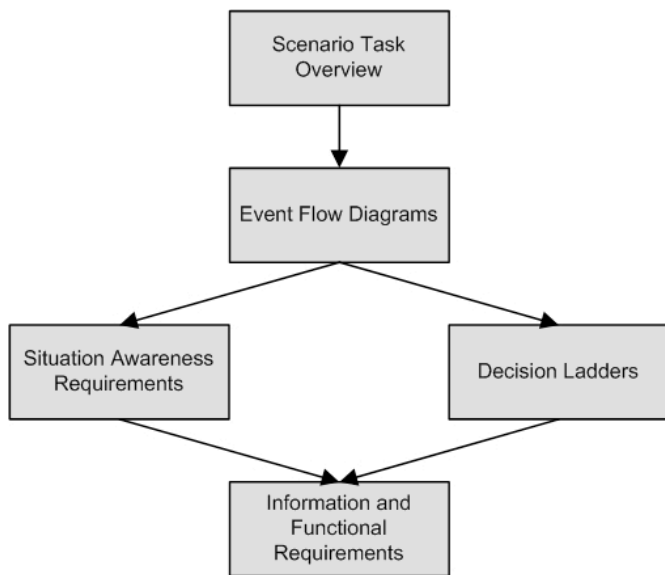


Figure 1: The hybrid Cognitive Task Analysis Method

Table 1: Partial Information Requirements for Utility and Telecommunication Field Workers

IR #	Information Requirement	Source of Requirement
1	Assignment time window	SAR1
2	Completion of issue within assignment window	SAR1
3	Available assignments	SAR1
4	Current time	SAR1, SAR2, SAR4, SAR9, SAR17
5	Selected issue assignment	SAR1, SAR5
6	Assignment location	SAR2
7	Estimated time to travel to assignment location	SAR2
8	Customer details	SAR2, SAR6
9	List of reported issue symptoms	SAR2, SAR12, SAR15, DL-DR
10	Estimated time to resolve issue	SAR2, SAR17, DL-DR

IR: Information Requirement,
 SAR: Situation Awareness Requirement,
 DL-DR: Decision Ladder Display Requirement

- The Motorola device is too bulky for phone use, the stylus is often lost, and the screen gets scratched due to pencil and pen use as replacement input devices.

When examining these seemingly different domains, some clear commonalities emerged, detailed in the next section.

THE COMMON WORK DOMAIN ANALYSIS

As mentioned previously, the first step of the hCTA is the Scenario Task Overview (STO). The STO formalizes the mission statement, in our two cases to respond to customer service calls, into a set of distinct phases and functions, and their associated tasks, similar to a hierarchical task analysis (Kirwan & Ainsworth, 1992). Each phase represents a different process step to be performed by the operator (either temporally or by function). Implicitly, each phase has a set of sub-goals that the operator is trying to achieve, which can be represented as specific tasks.

For both of the utility and telecommunication domains, five common phases were identified relating to a troubleshooter's mission of receiving and responding to a customer issue: Issue Selection (IS), Navigation to Issue (NI), Issue Review (IR), Issue Diagnosis (ID), and Issue Completion (IC). Both domain troubleshooters followed almost identical sequences in their first level of tasks required to support the phases. Indeed, for the utility domain there were 22 overall tasks, while in the telecommunication domain, there were 20. The difference was due to the extra steps of donning and doffing safety attire for utility workers.

In the next phase of the hCTA, an event flow diagram was developed which captures the temporal constraints (i.e., when and in what order) of events and tasks that occur within a specific phase of a mission. Typical event flow diagram elements include 1) Processes which define interactions between the operator and hardware and software in the

THE DOMAINS

The first domain we examined was that of a field troubleshooter of low voltage distribution networks in the power utility domain who must attend to calls from customers experiencing power and gas problems in residential settings. Currently these field workers have to manage cumbersome truck-mounted laptops, paper maps and forms, in addition to the equipment required for repair. Because of these disparate and multiple sources of information, the desire was to improve overall efficiency of operations, as well as reduce operator and customer frustration by developing more portable and usable technology in the form of a tablet computer.

Extensive interviews and ride-alongs were conducted with several utility field crews, with a few general issues noted, including:

- Software is confusing and convoluted
- Laptops are cumbersome, take up too much room in the vehicle, and cannot be taken outside of the vehicle to the actual trouble site.
- Filling out online forms can be lengthy and frustrating.

The second domain we examined was that of a telecommunications field troubleshooter who responded to service calls concerning Internet outage and problems with voice-over-internet-protocol (VOIP) phones. These field workers were equipped with a Motorola handheld Symbol®, but troubleshooters were required to navigate with paper maps. As a result, some troubleshooters would use their personal GPS devices or smartphones for electronic navigation assistance. A few general problems noted in the interviews and ride-alongs include:

- Troubleshooters often have to memorize information from one screen so that they can enter it into another screen. Some workers used their personal smartphones as intermediate agents to record information so it could be reentered into the Motorola device.
- The centralized Dispatcher must often communicate important customer information by voice as texting and other forms of data uplink are not available.

system, as well as communications, 2) Decisions which can be simple, rule-based judgments (i.e., binary “yes/no” decisions), or complex which include knowledge-based judgments involving many variables and uncertain environments, and lastly 3) Loops, which are processes that occur iteratively until a predetermined event occurs.

The partial event flow diagram in Figure 2 represents a series of events in the Issue Review phase, highlighting the major role customer presence plays in responding to service calls. In both the utility and telecommunication

domains, customers are often not home, which presents a problem and frustrations for troubleshooters who must determine whether they can fix the problem without the customer physically present. In both domains, finding the customer’s contact information was difficult, as the information was not co-located with other top-level information and operators often had to drill down through several displays or even contact dispatch to obtain this information.

While the event flow diagrams for the two domains are not identical, they were in agreement by 87%. The majority of

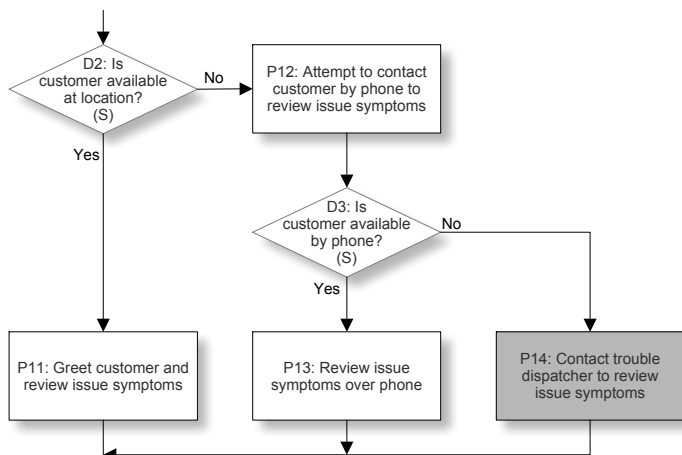


Figure 2: Event flow diagram for determining course of action if customer is not home. Rectangles represent processes, gray rectangles represent communications, and diamonds represent decisions, which in this example were both Simple (S).

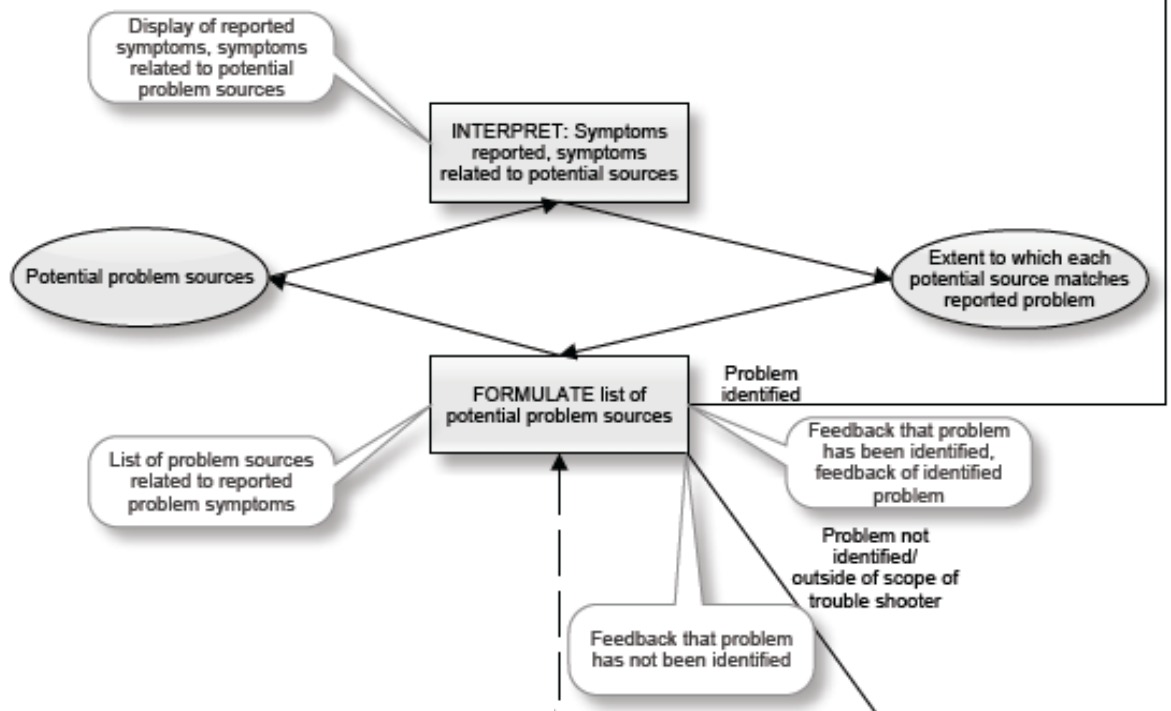


Figure 3: Common Decision Activity for Utility & Telecommunication Troubleshooters

these differences were due to differences in terms of equipment used for navigation and communication protocols, i.e., when Dispatch was engaged. However, regardless of the minor structural differences, the overall information requirements generated from this phase were the same.

The next step in the hCTA process is mapping complex decisions requiring judgment, determining what levels of automation *could* be used, and what information requirements would be needed on an associated decision support display. The hCTA relies on modified decision ladders to achieve this end. Decision ladders are tools that aid in capturing the states of knowledge and information-processing activities necessary to reach a decision (Rasmussen, Pejtersen, & Goodstein, 1994), and are found in other work domain analytic frameworks (Vicente, 1999).

Figure 3 illustrates the primary decision activity that occurs when either a utility or telecommunication fieldworker attempts to determine what the source of the reported problem is. Rectangles illustrate the information-processing activities involved in addressing the complex decision, while ovals represent the information or knowledge produced by those activities. The call-outs represent what information should be displayed to the operators in order for them to progress through the decision making phase. Again, despite the differences in the two domains, this specific decision process is identical at the level of abstraction of knowledge acquisition. Moreover, as in the event flow process, while the complete decision ladders are not identical across the two domains, they were within 95% agreement with the primary difference caused by the possibility that utility workers could call in a secondary crew if needed.

The last information-gathering phase of the hCTA is the generation of situation awareness (SA) requirements. Given

Table 2: Issue Diagnosis Situation Awareness Requirements

	SA Level I	SA Level II	SA Level III
SAR 15	Feedback of symptoms at issue area (P17)	Recognition that symptom area has been located (P17)	Possible other symptom areas (P17)
SAR 15	Feedback of symptoms at issue area (P17)	Recognition that symptom area has been located (P17)	Possible other/further complications (P17)
SAR 16	List of required tools to fix identified problem (P18)	Recognition of tools required to fix problem (P18)	
SAR 17	List of steps to fix identified issue (P19)	Understanding steps to fix problem (P19)	Time to complete fix (P19)
SAR 18	Feedback that issue is resolved (P19)	Issue resolved (P19)	

that the majority of time on the job for field personnel is spent monitoring the system for a service call, how to support such efforts is critical to the development of any display. Given that SA is commonly split into three levels, Perception (Level 1), Comprehension (Level 2), and Projection (Level 3) (Endsley, 1995), we detailed these three levels per phase. Table 2 demonstrates those SA requirements generated for the Issue Diagnosis phase. The numbers demoted with a P after each requirement indicate which process in the event work flow with which the requirement is connected. The SA requirements listed in Table 2 both applied to the utility and telecommunication domains.

Once the scenario tasks, event flow, decision ladders, and SA requirements are generated (which typically takes a few iterations), the information requirements are generated, as seen in Table 1. A total of 50 information requirements were generated for the utility domain, and a smaller subset of 41 were generated for the telecommunications domain. Again, the primary differences were due to navigation equipment and additional crew considerations. These information requirements were then used to form the basis for the design, demonstrated in the next section.

FINAL DESIGN

The resulting display conceived from the hCTA intended for both utility and telecommunication field worker (Figure 4) includes 1) the workflow phases at the top of the interface, identifying the current operational phase of the worker, 2) a selection panel, allowing the user to select between problems, navigation routes, etc., depending on the current workflow phase, 3) a main content bar providing key details related to the current workflow phase and selection, and 4) an interaction bar, including icons for interacting with the control room and other field workers through phone or text message, taking photos, and entering emergency status. The intended platform would be a tablet PC.

Preliminary feedback from field workers indicated that some of the most popular features were the integrated camera, customer history information, the list of tools in the truck, GPS navigation, and lower training requirements. Possible problem areas included the smaller display size, truck mounting, and cultural acceptance issues including use of automated diagnostic aids that provided recommendations.

It should be noted that while the core functionality of the display in Figure 4 is meant to be common for both utility and telecommunication displays, there will be differences in including domain-specific labeling, specific procedures (which can often vary even within each industry), and access to certain databases (such as customer history). However, the display represented in Figure 4, which included many more screens than can be shown here, was deemed a substantial success and has been transitioned to a private company for implementation in operation settings.

CONCLUSION

Cognitive work and tasks analyses are critical for the development of technology that truly supports human operators, especially in complex system operations. However, many companies are reluctant to commit significant time, monetary, and personnel resources to such efforts, even though such efforts typically provide better and often more cost efficient products.

In an attempt to reduce the time and resources spent on such analyses, we attempted to generalize one work domain analysis, in the form of the hCTA, from the low voltage troubleshooting domain to that of the telecommunication. We showed that overall the analyses were 87-95% in agreement with one another, with the telecommunication domain generating a smaller subset of information requirements due primarily to domain complexity and safety issues.

Because of the similarity in domains, one hCTA was able to form the core analysis for both, resulting in one display that could be adapted relatively easily to both domains. The results from this effort then led to many additional questions such as to what other domains could we extend the hCTA? The primary reason this hCTA could be generalized was the on-call service nature of the task. So theoretically, any domain that has the same basic five scenario task overview phases should be able to adapt a large part of the hCTA.

Such environments could include computer and information system repair as well as first responder systems including fire, police, and ambulance crews. Indeed, the decision ladder problem solving process in Figure 3 and the Situation Awareness requirements for Issue Diagnosis in Table 2 could be directly applied to Emergency Medical Technicians (EMTs).

Another related question is whether we could build ‘libraries’ of operator cognitive functions and tasks such that certain tasks could be represented via a previously constructed hCTA. For example, how different, from a functional and task perspective, are the information requirements for a GPS display for car navigation as opposed to one for an airplane? Would it be useful for companies to be able to access core task analysis components and then alter to them as needed?

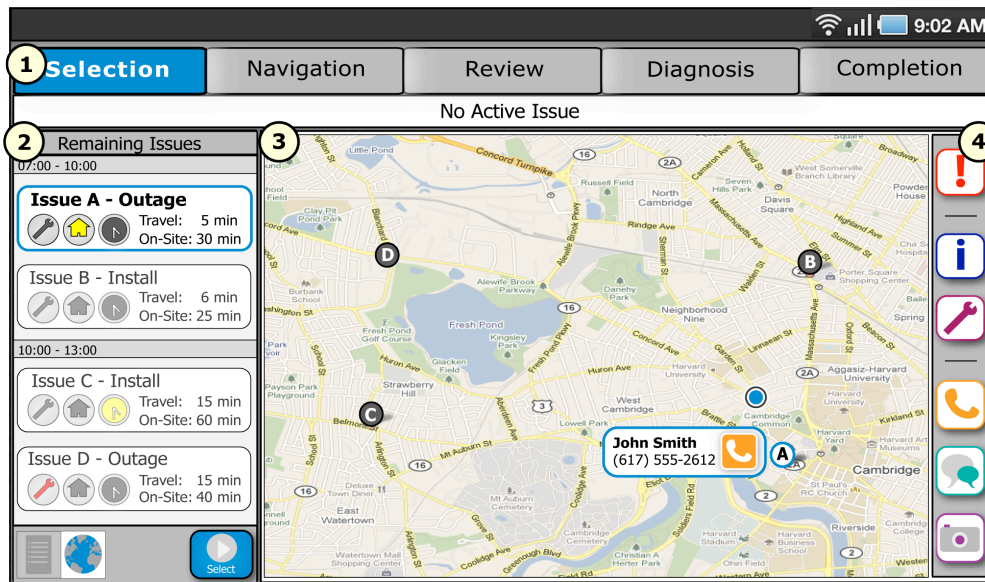


Figure 4: Resulting Display from the Common hCTA Information Requirements

It is likely that such libraries would become more divergent from the actual target tasks at the sub-task level, but it may be more useful to companies to start from a shell of a task analysis and then add and subtract as desired, as opposed to building one from scratch. For example, in the Issue Diagnosis phase for utility workers, the questions they ask and the tests they run are quite different from those of EMTs, but indeed, both domains require asking questions and running tests, so at one level of abstraction, the information requirements of providing a list of questions to ask and providing the checklist of tests to run are the same.

Building such libraries is an area of current research, as well as possibly estimating workload ranges from such analyses. More importantly, convincing industry that there is value in routinely investing in such methods is another major focus of this effort. To this end, a free version of hCTA software that walks a user through each of the phases and then generates traceable requirements can be accessed at <http://web.mit.edu/aeroastro/labs/halab/inventions.shtml>. Our goal is to provide a streamlined method in order to generate traceable information requirements for display design, and perhaps by doing so, make such methods more attractive to industry so that they will invest in tools of their own.

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