

Task Analysis through Cognitive Archeology.

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Analysis and observation of the user's task domain unveils a window of understanding into the behavioural patterns, contexts and scenarios that are required and utilized by users to attain success in completing a task. Task Analysis (TA) forms the foundation for interaction, behavior and usage since prioritisation of design elements is a serious issue for both users and designers.

Successful User Interface (UI) designs often utilise insight into tasks by studying user interactions, intentions, and expectations. User interaction itself amounts to the interplay of cognition and information processing as embodied by task routines or sequences that are commonly captured in a TA. This chapter will focus on procedures for uncovering cognitive processes relative to user goals and tasks including decision-making systems, the impact of information overload on screen display, and the significance of user roles to tasks. The notion of a "cognitive archeology" as a means to investigating task cognition will be explored and explained as a novel best practice in TA.

"Cognitive archeology" or the capture of cognitive processes required and utilized by users for task completion offers a necessary insight into the interchange of cognitive and task generated needs as they unfold at the design level. Concentrated analysis of explicit and implicit needs, decision-making processes, procedural knowledge, and motivation strategies creates a means for prioritization thereby improving interface effectiveness.

Keywords: task analysis, information processing, cognitive overload, ethnography, decision-making, cognitive artifacts, archeology, cognitive engineering

Introduction

The aim of Task Analysis (TA) includes gaining a detailed understanding of the tasks, goals, and expectations the user will bring to the new system. Perhaps one of the fastest ways to understand the context of the task problem is to uncover the landscape and nuances of physical and mental environments.

Analysis of the physical environment sets the stage from where the user as actor engages in task activities. Similar to analysis of context and tools in the physical environment, cognitive profiling explains why users choose the behaviours that make goals and tasks easier to execute. Typical task variables such as time, sequence, repetition, learning and error handling have correlates in the cognitive domain and can often effect the nature of how tasks are approached by users and measured by practitioners under usability testing conditions.

Cognitive engineering plays a catalytic role in the task life cycle, since perceptual and motor skills involved in performing a task originate from neurological functions and cognitive

activities. Cognitive activities are defined as the fluctuation in measurable and observable attributes driven by task initiated behaviour. In TA the main concern with regard to task completion involves the severity and complications of “cognitive overload” (Kirsh 2000; Woods et.al. in press). Successful completion of a task implies that the user is in control and able to manage workload while minimising information overload. A supporting architecture of perceptual, experiential, semantic, and procedural knowledge compatible with the task environment always characterise tasks that seem easy to complete.

The capture of cognitive activity exclusively as an information outlet appears to be represented as a by-product of TA as opposed to a central, integral data source for understanding tasks (Hackos and Redish 1998; Beyer and Holtzblatt 1998; Preece et.al 1994). For instance, the emphasis in a “contextual inquiry”, involves gaining insight into the context of use levied by the physical environment. To date, little emphasis in this widely practiced technique, has been placed on how cognitive processes influence and effect the environment, error handling and problem solving. Kirsh (2000) sheds light on this issue by viewing environment more as an ‘activity space’. He does not place emphasis on the environment itself as much as on how people alter their environments to increase ease of use and reliability.

Similar to analysis of physical environment constraints and opportunities, cognitive profiling offers explanation as to why users choose behaviours in task execution. Typical task variables such as speed, exploration, repetition, accuracy, learning and error are impacted not only by how a user engages with a task but also by the decisions, roles, interaction with artifacts and the significance or meaning the user imposes on the task problem. Hamilton (1996, 261) and Albers (1997, 2000) both underscore the need to understand how users construct questions about their tasks and to better understand task specific decision-making. According to Hamilton, neglect of these variables in TA constitutes a “major failure” in current design methodology.

Cognitive activity as pre-cursor to task performance

Cognitive needs that arise during task performance often represent the user’s implicit need to cope and adapt to environment constraints. According to Kirsh (2000), users adapt to environments not only by changing mental processes and behavior, but by altering the very environment posing the adaptive challenge. This is to say that a users cognitive patterns are not more important than the detection of external behaviors associated with a task, but rather it is the mental patterning itself that offers complete insight into what qualifies as success for the user when translated to the UI design.

Example: Altering task environments

Currently no RV (Recreational Vehicle) TV antenna manufacturer offers a warning signal, light or sound with their products. The result: many Rvers every year drive away from a campsite with the antenna raised, leading to thousands of accidentally broken antennas each year. To compensate, RV enthusiasts in the United States use a familiar hair clip or similar object attached to their steering wheels to remind them that TV antennas need to come down on departure from an RV campsite. Rvers report that on occasions where antenna damage did occur, they had forgotten to attach the hair clip to the steering wheel at that particular campsite.

Every task combines and includes cognitive, physical and perceptual actions (Drury et. al. 1997). These task processes are characterized by a defining starting point (trigger), middle point (often involving feedback from the environment) and an ending or closure state. Tasks

often contain nested sub-tasks or related main tasks and are typically impacted by either/or decisions within the task model (see Figure 1). The process of identifying a task model is central to Hierarchical Task Analysis (HTA) where tasks are viewed as goals and sub-goals as opposed to actions (Annett and Stanton 2001, 2). Preece et.al. (1994) define the goal as the state of the system the user wants to accomplish, the task as the activities required to achieve a goal and the action as the steps required to complete the task. Thus, user goals overlap both physically and mentally in relation to tasks.

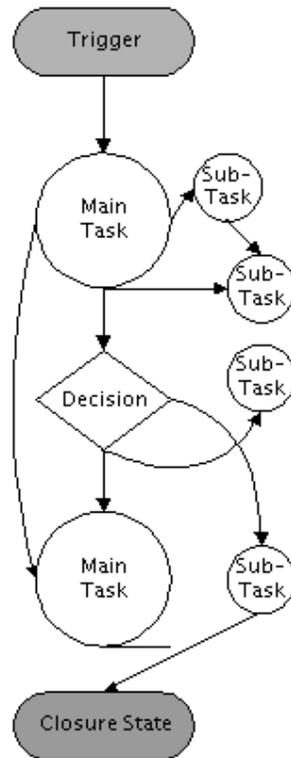


Figure 1. Example Task Model.

Tasks often sequence and connect according to fluctuations in time and relation to decision making. Performance can be degraded due to the need to accommodate a poor environment or by the physiological and cognitive resources of the user. For instance, task degradation is easily understood when the variable of stress or fatigue is introduced to the human operator. Decline in task performance due to error, fatigue or other reasons are well documented. Kilcarr (2002) reports significant impairment of driving ability and reaction time caused by fatigue and sleep deprivation and a diminishing of quality and quantity of work by 30% as estimated by employees at work. Task performance can clearly be hampered or enhanced by cognitive conditions and unpredicted nuances.

Origins of “Cognitive Archeology”

Departing from traditional notions of archeology, which study external environments and material evidence left from human organization, exists a new thinking in the field of archeology. Led by Renfrew (1994), the new focus of understanding past civilizations involves careful attention to the belief systems and thought processes that enabled humans to organize, communicate and engage in primitive tasks. Since the early 1980’s the field of archeology has sought to understand and gain insight into the thinking and cognitive realm of

primitive peoples. Efforts have been made to reconstruct the cognitive landscape of past peoples in order to answer questions about their knowledge, skills, purposes, practices, thought processes, and symbolic behaviors relative to objects, artifacts, and structures that have been found at archeological sites. Insights into the cognitive activity of the people who behaved, believed, worshipped, interacted and engaged with physical and spiritual artifacts reveals important details relative to understanding social organization as well as individual and group behavior. Renfrew has described the concept of “cognitive archeology” as 'the study of past ways of thought as inferred from material remains'. Segal (1994) argues that archeology is foundationally rooted in cognition in the sense that material objects only become archeological data if their existence can be shown to be a direct or indirect consequence of intelligent behaviour. Unlike TA which involves real-time analysis, cognitive profiling of past cultures entails ‘frozen in time’ evaluations of the material remains and long-term patterns evident from the archeological record. Similarities can be drawn however, between retrieval of past (static) cognitive activity and modern (real-time) observation, namely through the study and interpretation of artifacts.

Cognitive archeology itself represents a shift toward detection of the internal mental portion of user behaviour that is omnipresent in task activity. Cognitive archeology in TA involves elicitation, interception and capture of the cognitive activities that a user finds beneficial and essential to successfully complete a task.

The importance of artifacts

TA involves the systematic analysis of workplace, workflow and user interaction within the task environment. Task activities centre around manipulation, creation and interaction with artifacts of both a physical and cognitive nature. Hutchins (1995) defines cognitive artifacts as physical objects made by humans for the purpose of aiding, enhancing, or improving cognition. Norman (1991, 9) terms ‘cognitive artifact’ as an “artificial device designed to maintain, display, or operate upon information in order to serve a representational function”. Cognitive artifacts are those elements whose function is to aid or simplify task success.

Examples of cognitive artifacts include:

- a novel symbol system used on a calendar
- notes used to decipher a computer system
- a glance backward upon exiting
- a checkmark
- circle or colour coding scheme
- the sound of a warning timer
- a mental note
- a novel warning indicating an open or closed state
- changes in temperature or sound and often
- shifts in kinesthetic sensation or visual stimulus

Similar to the artifacts gathered in archeological settings, physical artifacts can include task specific tools such as calculators, “cheat sheets”, post-it notes, examples of output from the tasks or hand written notes or logs (Hackos and Redish 1998, 139). Physical artifacts serve an important role in the sequencing, triggering and closure of a task or set of tasks. Goel and Pirolli (1992) have found that artifacts are designed in order to assist with problem-structuring and problem-solving (cited in Pearce 1994, 3). Artifacts thus act as the glue that binds user cognition, information processing, workload management and task accomplishment (see Figure 2).

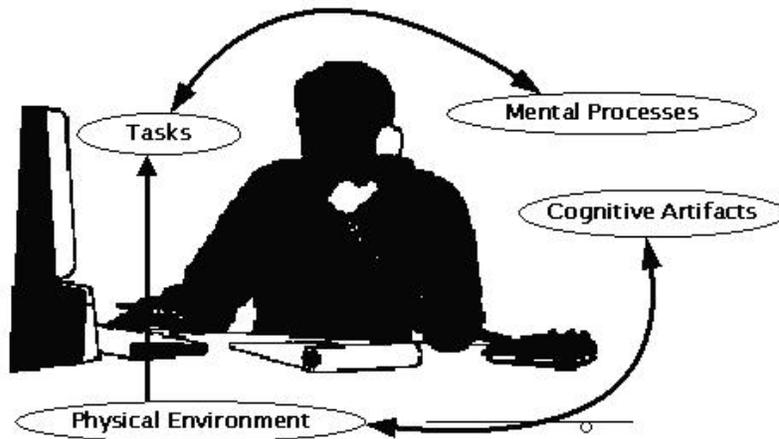


Figure 2. Cognitive artifacts in the task environment.

Cognitive data is revealed during task decomposition

One of the aims of TA includes understanding user needs and expectations in order to preserve the task integrity in the design requirements of a new system. The emphasis in cognitive archeology is on mental processes and interactions between task, environment and cognitive resources. Cognitive archeology applied to TA procedure bridges the gap between HTA and Cognitive Task Analysis (CTA) methodologies. Whereas HTA is behaviour focused, CTA is knowledge based, concentrating more on: internal representations, language, knowledge structures and cognitive/perceptual filters (Wilt 1998). Cognitive archeology would appear to approximate the influence CTA gives to understanding a user's cognitive resources, learning challenges and the areas of a design where a user is likely to err.

In using the cognitive archeology approach, TA and ethnographic study methods are augmented with an emphasis on detecting the following:

- What motivation, expectations and influences does the user bring to the task? [knowledge, values and biases]
- How does the user compensate mentally? [mental process and artefacts]
- How distracting is the environment? [context and sensory qualities]
- What actions trigger decision-making? [role and task needs]

The TA technique of “activity sampling” or the unstructured ethnographic interview yields the greatest amount of inference in task decomposition. Additionally, HTA adds insight into task sequence, hierarchies, goals and sub-goals. HTA however, becomes limited as a method when the aim is to determine wider issues related to the task such as social influences, subjective experience, and distinctions between global and local task interaction. Hence, Hutchins (1995) introduced the notion that cognition is distributed across agents in an interconnected ‘stream of activity’ contrary to remaining static within an individual’s cognitive domain or task. In this regard, task data can be viewed as non-local, meaning that it also resides outside the user’s cognitive process, ‘activity space’ and environment. Instead, task data often reaches beyond the user’s task, into the collective organisation and field where

the work is conducted. (Usability techniques such as “card-sorting” are an example of the attempt to address the discrepancies in how users perceive, categorise, interpret and apply meaning to the language of their particular domain).

The primary focus of approaching TA through cognitive archeology or “cognitive workflow” (Kirsh 2000) is to chart user motivation and needs, decision-making systems, influences and socio-environmental triggers. See Figure 3.

Example: Supermarket shopping task

An example of a supermarket-shopping task might include the following representation, codified by a cognitive artifact- the familiar grocery list. The motivation may be to cook a special dinner to impress guests. The choice of brand name items may be important in this context due to the social influence and expression of brand loyalty. Outside of these attributes, the observer would want to know which occasions other than the “special dinner” triggered the use of the list and whether or not brand loyalties were consistent. Which items were regular purchases and which were irregular? Did irregular items appear on the list? What influence did mood have on the creation of the list? Was the list actually used while in the store? What items were ignored from the list? How many items that were not on the list were purchased? From this TA, the researcher might understand more about the social activity of supermarket shopping and how different variables and artifacts are utilised. The researcher would also be able to identify opportunities to introduce new supermarket products and services that were rooted in detailed understanding of the user’s tasks. Profiling the cognitive archeology of the user group would allow business and marketing decisions to be made that were informed by an understanding of user behaviour and the cultural and task dynamics of supermarket shopping.

The main issue in this example is that simply modeling a task does not constitute effective TA. TA can be used as a justification to force-fit requirements to a product. For instance, a supermarket website that provides a shopping list feature online simply because it exists in the real world might be missing the cognitive clues around how a shopping list is used and mis-used. For example it may reveal that shoppers actually enjoy impulse buying in a supermarket and do not want to feel restricted by a shopping list. Such cognitive data offers greater insight into design and feature definition or as Colbourn (1995) states, “technology must be matched to the cognition required”.

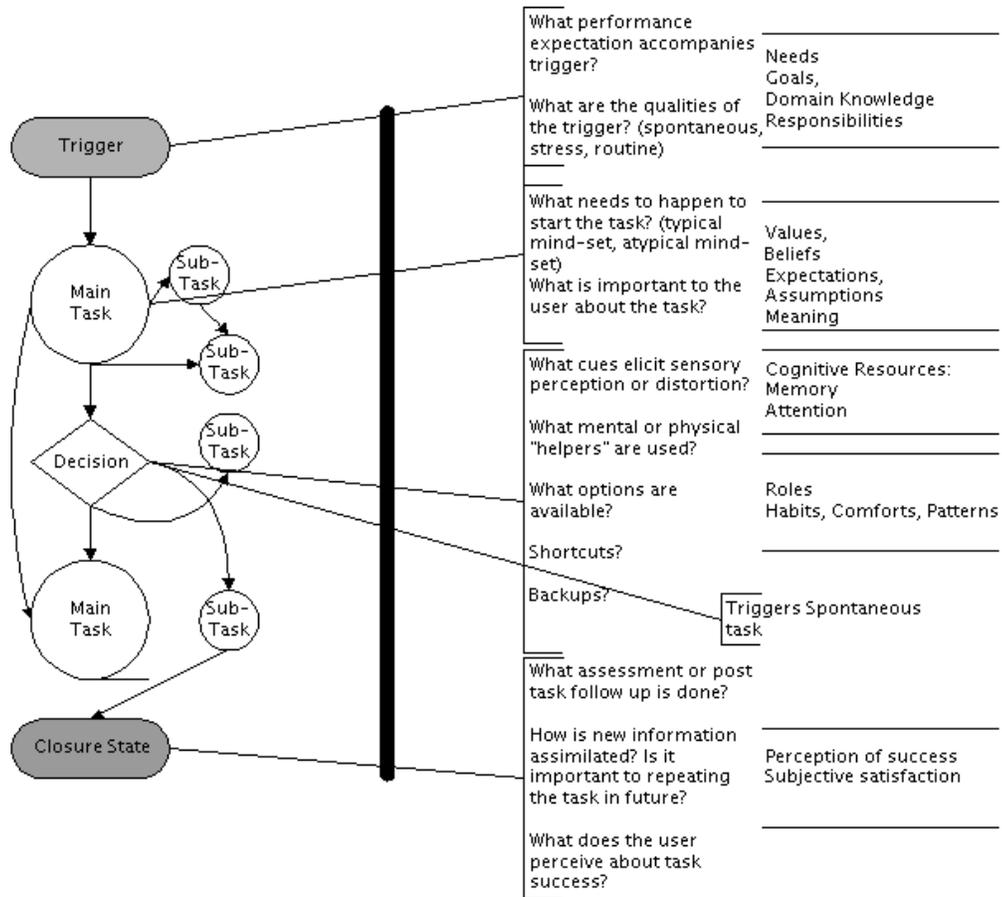


Figure 3. Capturing cognitive processing at the task level.

Error as an opportunity indicator

One of the aims of task analysis is to understand how tasks unfold, influence and/or interfere with user success when applied to user interface design and screen display. Perhaps the most logical point for simplifying a user's task on screen, is to understand what problems and issues the user is having under normal conditions. Error handling reveals the limitations and opportunities that demarcate what is suitable to present to the user in the UI. Lewis and Norman (1995, 694) note that determining what information is most useful to the user becomes the biggest challenge involved in the design of error recovery systems. Understanding where users fail and how errors occur offers a strategic leverage point for exceeding user expectations with the system.

The following questions capture task specific criteria that ought to be reflected in the design in order to reduce error occurrence and increase usefulness of error handling. (The questions are asked directly before the user begins a task).

- What does X mean to you? [Semantic construction]
- What is important to you about X? [Values elicitation]
- How do you know you need X? [Implicit or explicit knowledge]

- Whom else do you talk to about X? [Influence of other users]

Prioritizing tasks in decision-making

The significance and meaning imposed on the task by the user has a direct relationship to the user’s motivational state and perceived needs in the social and task environment. Whereas techniques such as “contextual inquiry” (Beyer and Holtzblatt, 1998) focus researcher observation on the context (location) of the task, and ethnography places emphasis on cultural and social influences, few methods explicitly encourage the profiling of decision making as a pivotal component of the task. Albers (2000) states that current TA techniques are not designed to support complex decision-making. Albers (1997) suggests serious attention be paid to decision making systems since they are integral to complex problem solving and mental modeling. The designer, according to Albers must understand the cognitive context or “cognitive workload” Kirsh (2000), or risk of failing to support the user’s mental model. Albers emphasizes that cognitive context is very situation specific and that generalization about user workload may be misleading: “Information about typical work situations is unreliable for designing information systems. No two work situations are identical since the context of a decision situation and the heuristics brought to bear depend on minute differences in situational and personal characteristics”. According to McGrew, the characteristics that determine how a person makes a decision in the real world can easily be captured and modeled (1998, 271).

Good decision-making is facilitated by effective presentation and display of information in a sequence and manner that is easy to understand and comprehend (Albers 1997; Hsee 1995). Selecting the best display is critical, especially when uncertain and ambiguous information must be presented and understood by the user (Coury and Strauss 1998, 327).

Looking for roles users play

Mapping user tasks to the roles users play (Smith and O’Neil 1996; Beyer and Holtzblatt 1998; Marine 2001) offers tremendous insight into decision-making at the task level. In this regard, users are not viewed as fixed agents but as dynamic actors that utilize all cognitive resources available in order to solve their problems. During task activity, users engage in “role switching” (Beyer and Holtzblatt 1998, 230) in the sense that they may make a decision that requires a different cognitive frame and hence the need to play a new role (Note the decision that triggers a spontaneous task in Figure 3). Role switching is an important element in to identify in a TA since it often causes tasks to be interrupted and left open or suspended. Role detection also allows for prioritization of task and data presentation in the UI based on frequency of user needs (see Figure 4).

ROLE:	<i>Daily Manager</i>	<i>Finances</i>	<i>Investment Strategist</i>	PRIORITY:
TASK:				
• <i>Update Chequebook</i>	X			
• <i>Transfer Funds</i>	X		X	High
• <i>Make Deposits</i>	X		X	High
• <i>Write out cheque to pay bills</i>	X			
• <i>Review statements</i>	X		X	High
• <i>Query a statement</i>	X			
• <i>Monitor Electronic Debits</i>	X			
• <i>Monitor Checking Balance</i>	X			
• <i>Monitor Savings Balance</i>			X	

Figure 4. (Role-Task) Decision Prioritization Matrix with Sample data for a Banking User.

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Tasks that are utilized across user roles indicate a higher need to be presented to the user in the design. The more roles that are satisfied, the higher the prioritization value in deciding where to position features and functionality that support critical task activities including complex decision making.

Knowledge and memory management

One of the crucial elements in task prioritization involves the amount of procedural or structural knowledge the user brings to the task. Users who are experts in their domain tend to handle errors and role switching more easily. An explanation of this tendency might include the fact that experts have multiple experiences to generalize from, causing the user to remember to close open tasks and trouble-shoot through better decision-making. CTA methods have been utilised to elicit structural knowledge used in decision-making systems (Randel et. al., 1996). Adams (1993) in his study of expert decision makers in aviation systems, found that the main cognitive limits to decision making include attention span, long term and short term memory. Memory management plays a critical role in role switching and error handling. Adams found that compared to novices, experts utilise a highly organized body of procedural and conceptual knowledge and have faster access to this and prior experience scenarios.

Decision making data is essential in TA. Hsee (1995, cited in Hamilton 1996) found that when presented with a factor tempting to the decision maker but not to the problem, the decision maker would often rationalize using the irrelevant factor. When solving problems, it seems users are attempting to manipulate cognitive resources including decision-making factors in order to gain advantage in workload management. Designs that reflect poor capture of decision-making systems have a tendency to be less effective due to distraction and cognitive overload that leads to errors. When user decision-making is supported in information design, the novice user, similar to the knowledge matter expert, gains enhanced cognitive resources including attention, memory, creativity, and superior situational awareness.

How environments mediate workload

The role of the physical environment and its artefacts in TA has been well documented (Norman 1991; Hutchins 1995; Beyer and Holtzblatt 1998; Hackos and Redish 1998). Physical environments define the context of use of a system as well as the constraints and opportunities available to the user. Environments are not static, but dynamic entities. Kirsh (2000) believes that people structure their workspaces in a way that promotes “scaffolding” or ‘cognitive safety nets’ (Spillers, 2001). Cognitive safety nets are the mechanisms, processes, and artifacts that users utilise simultaneously in the task environment. Kirsh explains, “Well designed environments ought to take note of the cognitive needs people have in performing their tasks and build in *scaffolding* that simplifies the way people make cognitive use of their environments to increase task reliability”. The processes by which users create and utilize cognitive artifacts are an example of the scaffolding phenomenon.

In conducting the TA, the ethnographer pays particular attention to the impact of sensory stimulation at key points of the task life cycle. Where for instance the user might be influenced by visual information, the interface must accommodate the need, providing less or more information bandwidth through appropriate interaction techniques. In the financial investment community a pie chart that shows the breakdown of amounts allocated to a portfolio can have tremendous value in monitoring financial conditions and decision-making. For Daimler-Chrysler, the design of choice of use of hard and soft keys in an interface is linked to a) hierarchy of task priority, b) time criticality, and c) safety relevancy for users of telematics systems (Kirn and Wreggit, 2002). Choices about what type of tasks are associated

with buttons and knobs, scrolling devices and navigation aids have paramount importance to safety, ease of use and error handling. The factors the designer is faced with include managing presentation of sensory information with sensitivity to divided attention, situational awareness, memory, and data overload.

Cognitive overload and stimulus screening

Sensory information forms the building blocks of experience. Part of our perceptual processes as humans involves the sensing, evaluating and interpreting of cues and feedback from the environment. The most pervasive problem with human information processing involves “**cognitive overload**”. Kirsh (2000) found that increases in the quantity of information degrade the usefulness of the information when more information is added to the mental stack. The more sensory information the user is given, the less meaningful information becomes. Arousal increases with environmental load according to Mehrabian (1976, 21). The bodies’ physical response to high levels of arousal is fatigue-- the stage after information overload. Fatigue is a natural reaction to what Mehrabian terms General Adaptation Syndrome (GAS).

Whether high levels of arousal play a part in task observation and cognitive profiling is of paramount importance. Mehrabian has found that people can be understood by their ability to handle cognitive load. People can be categorized by their level of ability to screen stimulus out of their environment. Screeners are people who can cope with a larger level of environmental distraction such as noise and extreme or unexpected sensory input. Non-screens have less of a tolerance for arousal and are distracted or tire easily (27). Based on Mehrabian’s work, detection of stimulus screening questions can be added to the TA practitioner’s investigation:

- Does the task require a high or low level of screening?
- What percentage of users profiled fit the task screening requirement?
- How does data presentation need to adjust to arousal level caused by environmental load?
- Is this user able to handle cognitive loading?
- Does ability to screen differ between roles and stages in the task life cycle?

The issue of stimulus screening as it relates to cognitive overload is central to design challenges in automotive environments, for example. ‘Driver distraction’ is a widely researched area of interest in transportation research. In their human factors research, Kirn and Wreggit (2002) have gone beyond driver distraction as an isolated metric and instead have tested subjective workload performance in order to determine which sensory information upsets driver workload equilibrium. Design techniques that accommodate environmental loading and stimulus screen in telematic devices have been pioneered at Daimler-Chrysler’s Vehicle Systems Technology Center (VSTC). Utilizing a design technique called “forcing functions” (Lewis and Norman 1995, 691); the VSTC has yielded positive results for driver workload management. In order for drivers to read email inside a moving vehicle, Kirn and Wreggit limited the display to two lines (the subject and who the message is from). To retrieve the message, the driver must stop or listen to the message through an audio channel. The team found that environment conditions inside the vehicle limited driver safety to a two second glance time under poor lighting conditions. Usability testing inside the moving vehicle indicated that drivers could only pick up a word or two at a time from an email message

Similar studies have been conducted with the use of mobile phones when driving. A study by Cain and Burris (1999) revealed that receiving a call is the most hazardous activity associated with using a cell phone when driving. The authors attributed the element of danger to the fact that drivers cannot choose the time when a call is received. Mobile phone usage while driving

illustrates how unexpected stimuli interferes with the ability to screen stimulus specific to the operation of the vehicle.

Conclusion

In short, profiling the user's cognitive landscape offers a window into understanding the emotional and intellectual factors that may affect memory, attention, confusion, situation awareness, interruption, and completion of the task. The emphases for future applications of TA, including the development of cognitive archeology, point to what Hammond (1988) and Kirlik (1995) call the "need to capture the importance of perceptual and cognitive processing in models of human performance" (cited in Zachary et.al., 1996). Albers (2000) and Kirsh (2000) both point to improved work analyses that expose the details of how people exploit their environments to make the cognitive aspects of their work easier (Kirsh 2000)

The key attributes of human cognition as related to the cognitive activity present in TA include attention, learning, knowledge and memory. Variables that tax these cognitive elements may have repercussions on how easy the user finds the task when represented on a screen as part of an application, software or web design. Furthermore, immediate task influences such as time pressures, conditions of the task, habits, sequences, roles, and duties are constrained by environmental load. The task environment provides data impacting design decisions by offering insight into the requirements necessary to bypass cognitive overload and the ability of users to screen out information irrelevant to their tasks.

Physical environments create the need for cognitive artifacts that trigger and facilitate interactions between the task environment and the user's information processing needs (Norman 1991). Artifact detection has paramount importance in user needs analysis for UI design. Cognitive artifacts when explored in detail can offer insight into the challenges the user faces and how well they are able to cope with workload management issues.

Profiling of the user's mental processes provides greater distinction between desired and required, perceived and actual needs relating to successful task completion. Identifying task attributes for interface design involves understanding the flux in user roles, motivation, goals, priorities, and decision-making systems. Cognitive archeology encourages detection of the cognitive expectations and needs that the user constructs and perceives to simplify his or her task activities. Cognitive archeology forms a basis from which to understand user needs and interface requirements while allowing for prediction of the overall effectiveness of an interface across time with greater accuracy.

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