1. In *Proceedings of the 45th Annual Meeting of the HFES*. Minneapolis, MN. 2001.

CAPTA: Cognitive Affective Personality Task Analysis

Eva Hudlicka
Psychometrix Associates, Inc.
Blacksburg, VA
hudlicka@ieee.org

Recent research has identified affective states and personality traits as critical factors influencing decision making and contributing to performance variations. However, traditional cognitive task analysis methods do not address these factors. In this paper we describe an augmented method, termed Cognitive Affective Personality Task Analysis (CAPTA), which focuses on the elicitation and explicit representation of affective states personality traits, and their influence on performance. CAPTA provides both an *analytic methodology* and a *representational formalism* for integrating the state / trait effects with cognitive factors, in an attempt to capture a broader, more complete description of the task problem space. CAPTA first defines the static and dynamic ontology of the task domain (behaviors, cues, situations, expectations, goals), and then identifies the user's state / trait profile, and its influence on performance. CAPTA has been successfully applied to several system designs requiring an analysis of state / trait induced performance variations.

INTRODUCTION

Recent research has identified affective states and personality traits as critical factors influencing decision making and performance. In addition to the more traditionally considered cognitive factors (e.g., skill level), differences in states and traits contribute to performance variations (Revelle, 1995). Much empirical research exists regarding the nature of these influences on perceptual, cognitive, and motor processes, both transient and long-term. These influences exist both at the "lower" levels of processing (e.g., attention orientation during an acute fear episode, increased working memory capacity correlated with positive affect), and at "higher" levels involving goals, situation assessments, expectations, and self schemas (e.g., complex positive feedback relationships between affective state and self-schemas) (Williams et al., 1997; LeDoux, 1989; Ekman and Davidson, 1994; Eysenck, 1997).

Traits tend to exert their influence via more stable structures (e.g., types of schemas stored in LTM, preferential processing pathways among functional components), whereas states tend to produce transient changes that influence the dynamic characteristics of a particular cognitive or perceptual process (e.g., attention and WM capacity, speed, and accuracy). Traits also contribute to the dynamic process characteristics, particularly with respect to affective state generation and expression (i.e., particular trait value combinations map onto specific values of affective state triggers, ramp-up and decay rates, and intensity levels) (Matthews et al., 2000).

As human-machine systems proliferate into critical applications, and increasingly heterogeneous user populations, it becomes particularly important that they accommodate these user characteristics. Failures to do so can lead to non-optimal behavior at best, and critical errors with disastrous consequences at worst (e.g., USS Vincennes (Pew, 1998)).

Recent interest in individual differences in general (Pew and Mavor, 1998), and affective user modeling in particular (Elliot et al., 1999), has led to efforts aimed at computational models of these influences (e.g., Hudlicka et al., 2000; Ball and Breese, 2000) and systems capable of assessing and adapting to variations induced by states and traits (e.g., Hudlicka, 1999; Andre et al., 1999)

A shared necessary element of these efforts is an analysis of the human-machine environment that takes into consideration the influences of affective states and personality traits on decision making, and the performance variations they induce.

THESIS

A number of issues exist in developing an analysis method that both explicitly includes the influence of affect and personality traits, and effectively integrates these with the cognitive elements typically considered during traditional task analysis. The primary challenges include:

- Identifying the most important affective states and personality traits that influence performance.
- Determining which of these states / traits are most critical for a particular user-task context of interest.
- Characterizing the possible affective states a user may experience, the likelihood of being in these states, the triggers causing transitions among states, and the associated cognitive / perceptual schemas.
- Identifying additional representational constructs necessary to fully capture the influence of states / traits on decision making and behavior (e.g., goals, expectations).

To address these challenges we developed an augmented task analysis method we termed Cognitive Affective Personality Task Analysis (CAPTA). CAPTA provides both an *analytic methodology* and a *representational formalism* for identifying and explicitly representing the influence of affective states and personality traits on performance. CAPTA thus differs from traditional CTA techniques which focus on cognitive factors and perceptual and motor constraints (e.g., Cooke, 1994; Schraagen et al., 1997). The CAPTA formalism integrates these influences with the more traditional cognitive factors, in an attempt to capture a broader, more realistic description of the user-task problem space. The end result of CAPTA analysis is thus a more comprehensive and more realistic description of the decision and performance space, one that explicitly includes affect- and trait-induced performance variations.

DESCRIPTION

The CAPTA methodology consists of the following steps:

- **Anchor Points: the CAPTA Process:** Anchoring the decision space by defining the constraining "end points"; that is, the repertoire of possible behaviors (output) and possible stimuli (input cues).
- **Task-Domain Ontology:** Defining constructs that mediate the mapping from input cues to behaviors via situation assessment, expectation generation, and goal management; that is, defining the situation, expectation, and goal vocabulary that defines the *static task-domain ontology*.
- **Dynamic Mappings Among Ontology Elements**:: Defining the mappings between cues and situations, situations and expectations, situations and goals, and situations & goals and actions. This set of mappings defines the *dynamic task-domain ontology*.
- **Traits:** Identifying user's key personality traits and their most likely effects on affective state dynamics, expectations generation, situation assessment, goal management, and, ultimately, behavior selection.
- **Affective States:** Identifying user's set of predominant affective states, including specific triggers, situation-relevant beliefs, goals, and expectations.
- **Affective State Transition Diagram:** Identifying the most likely transitions among these states.
- **State / Trait Linked Behaviors:** Identifying the most likely behavior choices linked with particular state / trait user profiles.
- **Self-Related Processing:** Identifying for each step above both *task-related* and *self-related* cues, intervening constructs, and behaviors.

The first three steps fall within traditional cognitive task analysis realm. A variety of specific techniques are available for eliciting both the static and dynamic task-domain ontology (e.g., structured / unstructured interviews, critical decision method, repertory grid analysis, etc.) (Cooke, 1994; Schraagen et al., 1997).

During the last five steps, the cognitive engineer works closely with both the user and subject matter experts, to identify the states / traits and self-related processing most likely to influence behavior. This process draws first of all on empirical research in emotion and personality theory, which helps identify the state and trait sets to consider, and their generic effects on behavior.

For example, the set of 'basic' emotions serves as a starting point for identifying those that are likely to occur and play a key role in a particular user-task context. (Basic emotions typically include fear / anxiety, joy, sadness, and anger / frustration) (Ekman and Davidson, 1994)). Similarly, several personality trait sets represent candidates for trait selection. These include the "Big 5" of Extraversion, Neuroticism, Conscientiousness, Agreeableness, and Openness (Costa and McCrae, 1992) and the "Giant 3" of Extraversion / Neuroticism / Psychoticism (Eysenck, 1997). Different affective states and personality traits are associated with particular processing biases and behavioral tendencies (see table 1), which provide the generic component of the CAPTA state / trait influence analysis.

Table 1: Examples of Generic State / Trait Influences

Anxiety and Attention (Williams et al., 1997; Mineka and Sutton, 1992) Narrowing of attentional focus Predisposing towards detection of threatening stimuli
Anxiety and Working Memory (Williams et al., 1997; Mineka and Sutton, 1992) Reduction in capacity Faster threat detection / slower otherwise Threat detection bias
High Neuroticism and Attention / Perception (Matthews et al., 2000) Preference for self and affective state stimuli Bias toward negative appraisal (self and non-self)
High E / High N and Behavior Preferences (Matthews et al., 2000) High E preference for approach / active behavior High N preference for avoidance / passive behavior
Traits and Affect Sensitivity (Matthews and Deary, 1998) High E and positive affect sensitivity High N and negative affect sensitivity
Traits and Reward / Punishment Behaviors (Matthews and Deary, 1998) High E and reward seeking High N and punishment avoidance

The task-specific performance influences are then identified by first defining the user state / trait profile, and then instantiating the known *generic effects* of these states / traits within the *specific task environment*. The profile is identified by combining detailed information about the user obtained via interviews, expert observations of user task performance, standardized state / trait assessment instruments, or physiological measurements during task performance. The resulting profile is then captured in an affective state transition diagram (see figure 1), which explicitly represents the possible affective states the user is likely to experience, the relative frequency of each state, the transitions among these states and their triggers, and the cognitive-perceptual schemas associated with each state. These latter constructs include situation- and self-related beliefs, goals and expectations. Each state also includes the most likely behavioral choices. For example, the generic empirical knowledge that anxiety biases attention and perception towards threat detection, and the interpretation of ambiguous perceptions as threatening, is combined with the expert's knowledge of the task (e.g., air combat), to derive possible anxiety-induced decision-making and behavioral biases (e.g., pilot may interpret ambiguous radar returns as threats and fire at friendly aircraft) (see table 2).

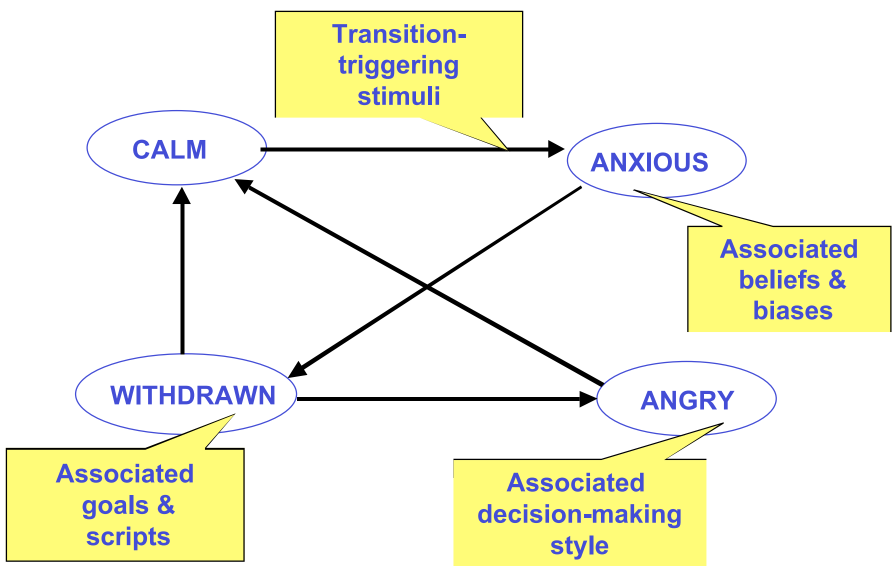

Figure 1: Affective State Transition Diagram

The explicit inclusion of self-related goals, expectations, and situations allows the representation of frequently seen behaviors, which are difficult to explain in terms of solely cognitive factors. For example, 'perseveration' behaviors in human-machine interaction, where user repeatedly performs an action such as a key press which has no clear effect on the task. Exclusive focus on cognitive factors often cannot explain or predict these types of behaviors, which are frequently associated with high-stress situations. The explicit representation of affective states and self goals makes it possible to both account for these behaviors as attempts to reduce anxiety and stress level, and to help predict situations when they are likely to occur.

By combining the available empirical evidence with the practical knowledge of the domain expert, the cognitive engineer thus constructs more complete and more realistic specification of the user-task *problem* *space,* which takes into account not just the nominal path through the decision-space space, but also the variations resulting from different state / trait profiles, and from alternating focus between task- or self-related goals. This problem space then becomes the basis for defining human performance models, decision support system requirements, user interface specifications, etc., depending on the specific application being designed and the desired end-product.

FINDINGS

The CAPTA methodology was developed and evaluated in the context of several projects whose core element was a detailed analysis of state / trait induced performance variations. These included the development of proof-of-concept prototypes for several applications in different domains (e.g., fighter pilot affect-adaptive interface (Hudlicka and Billingsley, 1999); computational human performance models for an Army training simulation environment (Hudlicka et al., 2000); and a decision-aid for psychological operations behavior prediction (Hudlicka et al., 2001). CAPTA was able to capture the decision and behavior spaces resulting from variations in state / trait profiles for representative individual types (e.g., pilot, military commander, potential PSYOP target). These data were then used to define knowledge bases assessing pilot affective state and predicting its effect of performance, to construct rules and belief nets for human performance models, and to define likely behaviors for potential targets during psychological operations. Table 2 lists examples of state / trait behavior influences in the pilot domain. Figure 2 shows example results of CAPTA analysis of the behavior variations among different commanders resulting from alternative interpretations of a particular unexpected situation (enemy illumination rounds).

	Co A	Co B	Co C	Co D	BN CMDR	Enemy
Hi Anxious	Slow down, Get Info, Report excessively	Slow down, Get Info, Report excessively	Stop, Report Excessively, Call for Help, Call for fire	Slow down, Get Info, Report excessively	Direct Caution	Fire
Low Anxious	Continue as Normal	Continue as Normal	Speed up, Report Normally	Continue as Normal	Continue as Normal	Continue as Normal
High aggressive	Speed up	Speed up	Speed up, Call for fire	Speed up	Order Press On	Fire
Low aggressive	Slow down, Get Info, Report excessively	Slow down, Get Info, Report excessively	Stop, Dismount, Prepare Defense, Report Excessively, Call for Help, Call for fire	Slow down, Get Info, Report excessively	Direct Caution	
High obsessive	Speed up, Report Excessively, Get Info	Speed up, Report Excessively, Get Info	Speed up, Call for fire, Report Excessively, Get Info	Speed up, Report Excessively, Get Info	Order Press On	Fire
Low obsessive	Continue as Normal	Continue as Normal	Speed up, Report Normally	Continue as Normal	Continue as Normal	Continue as Normal

Figure 2: Possible Commander Behaviors for Surprise Situation "Unit C illuminated by enemy illumination rounds"

Table 2: Summary of Possible State-Induced Influences on Pilot Behavior

Anxiety-Induced Narrowing of Attention
Lead focusing on "centering the dot"
Misses "friendly ID" voice communication from wingman
Misses results of NCTR (friendly ID) on radar display
Anxiety-Induced Perceptual Bias
Lead misinterprets ambiguous radar returns as threats
Obsessiveness-Induced Checking Behavior
Lead engages in obsessive checking behaviors, delaying firing at enemy (e.g., repeated IFF interrogations, rechecking weapon switches, unnecessary repeating of messages, etc.)

DISCUSSION

Application of the CAPTA methodology in several task contexts demonstrated general feasibility of the explicit representation of affective and personality factors within several representational formalisms (i.e., rules, belief nets, frames), and their integration with cognitive factors. The sine qua non requirement of effective CAPTA application is a highly constrained performance environment, within which both the set of affective states and their behavioral expression, can be defined, along with the key influential traits and limited and well-defined sets of situations, goals, and expectations. If these conditions are met, CAPTA represents a useful tool for affective user modeling applications.

Affective user modeling is in its infancy and many issues must be addressed, both practical and theoretical, to successfully integrate state / trait influences into existing human-machine systems. These include:

- Accurate and complete off-line characterization of possible user affective states.
- Accurate real-time assessment of user affective states.
- Adequate characterization of state / trait influences across multiple task contexts.
- Accurate prediction of state- / trait-induced behaviors during the course of a task.
- Effective elicitation and characterization of user goals and expectations, their role in situation assessment and behavior selection, and the influence of states / traits on these constructs.

These issues are being currently being addressed within the flourishing area of affective computing (Picard, 1997).

While much further work is necessary, and many issues remain unresolved, the CAPTA process described above represents a step towards more systematic performance analysis that takes into consideration a broader set of motivational and performance factors.

REFERENCES

Andre, E., Klesen, M., Gebhard, P., Allen, S. , Rist, T. (1999). Integrating Models of Personality and Emotions in Lifelike Characters. In *Proceedings of IWAI*. Siena, Italy.

Ball, G. and Breese, J. (2000). Modeling the Emotional State of Computer Users. In *Proceedings of the 1st Workshop on Attitude, Personality and Emotions in User-Adapted Interaction*. Banff, Canada.

Cooke, N. M. (1994). Varieties of Knowledge Elicitation Techniques. *Intl. Jnl. of Human-Computer Studies*, 41(6), 801-849.

Costa, P. T. & McCrae, R. R. (1992). Four ways five factors are basic. *Personality and Individual Differences*. 13, 653-665.

Ekman, P. and Davidson, R.J. (1994). *The Nature of Emotion: Fundamental Questions*. New York: Oxford.

Elliot, C., Lester, J., & Rickel, J. (1999). Lifelike pedagogical agents and affective computing: An exploratory synthesis. In M. Wooldridge and M. Veloso, (Eds.). *AI Today*. Lecture Notes in AI. NY: Springer-Verlag.

Eysenck, M.W. (1997). *Anxiety and Cognition: A Unified Theory*. Hove, East Sussex: Psychology Press, Publishers.

Hudlicka, E. and Zacharias, G. (2001). *Command and Control Warfare Analysis Reasoning System*. Cambridge, MA: Charles River Analytics (in preparation).

Hudlicka, E., Zacharias, G., and Psotka, J. (2000). Increasing Realism of Human Agents by Modeling Individual Differences: Methodology, Architecture, and Testbed.. In *Proceedings of the AAAI Fall Symposium*. Falmouth, MA..

Hudlicka, E. & Billingsley, J. (1999*). ABAIS: Affect and Belief Adaptive Interface System.*. In *Proceedings of the 43rd Annual Meeting of the Human Factors and Ergonomics Society*, Houston, TX.

LeDoux, J.E. (1989). Cognitive-Emotional Interactions in the Brain. *Cognition and Emotion*, 3(4), 267-289.

Matthews, G., Derryberry, D., & Siegle, G.J. (2000) Personality and emotion: Cognitive science perspectives. In S.E. Hampson (Ed.), *Advances in personality psychology* (Vol. 1). London: Routledge.

Pew, R.W. and Mavor, A.S. (1998). *Representing Human Behavior in Military Simulations*. Washington, DC. National Academy Press.

Picard, R. (1997). *Affective Computing*. Cambridge: MIT Press.

Revelle, W. (1995). Personality Processes. *Annual Review of Psychology*, 46, 295-328.

Schraagen, J.M.C., Chipman, S.E., Shute, V., Annet, J. Strub, M., Sheppard, C., Ruisseau, J.-Y., and Graff, N. (1997). *State-of-the-art review of CTA Techniques*. TR TM-97-B012. Soesterberg, The Netherlands: TNO Human Factors Research Institute.

1. In *Proceedings of the 45th Annual Meeting of the HFES*. Minneapolis, MN. 2001.

Steinweg, K.K. (1995). Dealing Realistically With Fratricide. *Parameters*, Spring, 4-29.

Vicente, K. J. (1999). *Cognitive work analysis: Towards safe, productive, and healthy computer-based work.* Mahwah, NJ: LEA.

Williams, J.M.G., Watts, F.N., MacLeod, C., and Mathews, A. (1997). *Cognitive Psychology and Emotional Disorders*. NY: John Wiley.