Neurally-Driven Adaptive Decision Aids

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Abstract. Warfighters are constantly challenged with increasingly complex mission environments, roles, and tasks, which require rapid and accurate decision making. Most current military and commercial decision aids leverage a single strategy: they retrieve and fuse information about well-defined objects and events for the user. Such aids effectively discourage users from considering contextual information and patterns that may help them recognize or think critically about hostile or innocent events. If a decision aiding system were to be truly effective, its adaptive strategies should be driven by more than manipulation of well-defined information presented to the user. In this paper, we propose several critical factors - (1) Information state, (2) User cognitive state, and (3) Interaction state – that will enable for discern what must be decided and by when; discriminate which cognitive state and process are in play; and assess interactions (queries, selections, etc.) with the information. Most importantly, these factors will allow for a decision aid to capitalize on –the distinctly human ability to find meaning in swarm of objects and events being perceived.

Keywords: adoptive decision aids, intuition, cognitive state, warfighters.

1 Decision Aids

Warfighters are often faced with dynamic and increasingly complex mission environments, roles, and tasks, which necessitate rapid and accurate decision making. Army combat operations occur in densely-populated urban settings where the physical dimensions and cultural and social characteristics of the environment interact to dramatically compress and complicate the dynamics of the battlespace. The enemy is no longer a large, slow-moving, monolithic entity from the Cold War; the enemy is diverse, numerous, and includes asymmetric threats—small bands of unknown and highly adaptive terrorists, insurgents, drug-traffickers, and other criminal elements. There is a need for adaptive decision aids that support operators in these complex,

D.D. Schmorrow et al. (Eds.): Augmented Cognition, HCII 2009, LNAI 5638, pp. 30–34, 2009.

dynamic contexts. Most current military and commercial decision aids leverage a single strategy: they retrieve and fuse information about well-defined objects and events for the user. This is the purpose of track correlation functions (which associate track radar, emissions, ID and other data) on consoles in the AEGIS Combat Information Center (CIC). It is the function of most information management tools for the intelligence community [1]. Such aids effectively discourage users from considering contextual information and patterns that may help them recognize or think critically about hostile or innocent events. These aids, in short, focus user attention on the most recognizable data at the finest level of granularity. They fail to capitalize on – and may even suppress – the distinctly human ability to find meaning in swarm of objects and events they perceive. For example, CIC systems encourage users to focus on the kinematics of individual entities, but do not support inferences about coordinated actions (e.g., one aircraft is the sensor, another is the shooter) between them.

If a decision aiding system were to be truly effective, its adaptive strategies should be driven by more than manipulation of well-defined information presented to the user. An effective system should be able to dynamically adapt the aid it offers as a function of several critical factors: (1) Information state - the evolution of the decision task over time towards a deadline; (2) User cognitive state - the decision maker's cognitive state and decision processes; and (3) Interaction state - the decision maker's interactions (queries, selections, etc.) with the information.

(1) Automated assessment of the state of Information should enable the aid to discern what must be decided and by when. Specifically, these measures enable the system to (A) estimate the focus of decision activity, (B) the time course of a decision (to discriminate early from late decisions, and (C) manipulate that information in many of the ways above (testing, exploration, algorithm support).
(2) Automated assessment of the Cognitive state should enable the aid to discriminate which cognitive state and process are in play.
(3) Automated assessment of Interaction state should provide behavioral data with which to triangulate on information state and cognitive state.

Assessing each of the three states described above presents challenges in an environment in which time is scarce, stakes are high, and uncertainty is ever present. However, the challenge of measuring cognitive state is perhaps the most difficult. Cognitive psychology has developed methods of inferring cognitive state and process from reaction time and accuracy data but these methods are highly artificial, suitable only for laboratories and not for operational environments. However, recent advances in neuroscience may enable us to measure aspects of cognitive state and cognitive process reliably, in operational settings. For example, a number of neuroimaging and neurophisiological studies examined the nature of decision making and the process that underlie it, such as – Intuition [2][3][4]. We are engaged in research in research that focuses on intuition.

2 Intuition

Intuition is often credited with helping warfighters succeed in critical situations. Research in human pattern recognition and decision-making suggest that there is a sixth sense through which humans can sense unique patterns without consciously seeing them [5][6]. This fast-acting mode of recognition may act as a first-pass filter for gleaning insight of an entire scene [7]. Cursory evidence at an aggregate level suggests that this capability, known as “sixth sense” or “intuition” may be detectable at both the behavioral [8] and neurophysiological [2] [3]. We define intuition as an affectively charged, internal cue to the existence of meaningful information in the environment that arises rapidly and unconsciously. Intuition is not a decision or solution. There is accumulating evidence that indicates that this capability may be trainable [5] [8] and malleable [9] in extremely limited contexts, although it is certainly subject to biases [10] and other types of errors [11].

Recent advances in neuroscience may enable us to reliably measure aspects of cognitive states and cognitive processes involved in decision making, in operational settings [2] [3] [4] [12] [13]. For example, Volz et al. (2006) utilized functional Magnetic Resonance Imaging (fMRI) to examine the neural basis of intuition in participants who were engaged in a modified version of the Waterloo Gestalt Closure Task that involved presentation of images that had been fragmented (i.e., some of the pixels were removed) to varying degrees. The participants were instructed to indicate whether each image contained an object. Fragmenting the images as well as the brief presentation (400ms) made it harder for participants to identify objects in the images. Some of the fragmented images were also scrambled in a way that made them appear incoherent. Participants were instructed to use their “feeling” of whether each image contained/did not contain an object, but they did not have to identify the object. The results of this study revealed activations in the median Obitofrontal Cortex (OFC), the lateral portion of the amygdale, anterior insula, and ventral occipito-temporal regions. The authors identified the OFC to be the area subservient for intuitive coherence judgments. Volz et al. (2008) study further confirmed these conclusions as well as demonstrated that activation in the OFC is modality independent.

In order to further characterize the temporal, spatial, and contextual parameters of intuition, we recently carried out an experiment, utilizing high-density array Electroencephalography (EEG). The results of experiment demonstrated activation in the Orbitofrontal Cortex (preciously identified to be associated with intuitive processing, see [3] [4]) as early as 220ms after stimulus onset in response to images that were perceived to be coherent, regardless of whether there was an actual object in the image or not. These results provided additional support for the notion that intuition can be characterized temporally and spatially, and that we can reliably measured its occurrence with neurophysiological tools.

3 Decision Aids Guided by Intuition

The development of reliable measures of intuition provides new opportunities to understand and aid human cognition. Here, speculate on the function of intuition in human cognition, and the way that intuition-aware devices might enhance human performance.

Intuition is a rapid, automatic cue to the decision maker that aspects of the current situation are coherent or meaningful. Intuition in and of itself does not convey the meaning of an object or event. It merely signals that recognition or comprehension of a scene is approaching.

This signal may help a domain expert to manage the decision process. Thus, intuition serves a metacognitive function. For example (see Figure 1):

The presence of intuition indicates to the decision maker that it is better to wait out the process of recognition than to guess, if time is short. Even if time is plentiful, it may be best to wait briefly for recognition to produce solutions instead of (or before) engaging in deliberate analysis.

Conversely, the absence of intuition indicates that waiting for recognition may be futile. Thus, it may be best for the decision maker to apply a default response or guess if time is short; it may be best to invoke deliberate, analytic processes if time is plentiful.

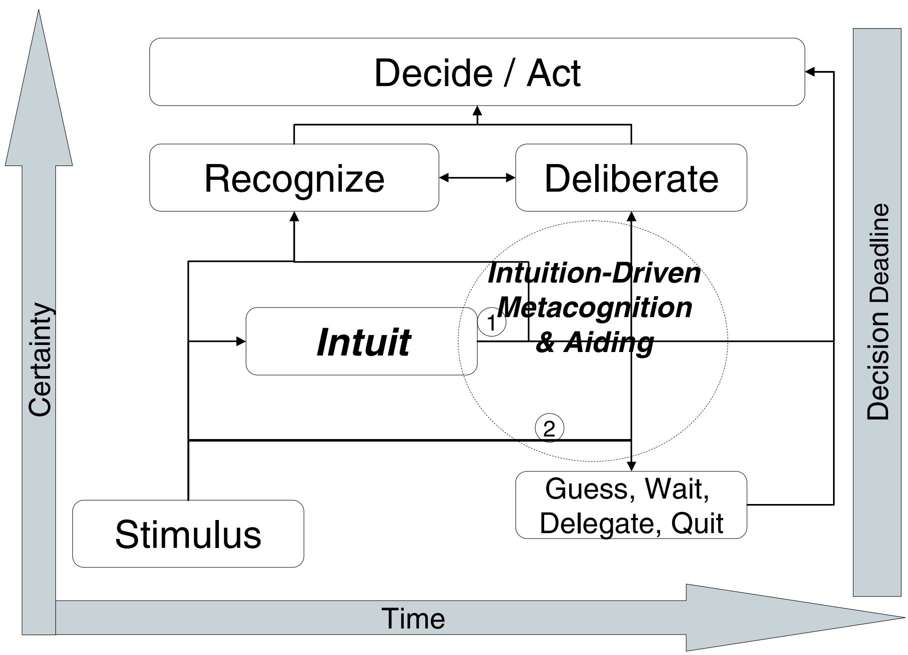

Fig. 1. Intuition may support metacognition and decision aiding. Its presence (1) may promote recognitional processing and rapid action. Its absence (2) may promote guessing or deliberation.

If intuition helps people to manage decision processes and decision time, then reliable measures of intuition might enable us to create a new generation of machines to support decision making.

A decision aid that senses its user's intuitive moments might, perversely, serve its owner best by withholding information that could conflict with the user's rising solution. For example, automated target recognition aid typically overlays sensor imagery (e.g., a vehicle obscured by trees) with a diagrammatic template of the most likely target (e.g., a technical or pickup truck mounted with a machine gun). Given a reliable signal of intuition, the aid might withhold that template while the user's recognition of the scene resolves, with the expectation that the user's response will be more accurate and sufficiently quick.

A decision aid that senses the absence of an intuitive moment might serve its owner by rapidly cueing a solution (e.g., a technical) if time is short. It might, if time is plentiful, present its owner with decision analysis tools (e.g., a decision tree for discriminating technicals from standard pickups, light armored vehicles, etc.).

These are real time, personal applications, in which the intuitions of the decision maker instantaneously drive his (or her) own decision aid.

We are devising an array of other applications that may use measures of intuition in real time to support teams of humans in real time, and other applications that use intuition offline to train autonomous robots.

In sum, reliable measures of intuition may help us to devise a new generation of tools that enhance human decision processes or protect them from interference. The net result should be faster and better decisions when they are needed most.

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