Human-Machine Interface Possibilities: “What If the Machine Is a Human-Like Cognitive Entity?"

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http://www.sandia.gov/cog.systems/Index.html

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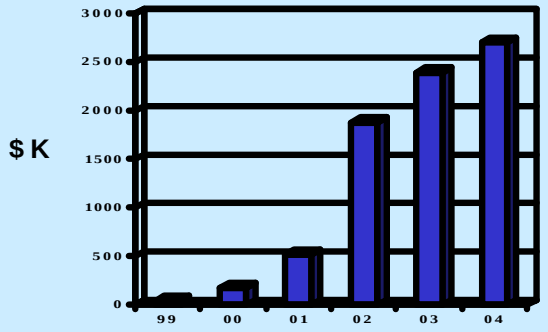
Sandia Cognitive Systems Program

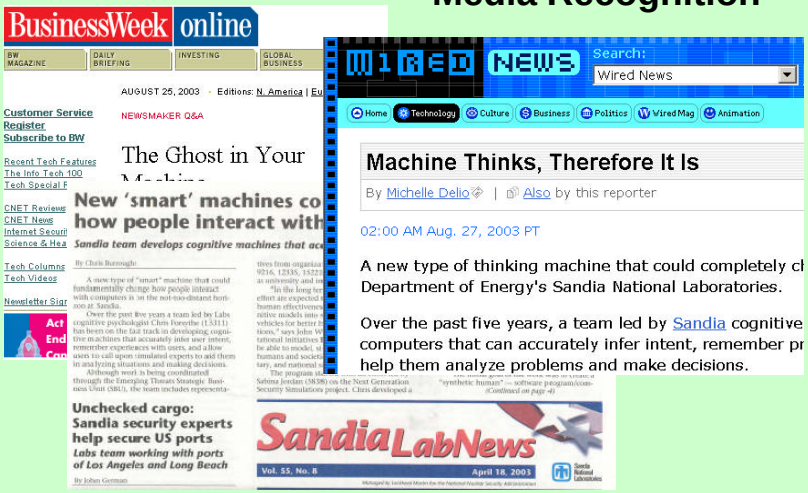
Some Facts

- 5 yrs R&D to develop plausible computer model of human cognitive processes
- 2 yrs R&D to develop solutions for augmenting cognition
- Cognition Grand Challenge LDRD entering second of three years
- Phase 2 DARPA Augmented Cognition

Growth Since Program Conception



Media Recognition



External Partnerships

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Objectives for Cognitive Systems Program

- Develop and apply technologies that will augment the capacity of humans to detect and interpret meaningful patterns in massive volumes of data from diverse sources.
- Enable humans to operate beyond the bounds of their own knowledge and experiences, fully cognizant of their biases and how these biases shape their cognitive processes.
- Create systems that interact with users in a knowing cognitive manner:
  - (1) know what you know, what you don't know, what you do, how you do it,
  - (2) can place current events in the context of past experiences and
  - (3) make readily accessible the knowledge and experience of diverse experts.

Our approach to achieving the vision

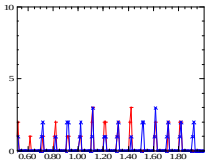
- Embed within machines highly realistic and individualized computer models of cognitive processes vital to human communication, cooperation and collaboration.
- Develop software that acquires accurate models of an individual's knowledge of a domain or task by observing their day-to-day computer interactions.
- Develop products that serve as an externalized memory providing useful access to past records, transactions and events.
- Develop products that interact with a user on the basis of their individual knowledge and experience.
- Create systems that use expert cognitive models to interpret data and collaborate with users to put diverse knowledge and experience at the fingertips of analysts, engineers and scientists.

Why this is not Artificial Intelligence

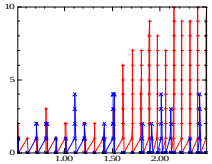
- Intent is to model specific individual, instead of a generalized expert model, or absolute truth.
- While many AI systems have been inspired by human cognition, our systems' "human-likeness" is attained through a rigorous engineering process with no known counterpart in AI.
- Dynamic complex system that responds gracefully to anomalous events and may easily adapt to changing circumstances, as opposed to brittleness of rule-based expert systems.
- Knowledge is associative with emphasis on pattern recognition, as opposed to rule-based representations of knowledge and emphasis on logical operations.
- Machine interaction with human user based on adaptation to the unique knowledge and experience of individual with emphasis on systems that conform to the user, as opposed to one-size fits all approaches or customization based on statistical profiles.
- Ultimate goal is to augment the human, not replace the human.

Psychologically plausible model of human cognitive processes

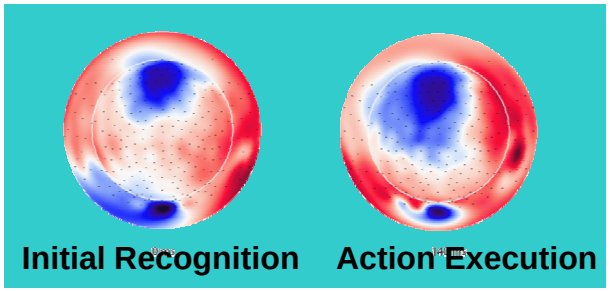
Computational model inspired by naturalistic decision making and oscillating systems concepts.

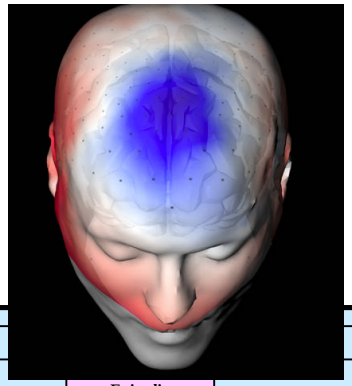


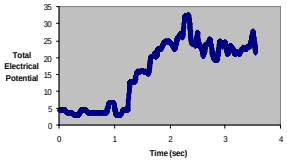
Entrainment with Pacemaker



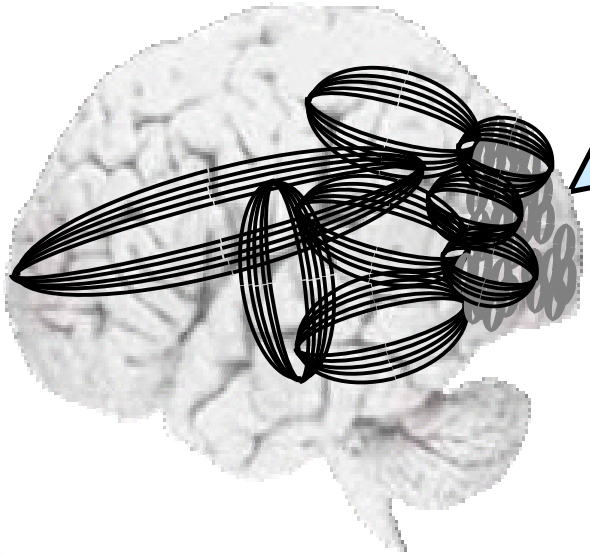
Selective Phase-Locking with Stimulus

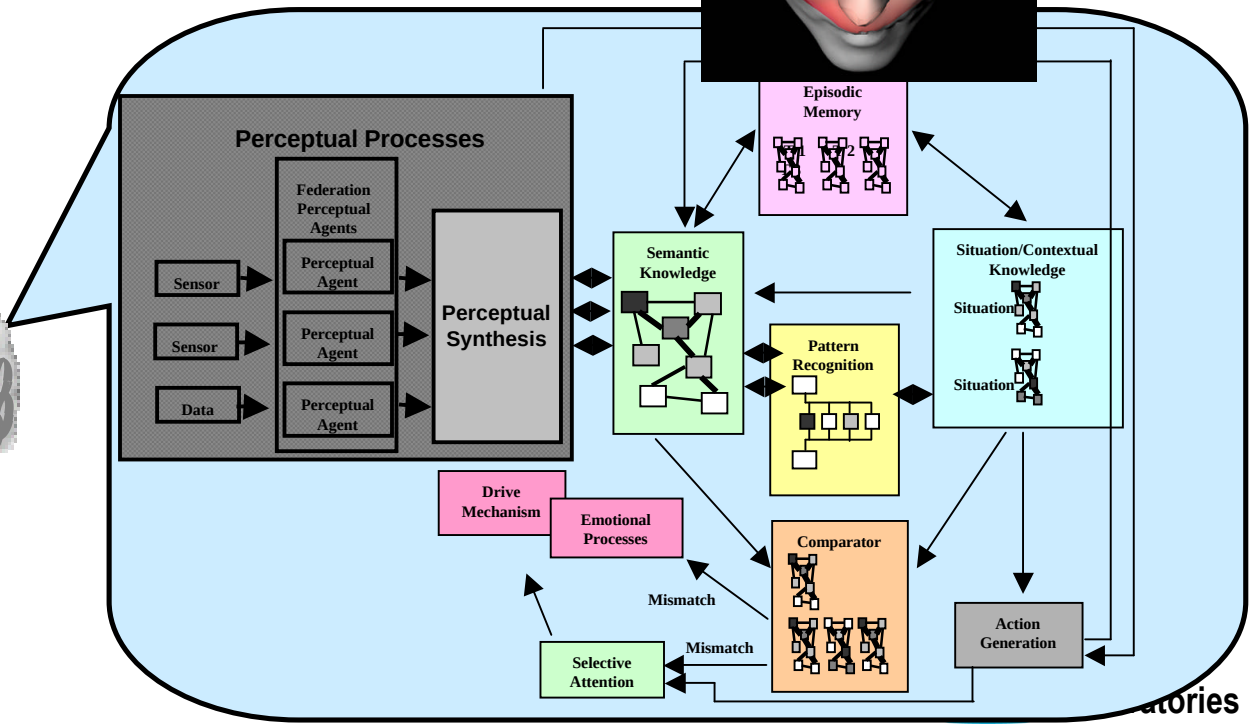




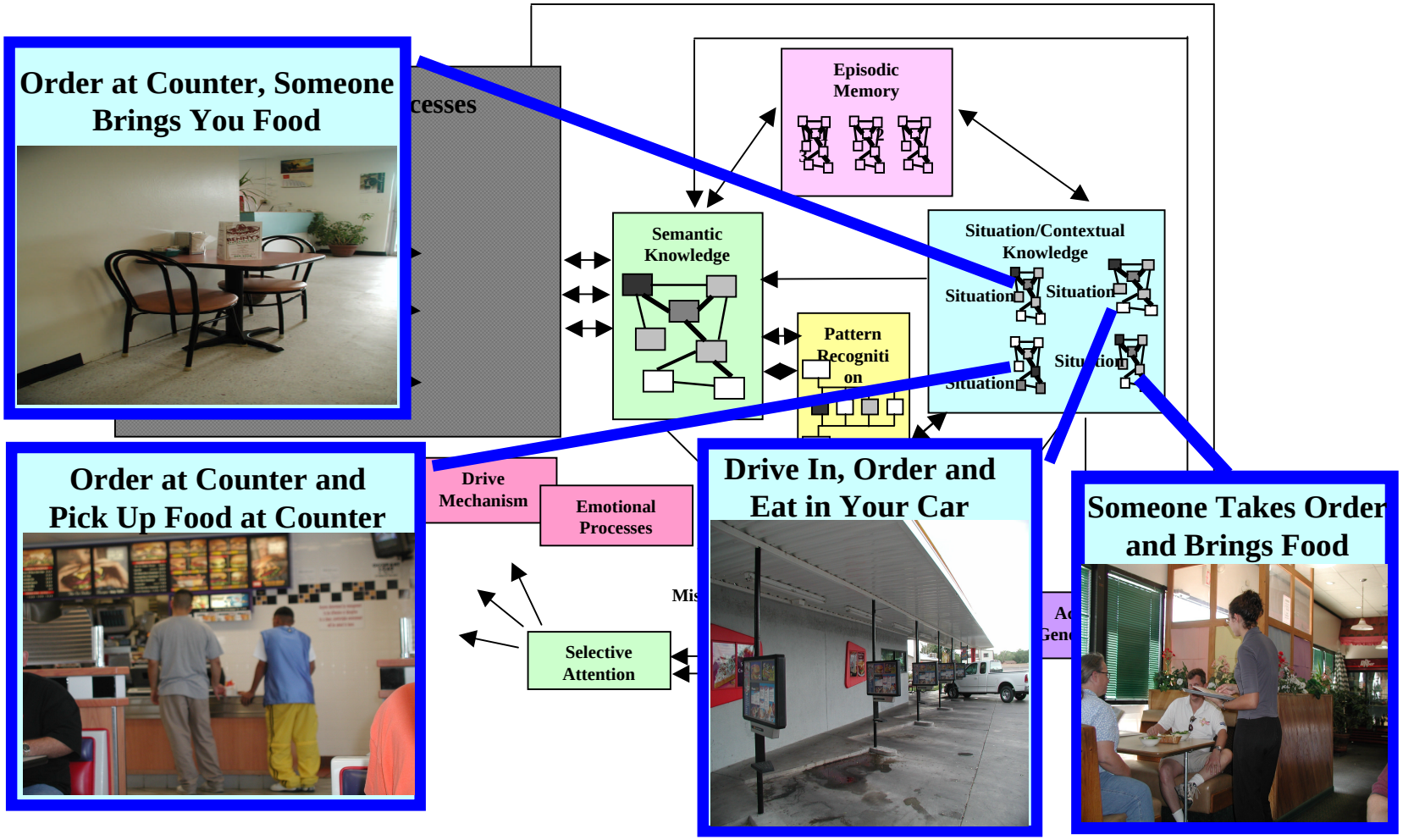


Event-Related Activation





Knowledge of situations: Different types of restaurants



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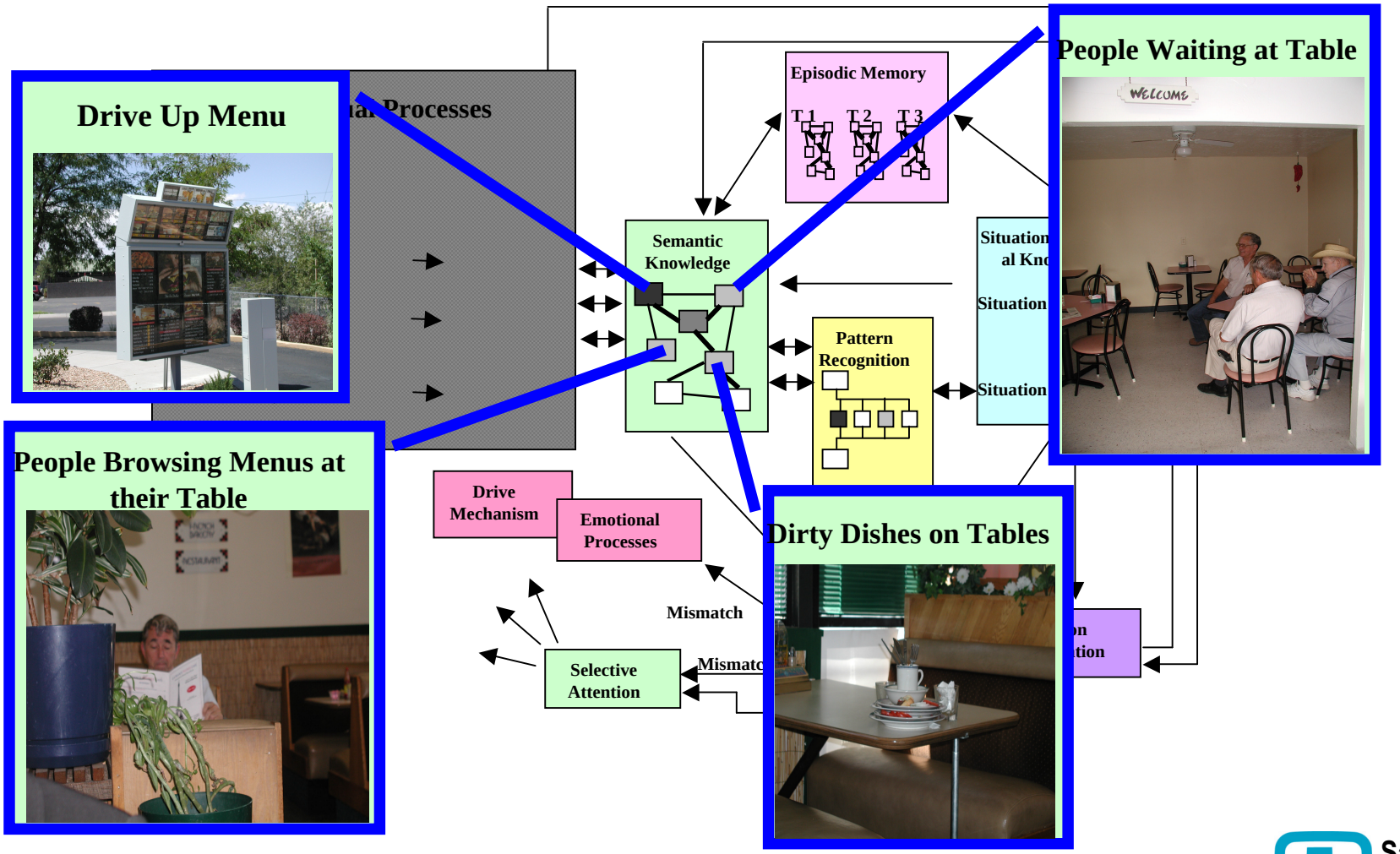
Different cues are associated with different situations



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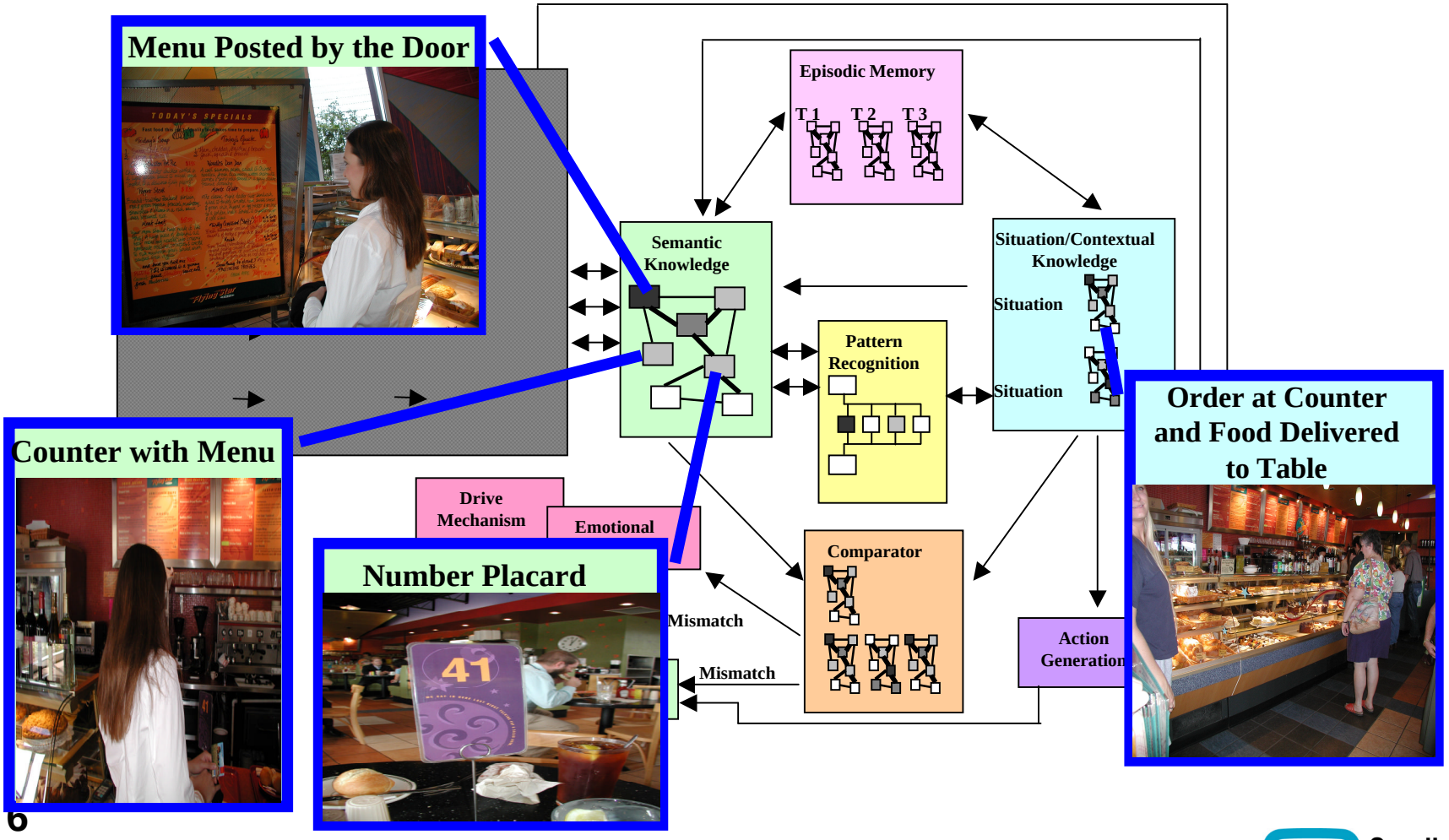
Situation Recognition based on patterns of cues



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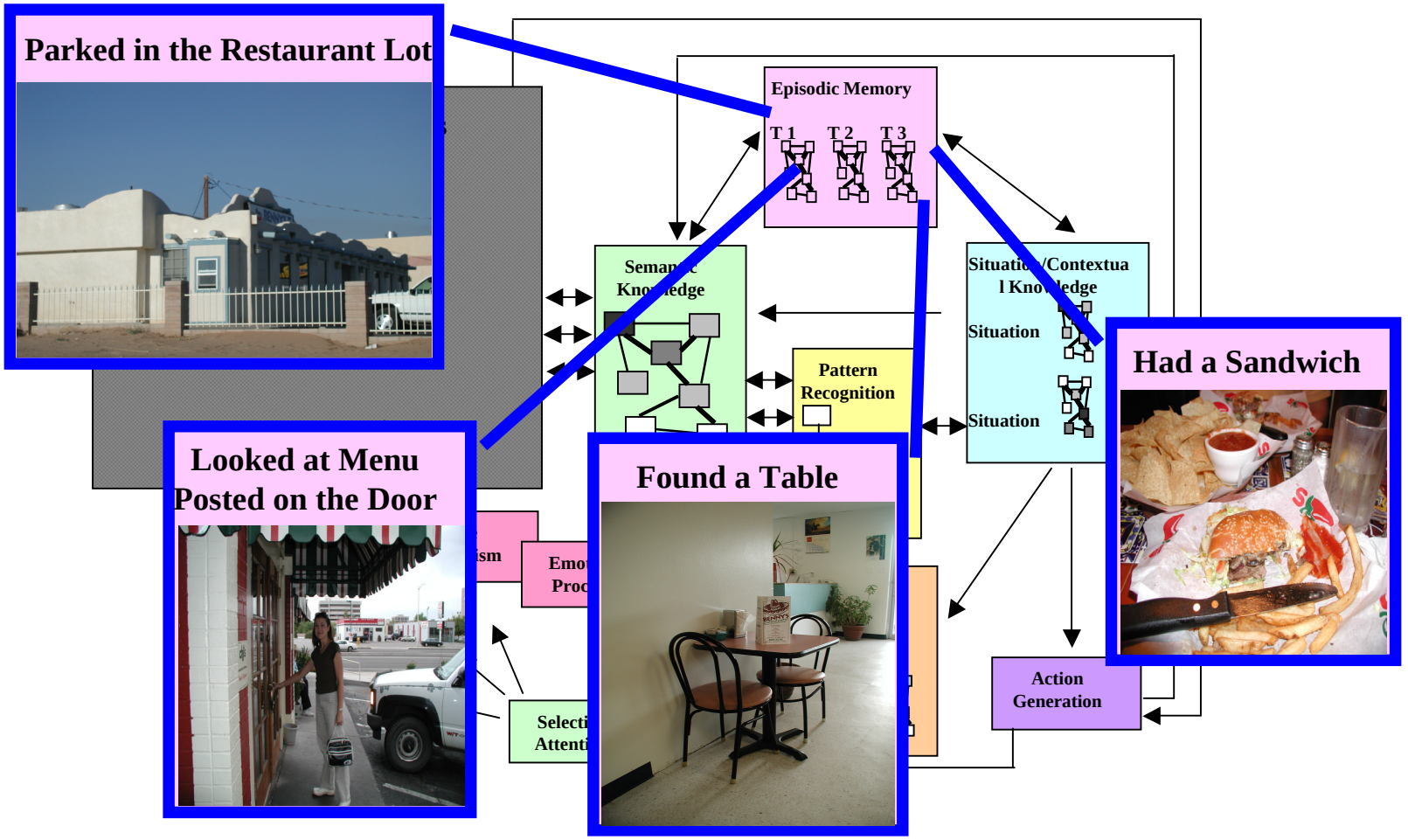
Situation recognition triggers memory of similar situations



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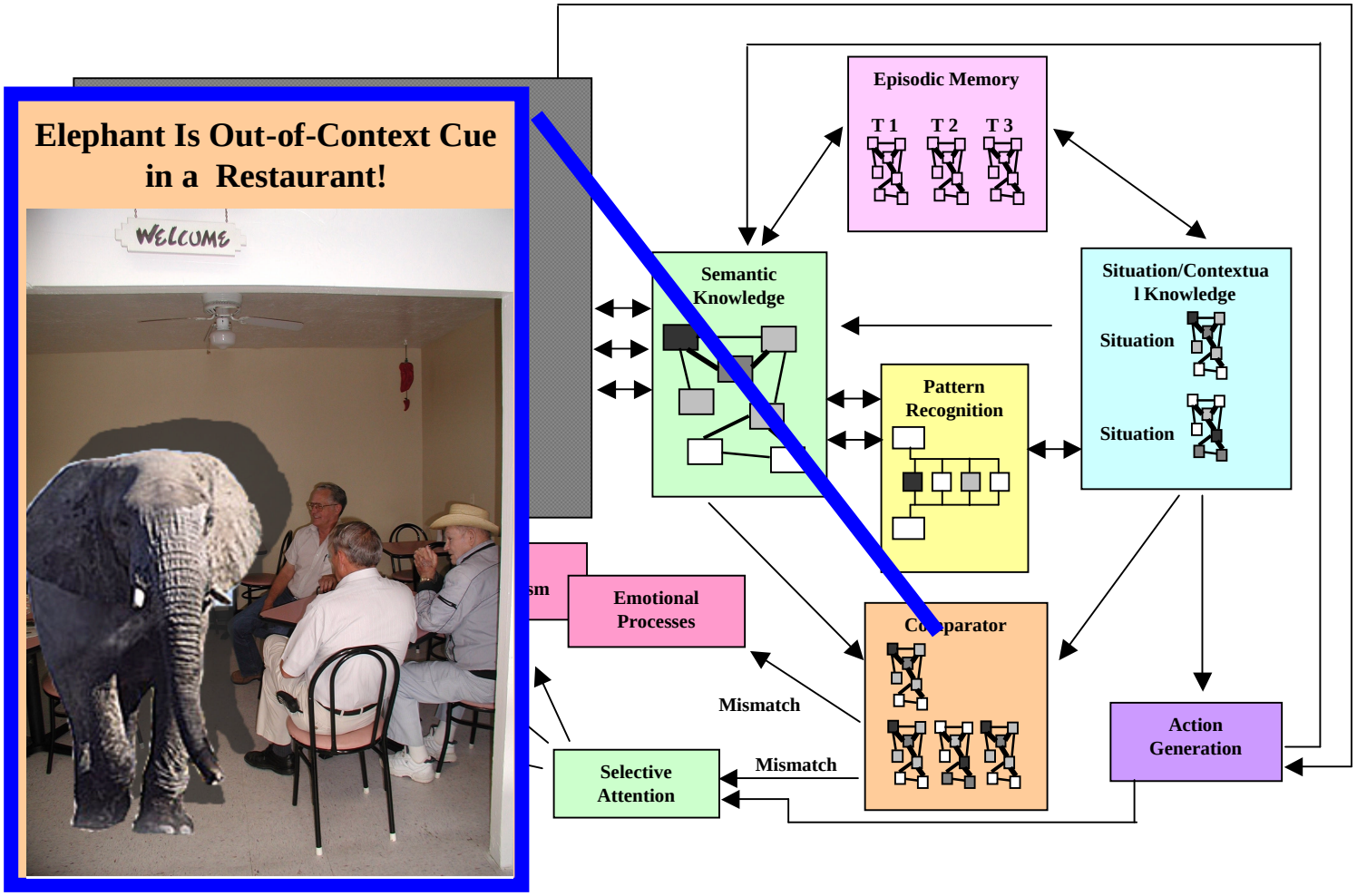
Out-of-context cues trigger emotional and attentional response



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Continued cognitive framework development has a sound scientific basis

Most recent set of Specifications consists of 153 functional characteristics from the cognitive psychology and neuroscience literature.

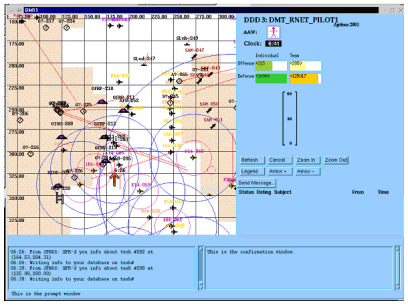
	Specifications	Basis for Specification	Findings and Notes	Source
SpOS-3	Generally, in response to cognitive demand, the firing patterns of neural units with an oscillatory component in the theta bandwidth should exhibit an increased synchronization.	Subjects were sequentially presented feature-concept pairs (e.g. claws-eagle, wings-banana) and asked to indicate if they were semantically congruent. Subsequently, subjects were presented feature words and required to recall the concept with which the feature had been paired	Found increased synchronization in the theta bandwidth associated with episodic memory recall.	Klimesch, W., Doppelmayr, M., Pachinger, T. & Russegger, H. (1997). Event-related desynchronization in the alpha band and the processing of semantic information. Cognitive Brain Research, 6, 83-94.
SpSem-6	Generally, there should be decay whereby activation of a concept diminishes following removal of the associated stimulus.	Subjects were presented stories in which characters entered and left the activities. At different points, probes asked subjects to indicate if words associated with one of the characters had appeared in the story.	Accessibility of knowledge reflected by reaction times to probes varied in response to whether characters were involved in activities within the story at the point the probe was presented.	Gerrig, R.J. & McKoon, G. (2001). Memory processes and experiential continuity. Psychological Science, 12, 81-85.
SpEmo-Epi-2	Generally, the accessibility of episodes from episodic memory should be greater for episodes involving activation of emotional processes.	Pictures were presented and subjects rated each relative to emotional intensity and pleasantness. Subjects listed all the pictures that they could recall. Next, subjects were presented a series of pictures and indicated if each appeared in the original s	Emotional intensity, regardless of valence, enhanced recall.	Hamann, S.B., Cahill, L. & Squire, L.R. (1997). Emotional perception and memory in amnesia. Neuropsychology, 11, 104-113.

Sandia is currently working on the DARPA AugCog Program

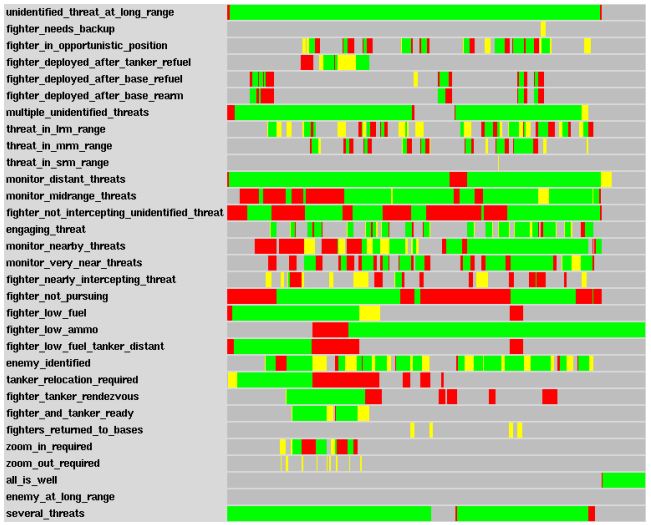
Real-Time Inference of Operator Cognition

Cognitive model for an operator observes data and events and interprets situations based on the operator's cognitive model.

Compared to a reference stating the operator's true interpretation of data and events, the model interpretation was 87% accurate overall, and 91% accurate in recognizing the occurrence of situations.



AWACS simulator presented complex cognitive task involving management of multiple assets and threats



Comparison of model to reference. Green and gray indicate accurate inferences, red false positives and yellow false negatives.

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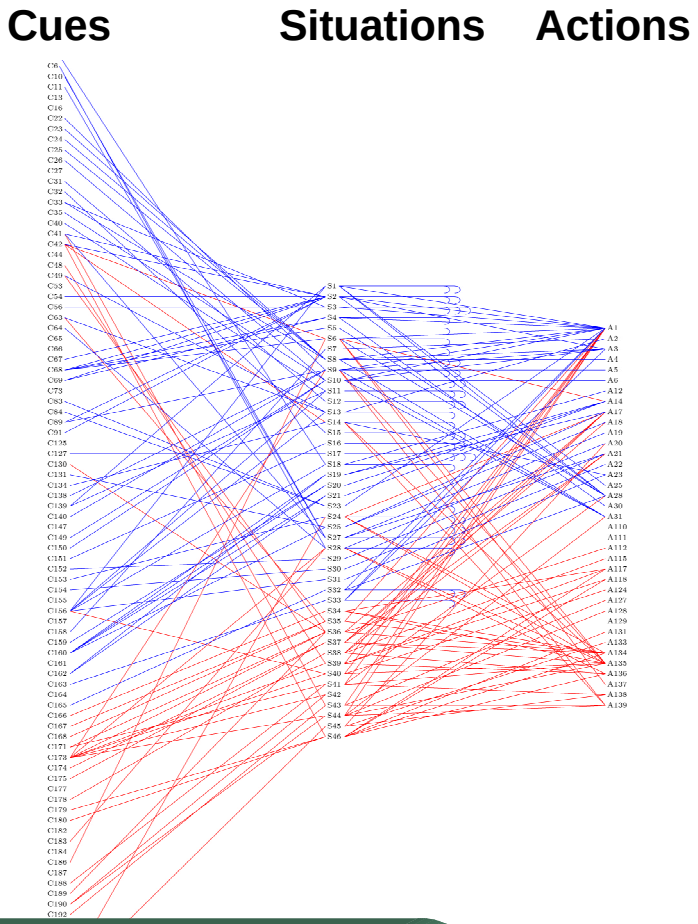
Preliminary results indicate importance of conforming to operator

Individualized Cognitive Models

Utilized knowledge elicitation to develop individualized cognitive models that reflected the unique knowledge of each operator.

As illustrated in the accompanying figure, operators trained to equivalent levels of expertise may possess different cognitive models of a task. Here, the blue and red connectors distinguish the two operators.



Designing the machine to adapt to the individualized human cognitive model is critical, one size does not fit all

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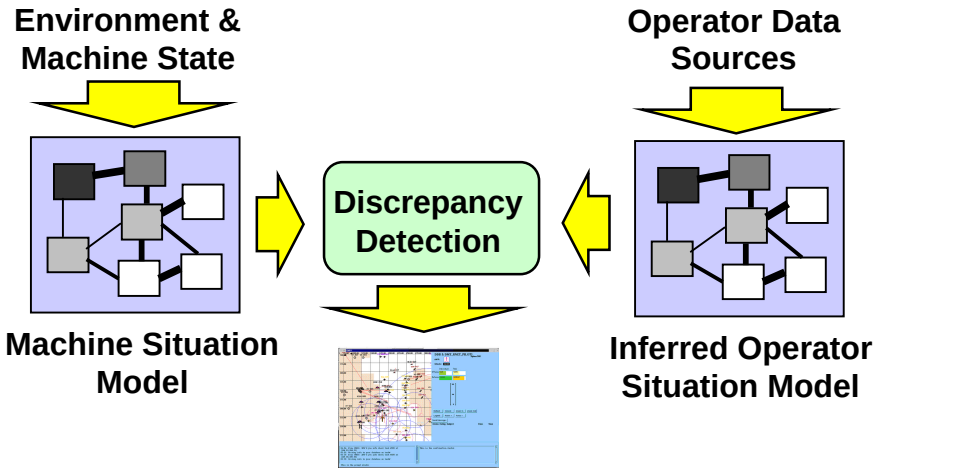
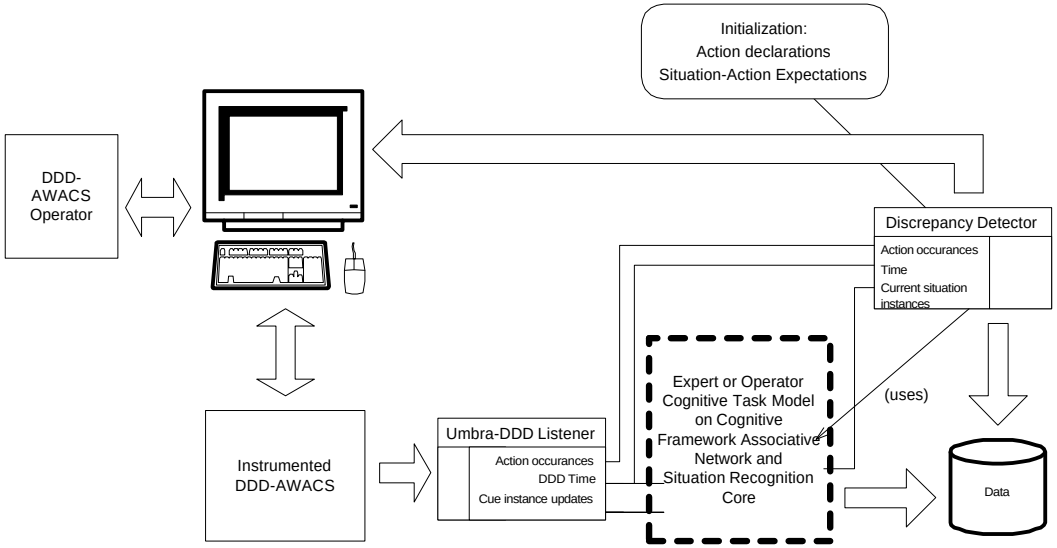
Real-time inference of operator cognition enables unique modes of human-machine interaction

Discrepancy Detection

Demonstrated discrepancy detection where the machine detects when there is a mismatch between machine state and operator perception of the machine. This was accomplished by comparing ongoing input from the operator to machine-based cognitive model of the operator





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Cognitive collective of expert models

A cognitive collective utilizes multiple embedded experts to attain a collective situation recognition.

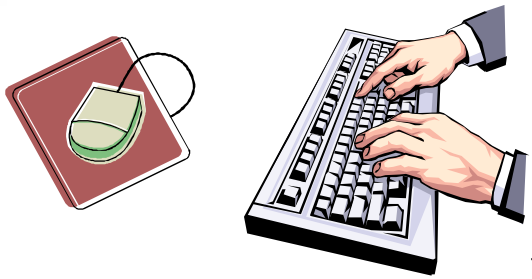
- Police Records
- Financial/Credit Records
- Legal Records (lawsuits, etc)

Cognitive Collective

End User

- HR Database
- Need-To-Know App
- Network Logs
- SNL Phone Records
- SNL Cell Phone Records
- Email Records
- Foreign Nat'l DB
- Security DB
- Employee/Labor Rel'n DB
- Access Control System
- Expense Reports
- Foreign Travel Req. DB
- Audits
- Patents and Licensing
- LDRD Project DB
- WFO DB

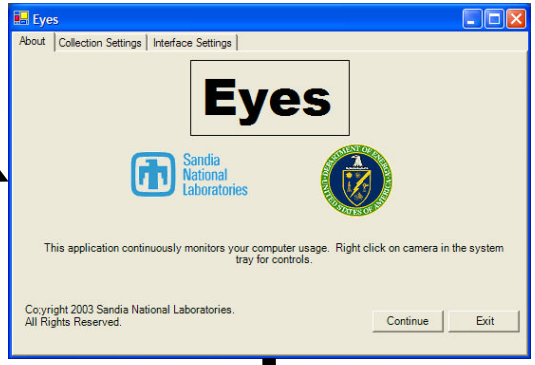
Personal information management

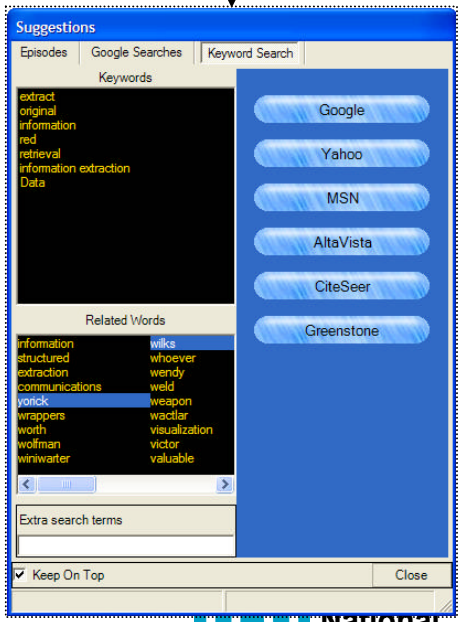


Data Analysis and User Profile

Data Collection

Keyboard/Mouse
IE Watcher
Word Watcher
Outlook Watcher
PowerPoint Watcher





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What We Can Do Today

- **Model the individual.** Accurately capture individual knowledge in a computer-based cognitive model.
- **Surveillance using cognitive collective.** Integrate cognitive models with systems to interpret events in real-time with expert models operating individually and as a collective.
- **Error detection and recovery.** Recognize conditions indicative of situational errors (i.e. fail to recognize emerging situation, misinterpret situation, etc.)
- **Personal knowledge management.** Capture ongoing record of computer-based transactions that may be queried or visualized to provide enhanced awareness and access to personal knowledge and experience.

What We Will Be Able to Do in 6-12 Months

- **Automated capture of domain knowledge.** Automatically capture an individual's semantic knowledge of a domain through their computer-based transactions.
- **Automated capture of task knowledge.** Automatically capture an individual's semantic knowledge of a software application and associated tasks through their computer-based transactions.
- **Interact with expert models.** Allow comparisons and contrasts of the semantic knowledge of cognitive models (e.g. Expert A vs Expert B, Expert A vs self).
- **Externalized and collective memory.** Capture record of experiences in a cognitive model that allows for comparison of current to past events (i.e. has anyone seen anything like this before, where have I seen this before?)

Conclusion

- Arguably, many of the technologies in which we've invested the past few decades may have reached the point of diminishing returns.
- New approaches are needed that have a breadth of application ranging from cell phones/PDA's to massive systems-of-systems.
- A transformation in human-machine systems comparable to the 80's transition from command line interfaces to GUI's is sorely needed.
- We believe our approach to cognitive systems offers a path to future breakthroughs in human-machine interaction, with enhanced human capability and productivity.