



From Cognitive Models to Cognitive Systems

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



What Are “Cognitive Systems?”

A “Cognitive System” is one that utilizes psychologically plausible computational representations of human cognitive processes as a basis for system designs that seek to engage the underlying mechanisms of human cognition and augment the cognitive capacities of human users, not unlike a “cognitive prosthesis.”

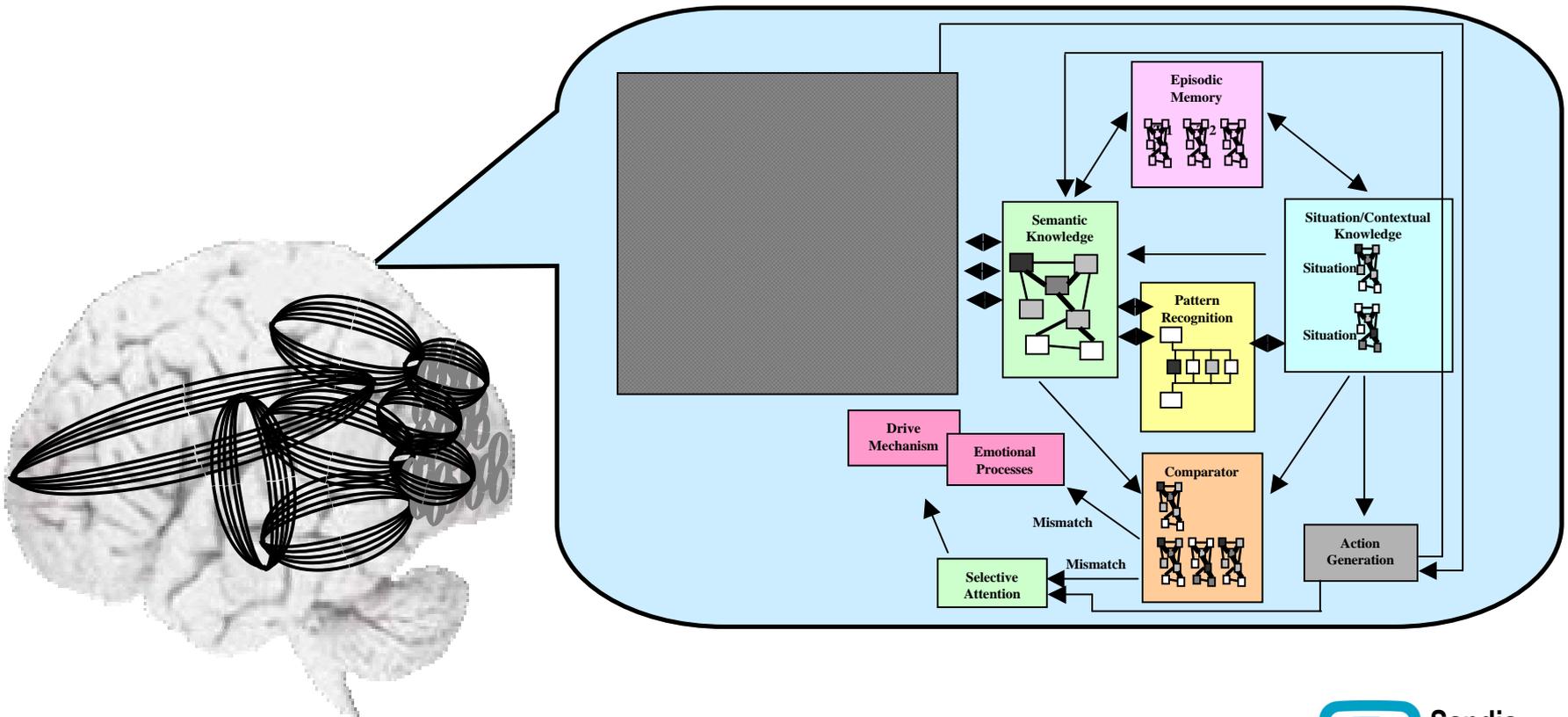


Our Vision for Cognitive Systems

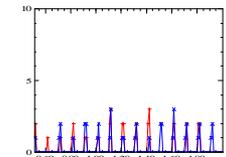
- Reverse current trends so that the machine conforms to the human, as opposed to the human conforming to the machine.
- Embed within machines highly realistic and individualized computational representations of cognitive processes vital to human communication, cooperation and collaboration.
- The machine becomes an augmented human cognitive entity that knows you like your best friend.

Psychologically Plausible Model of Human Cognitive Processes

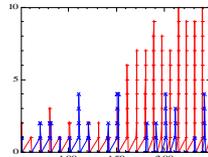
Computational model inspired by naturalistic decision making and oscillating systems concepts



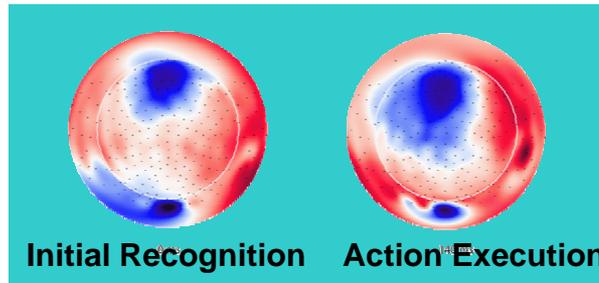
Cognitive Framework Composed of Oscillating Systems



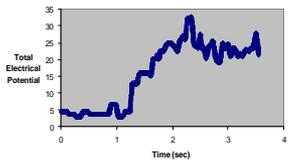
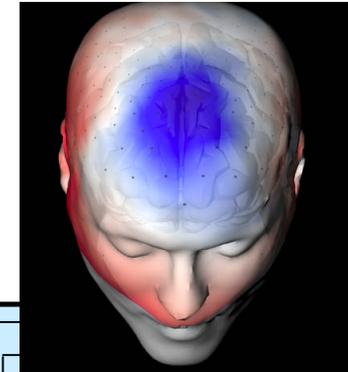
Entrainment with Pacemaker



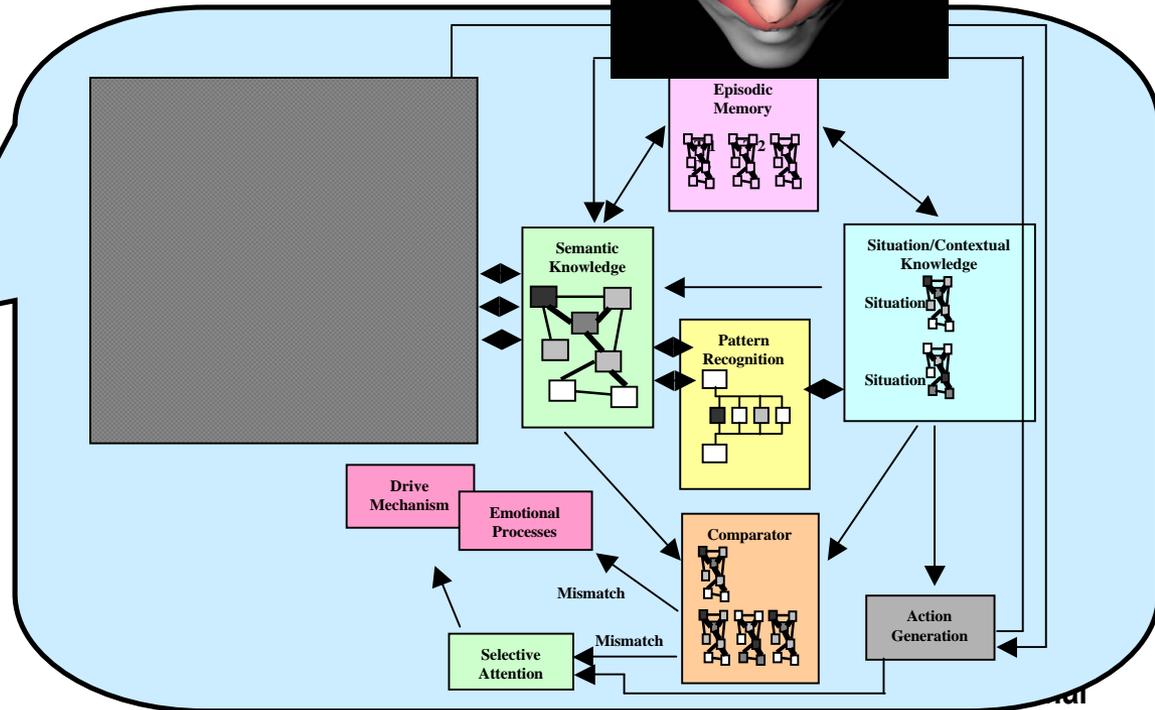
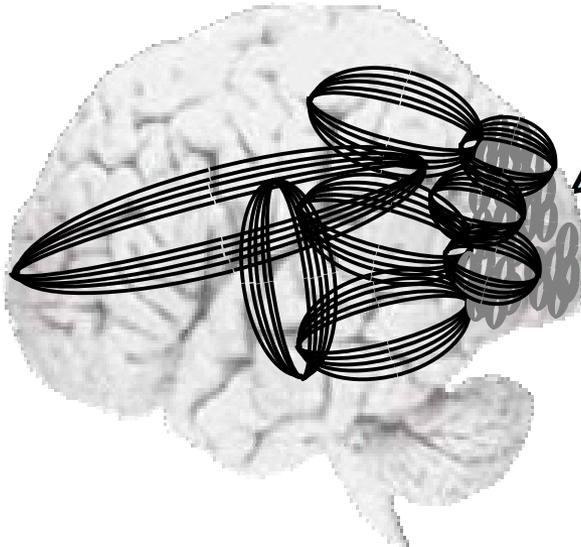
Selective Phase-Locking with Stimulus



Initial Recognition Action Execution



Event-Related Activation



Standardized Knowledge Components

Knowledge components provide standardized format for representing knowledge to enable automatic generation of cognitive model components

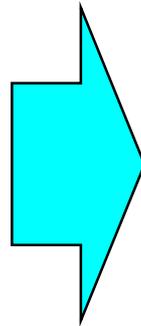


Knowledge Elicitation

Automated Knowledge Capture

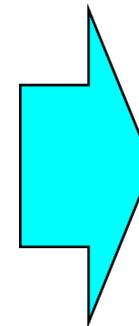


Text and Related Sources

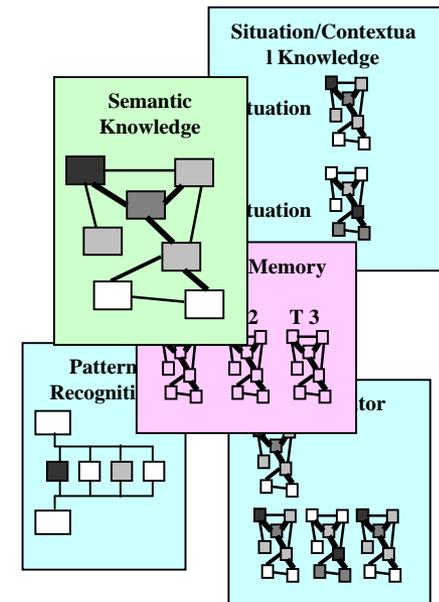


Knowledge Component

	B	C	D	E
A	0	4	0	0
B	-	1	2	1
C	1	-	0	0
D	2	0	-	4
E	1	0	4	-

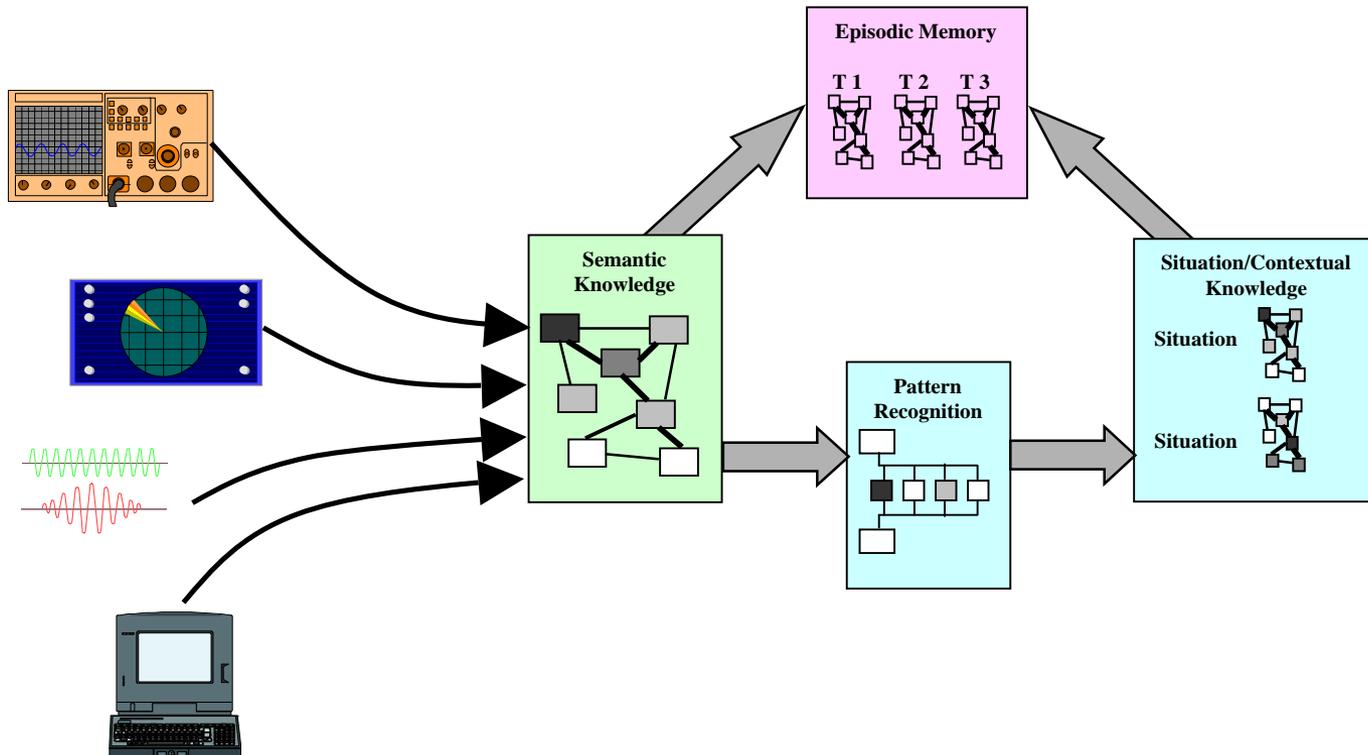


Cognitive Model Components



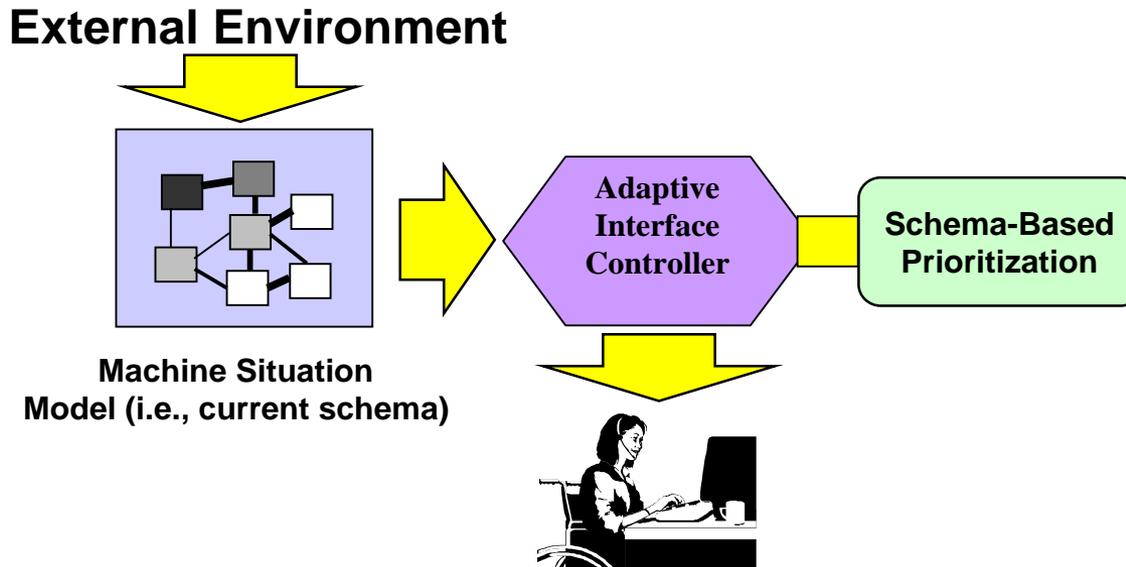
Flexible Modular Construction of Cognitive Systems

Cognitive model components may be combined and linked to inputs and outputs to construct integrated systems



Knowledge for Adaptive Systems

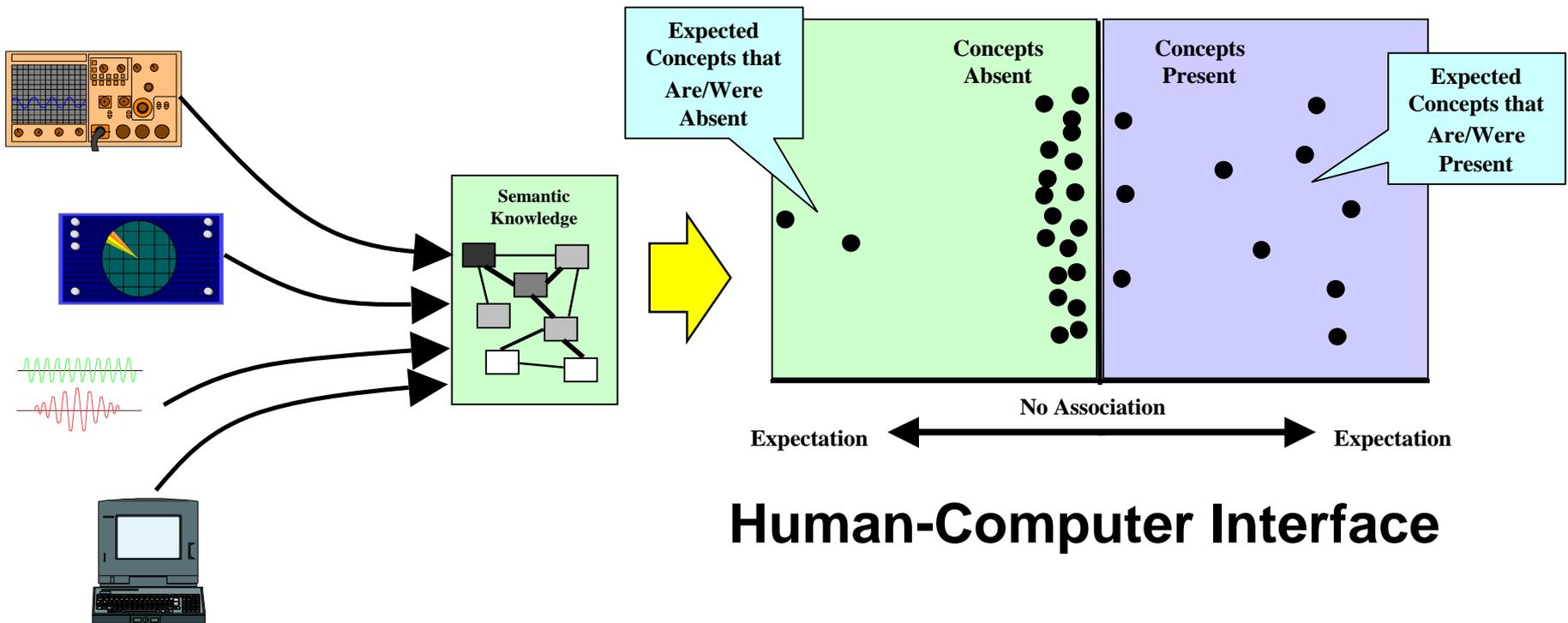
Some components provide standardized representations of knowledge for adaptive systems – e.g., Schema-Based Prioritization



Component indicates the situation-based prioritization of information or tasks for systems employing information filtering, task delegation, interruption mediation, etc.

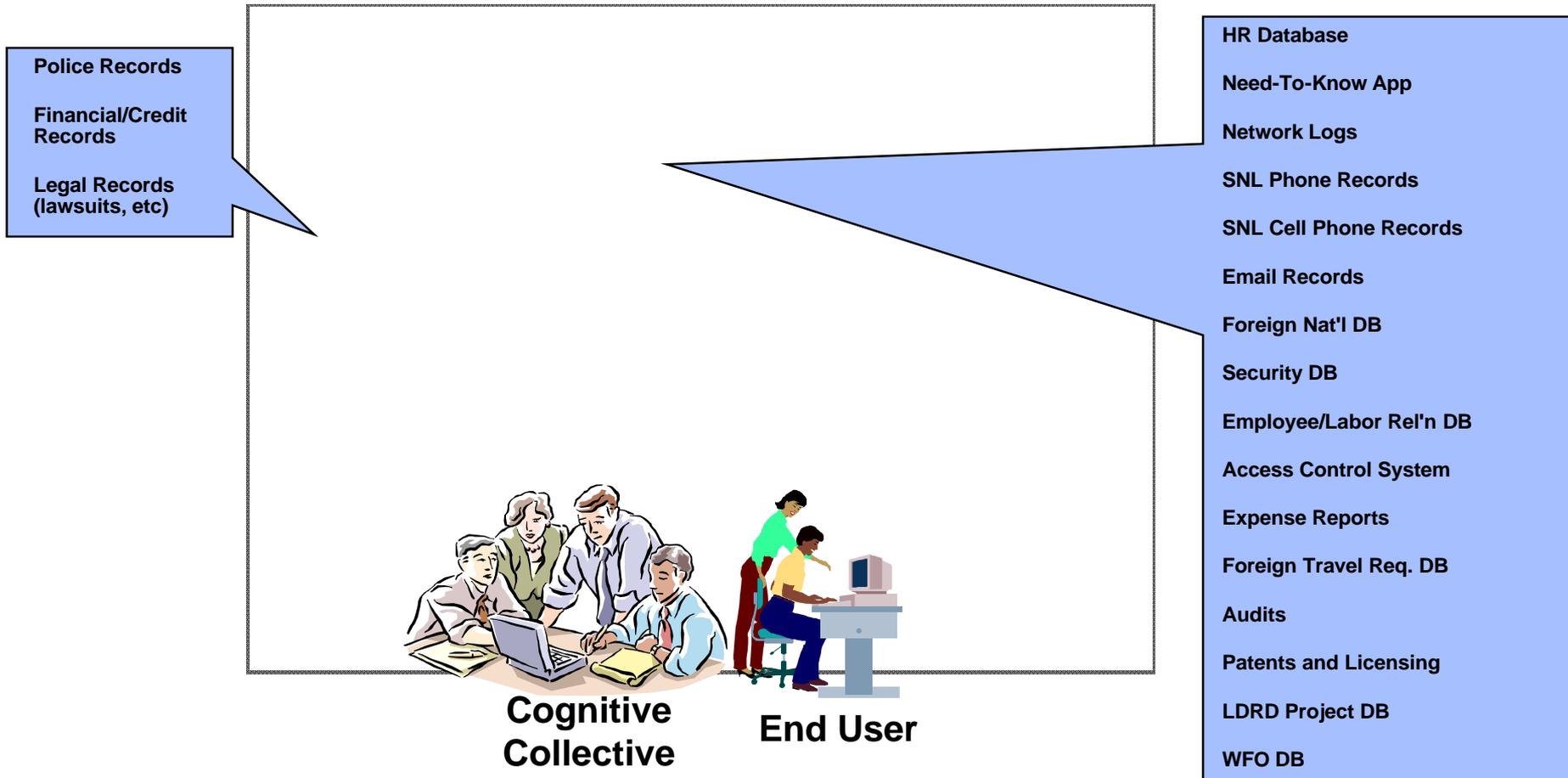
Cognitive Systems for Perceptual Representation

Mechanisms for utilizing perceptual representations to augment cognition – e.g., Counter-bias Transformation for Illusionary Correlation

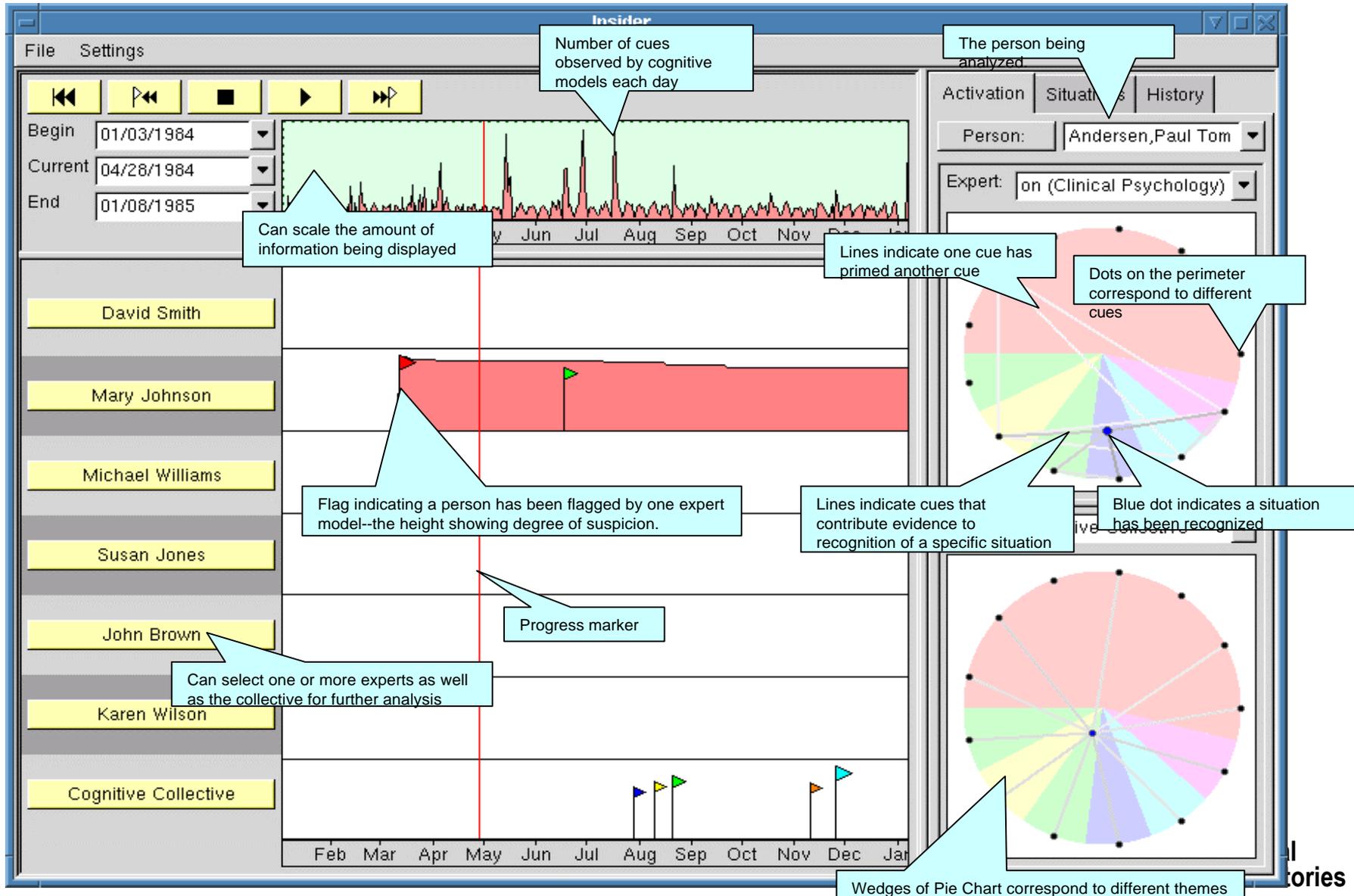


Cognitive Collective of Expert Models

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



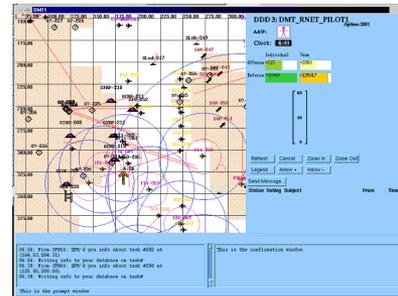
Making Expert Knowledge Explicit



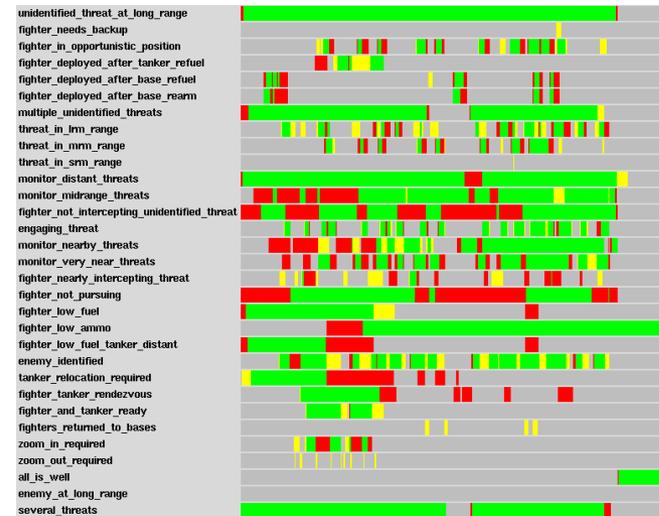
Real-Time Inference of Operator Cognition

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.

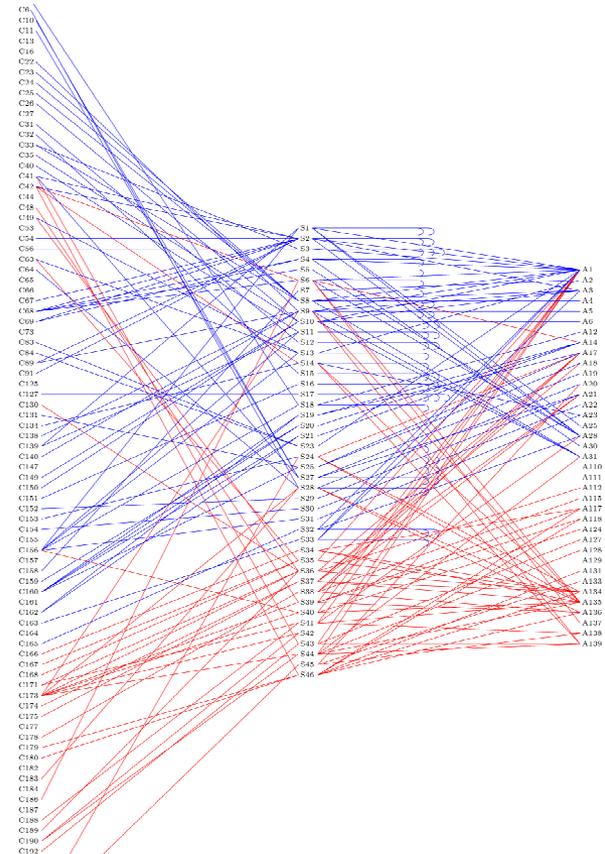
Preliminary Results Indicate Importance of Conforming to Operator

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.

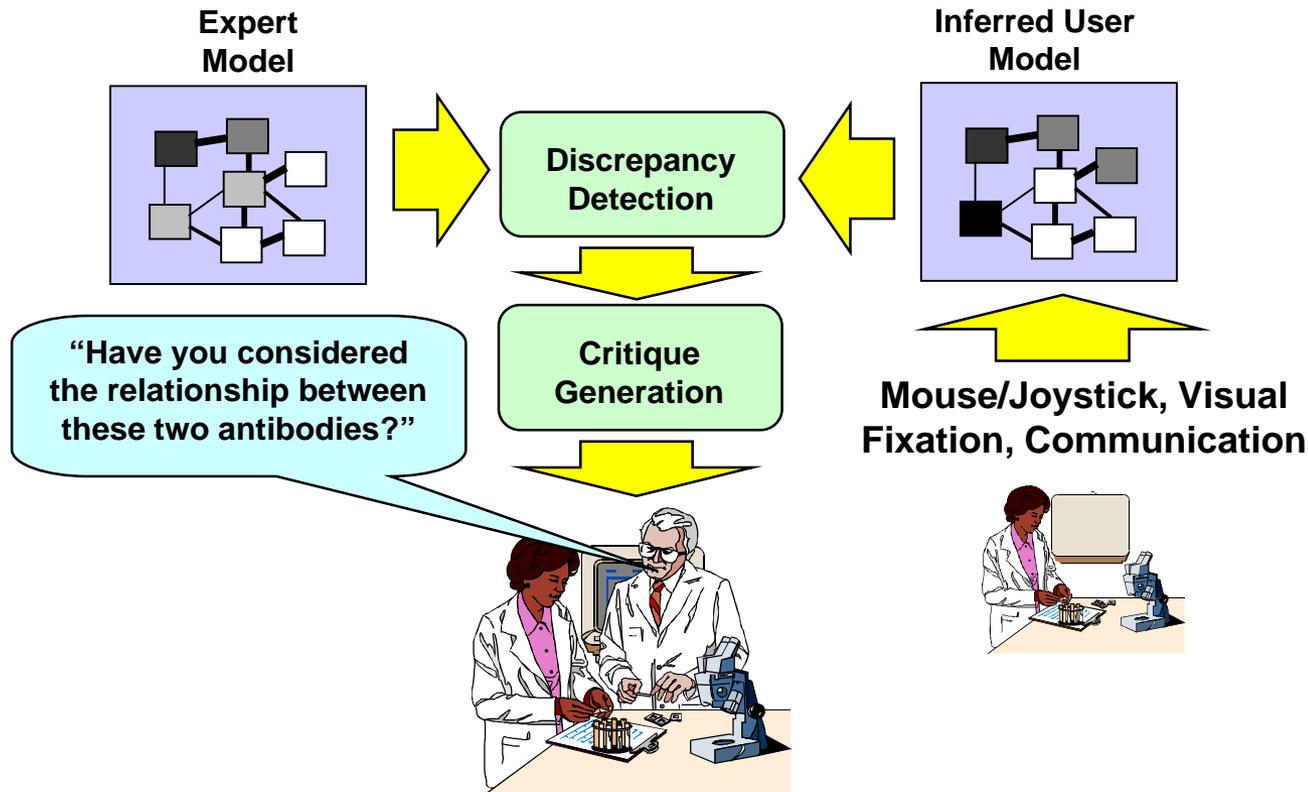
Cues Situations Actions

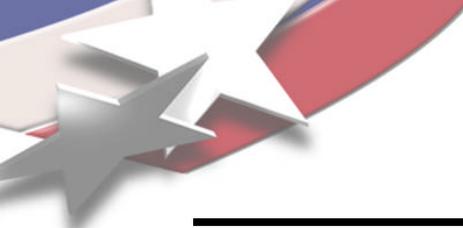


Designing the machine to adapt to the individualized human cognitive model is critical, one size does not fit all

Cognitive Systems for Interaction

Embedded experts engage user in interaction exposing user to alternative perspectives and expanding their interpretative powers – e.g. Critique Generation





Part 1 of Our Vision: Aide

Aide

- Goes where you go
- Knows what you do
- Knows what you know
- Knows your priorities, interests, etc.
- Co-evolves with you
- Self-aware , meta-cognition
- Serves as mediator, shield
- Mentor / tutor or student/trainee
- Trusted



Part 2 of Our Vision: Council

Aide

- Goes where you go
- Knows what you do
- Knows what you know
- Knows priorities, interests
- Co-evolves with you
- Meta-cognitive, self-aware
- Serves as mediator, shield
- Mentor / tutor or student/trainee
- Trusted

Council

- Virtual meeting with synthetic experts
- Flexible mixture humans and agents
- Agents possess unique domain knowledge
- Dialogue-based interaction with agents
- Agent-agent synthesis / contrast of knowledge/perspective
- Incorporation of supporting artifacts
- Multiple interaction paradigms

Part 3 of Our Vision: Oracle

Aide

- Goes where you go
- Knows what you do
- Knows what you know
- Knows priorities, intent
- Co-evolves with
- Meta-cognitive
- Serves as
- Mentor /
- Trusted

Council

- Virtual meeting with synthetic experts
- Flexible mixture humans and agents
- Agents possess unique domain knowledge
- Facilitates interaction with agents
- Synthesis / contrast of opinion
- Supporting artifacts
- Paradigms

Oracle

- Rapidly configurable simulation with highly realistic synthetic humans
- Flexible mixed human, agent, robot, sensor and electronic systems
- Automatic generation populations of unique cognitive entities
- Specific political decision makers
- Reusable entity libraries
- Empirically validated models

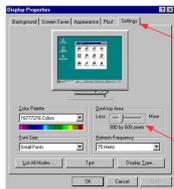
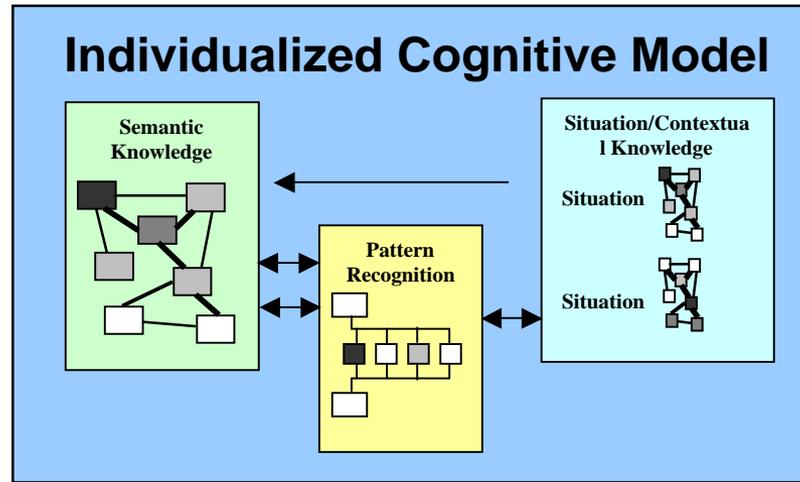


Anticipated Challenges

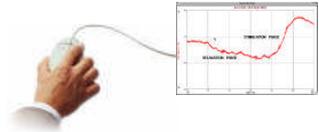
- **Automated knowledge capture**
- **Multi-modal memory representation**
- **Emergent perception**
- **Cognitive-affective interplay**
- **Meta-cognitive self-awareness**

Alternative Data Sources for Automated Knowledge Capture

There are many different data sources that may be used to infer individual knowledge and ongoing cognitive processes.



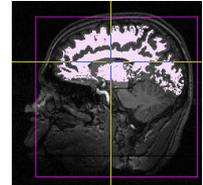
Instrumentation of Software



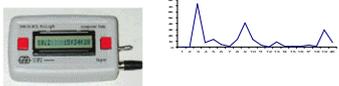
User Actions



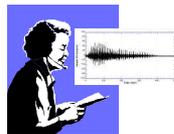
User-Generated Text



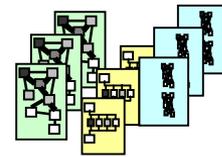
Brain Activation



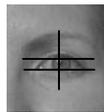
Autonomic Response



User-Generated Speech



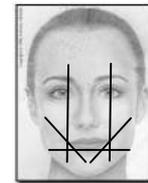
Known Cognitive Models



Eye-tracking



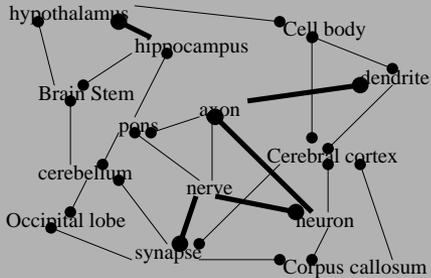
User-Read Text



Facial Expressions

Multi-Modal Memory Representation

Semantic



Episodic



Perceptual



Spatial World Model



Action

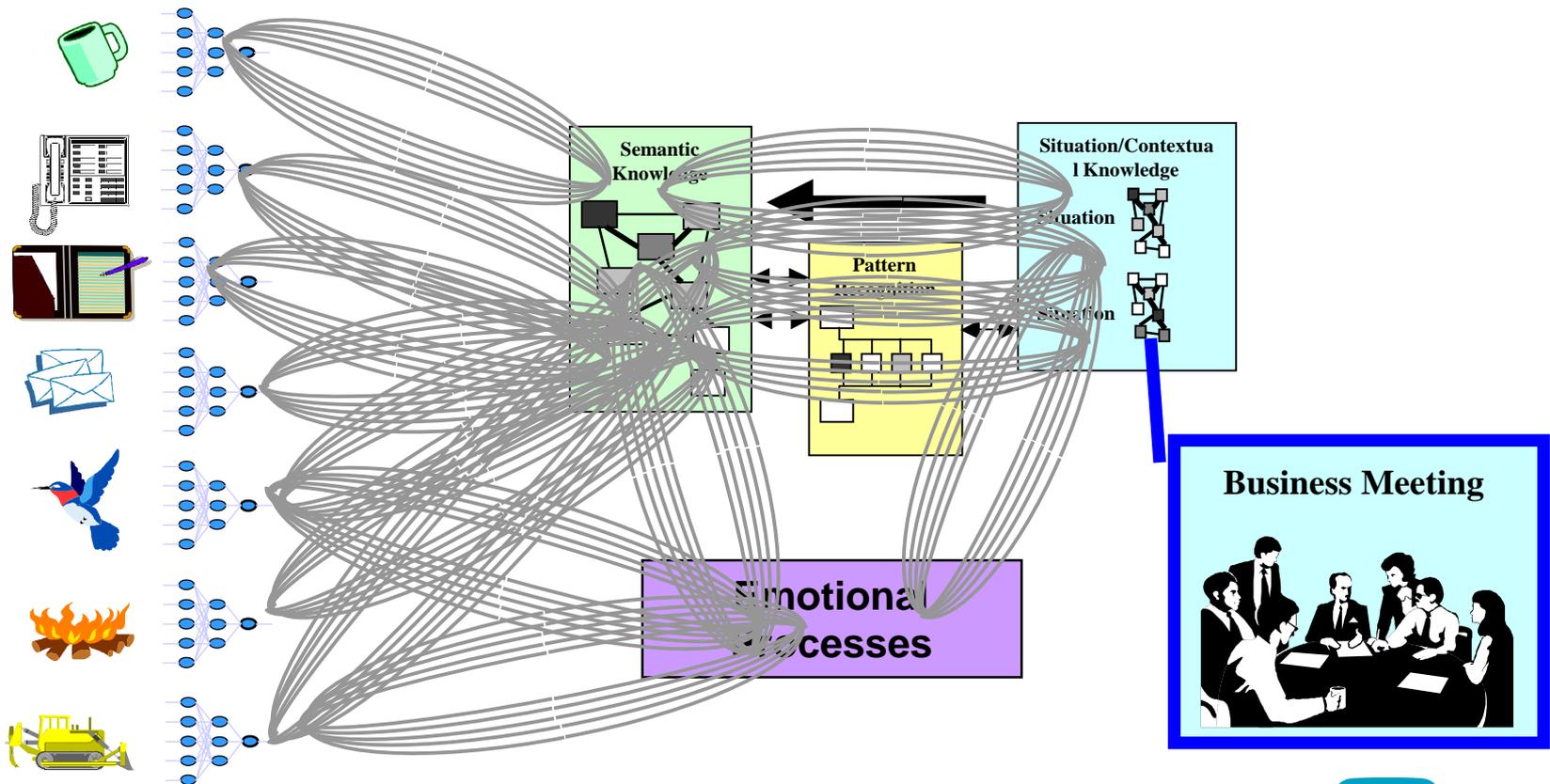


Lexical

a. Something regarded as the ultimate basis of all thought and being. Used with *the*. **b.** Something regarded as independent of and unrelated to anything else. [ME *absolut* < Lat. *absolutus*, unrestricted, p.part. of *absolvere*, to absolve : *ab-*, away; see *as-1* + *solvere*, to loosen; see *leu-2*.] — **ab'solute'ness** *n.*
absolute alcohol *n.* Ethyl alcohol containing no more than one percent water.
absolute ceiling *n.* The maximum altitude above sea level at which an aircraft or missile can maintain horizontal flight under standard atmospheric conditions.
ab'solute-ly (*äb' sà-lōōt' lē*, *äb' sà-lōōt' lē*) *adv.* 1. Definitely and completely; unquestionably. 2. *Gram.* In a manner that does not take an object.
Usage Note: For some time *absolutely* has been used informally as a vague intensive, as in *an absolutely magnificent painting*. In an earlier survey a majority of the Usage Panel disapproved of this usage in formal writing.
absolute magnitude *n.* The intrinsic magnitude of a celestial body computed as if viewed from a distance of 10 parsecs, or 32.6 light-years.

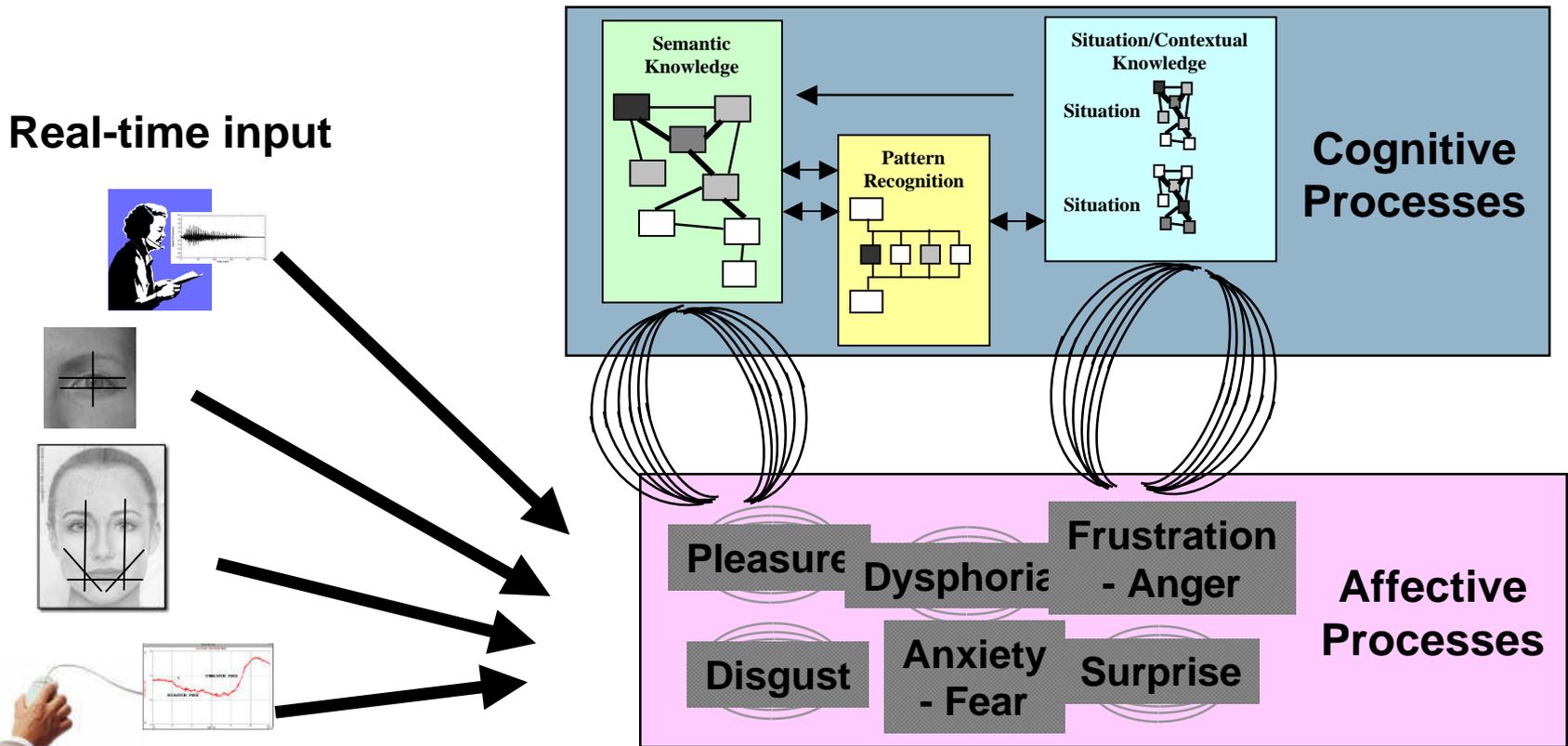
Emergent Perception

Perceptual Processes as an Emergent Phenomenon,
as Opposed to a Bottom-Up or Top-Down Process



Cognitive-Affective Interplay

Cognitive and Emotional Representations and Processes Inseparably Linked



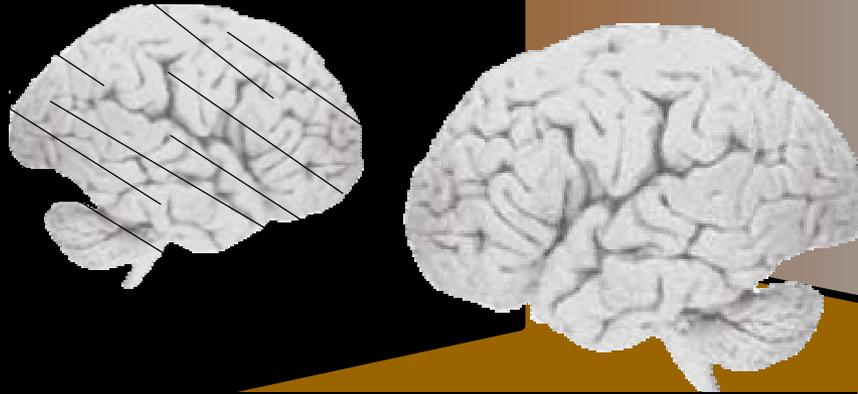
Meta-Cognitive Self-Awareness

Level 1: Knows of Its Cognitive Limitations

- What effects performance, e.g., arousal
- Limits of knowledge and skills
- Expectations/bases

Level 2: Learns Its Cognitive Limitations

- Monitors own cognition
- Diagnoses own cognition

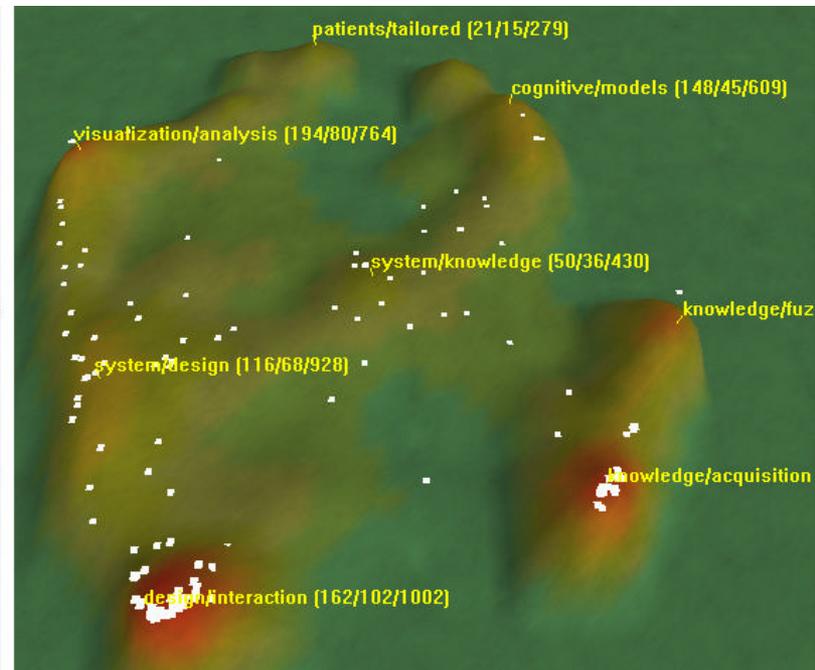
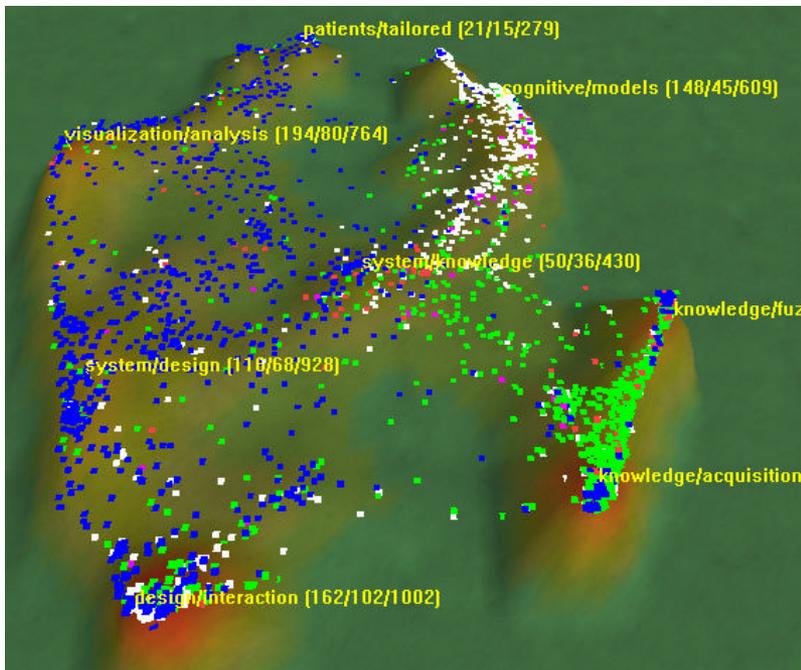


Level 3: Overcomes Its Cognitive Limitations

- Differential accessibility of knowledge
- Optimization of processes
- Mechanisms for self-perturbation

VxInsight Analysis of Relevant Scientific and Technical Literature

There is modest overlap between technical concepts and fields being bridged by this program, but the lack of more significant overlap indicates an opportunity for the laboratories to create a unique capability.



- Cognitive models (white dots-frame on left)
- Knowledge elicitation (green dots)
- Knowledge representation (magenta dots)
- Decision making (orange dots)

- Human-computer and user interfaces
- Customization (blue dots).
- Papers retrieved by two or more
- queries (white dots-frame on right)



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**