Toward a Human Emulator

A Comprehensive Representation of Human Cognition

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LOCKHEED MARTIN

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Human Emulator Defined by Applications

Near-Term

- **Synthetic Human Agents for Training and Simulation (generic, domain-specific, culture-specific, known individual)**
- **Intelligent Machines**

Long-Term

- **Human-on-a-Chip**

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Small Unit Combat Simulation

Objective: Intelligent agent-based simulation for assessment of effectiveness of small forces.

Technical Challenge: Computer-generated entities capable of planning and executing an attack, and reacting to events in a manner that realistically simulates the behavior of human combatants

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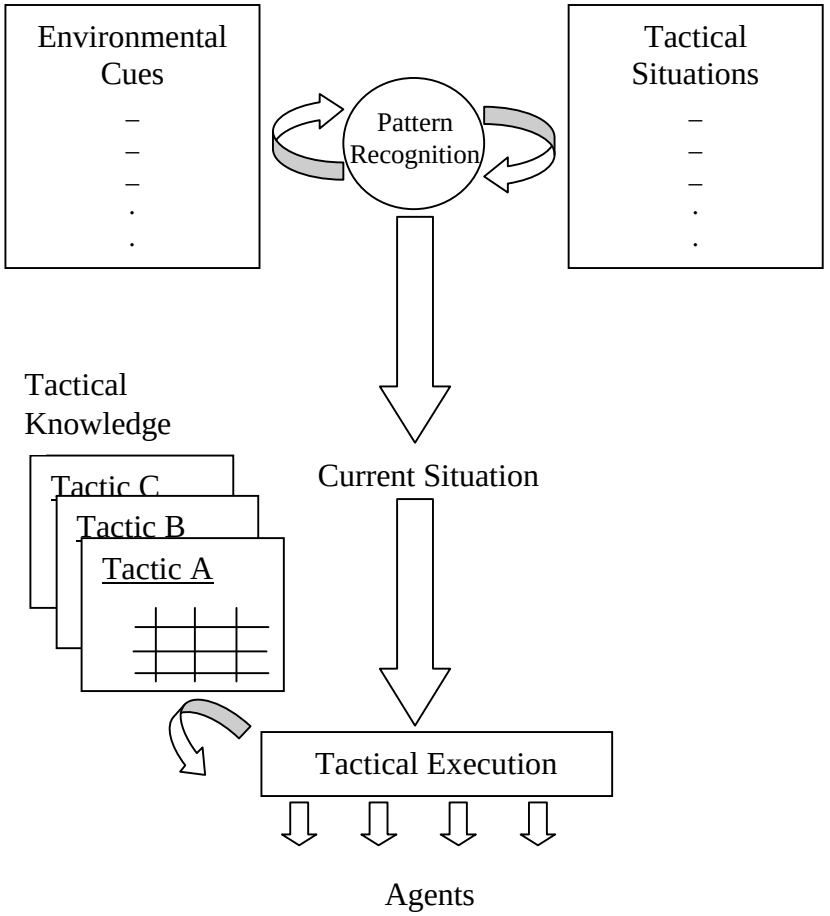
Modeling Naturalistic Decision Making

- **Small unit tactics provide a collection of "situations"**
- **Patterns of cues defined for recognition of situations (i.e., tactics)**
- **Tactics specified generically on basis of team member roles and responsibilities**
- **Genetic programming used to train agents to flexibly apply tactics**



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Comprehensive Computational Representation

One component of a Sandia National Laboratories Initiative in Human Decision Making

Objective: Project aimed at development of a framework for the comprehensive modeling of factors that shape human decision making

Technical Challenge: realistically model decision making processes in a manner that is comprehensive, defensible, extensible and doable.

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Approach to Comprehensive Representation

- **Purely psychological and correlation-based models believed inadequate**
- **Brain-based, mechanism-based approach taken with emphasis on brain electrophysiology**
- **Reverse engineering (i.e., specify known behavior of brain systems and construct model that mimics that behavior)**

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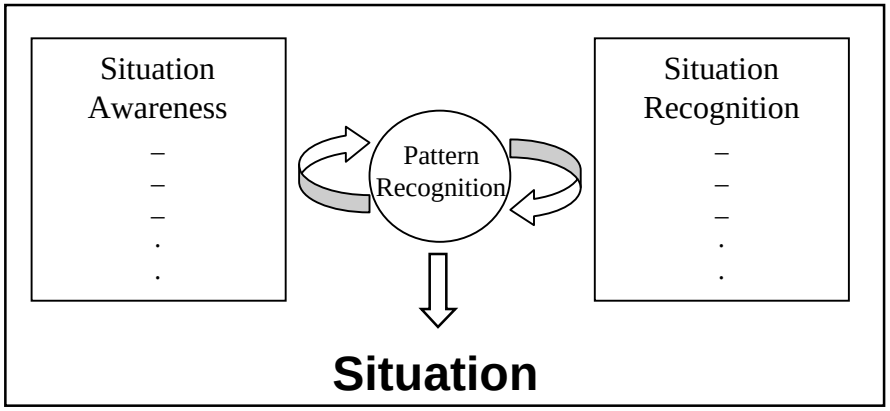
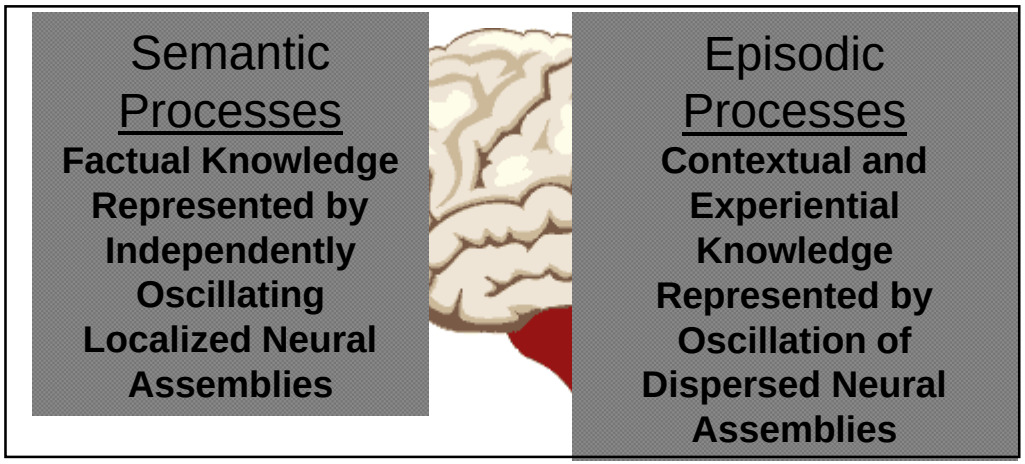
Mapping Decision Model to Brain Model



Psychological Model



Brain Model

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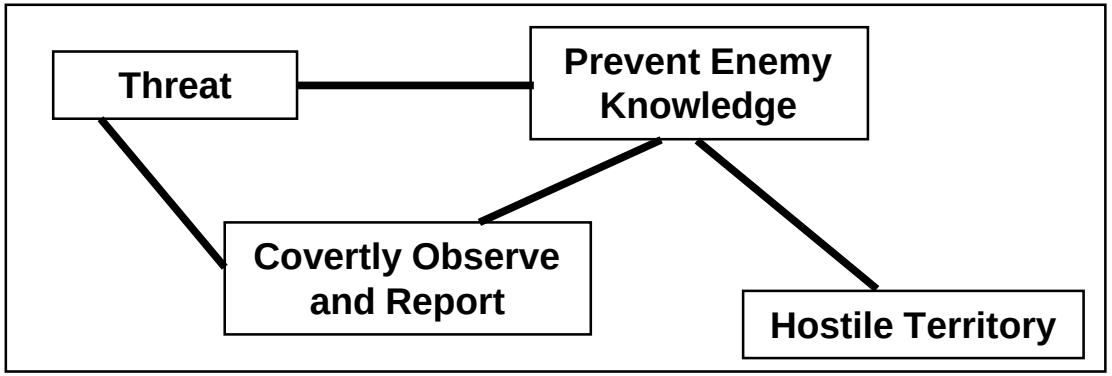
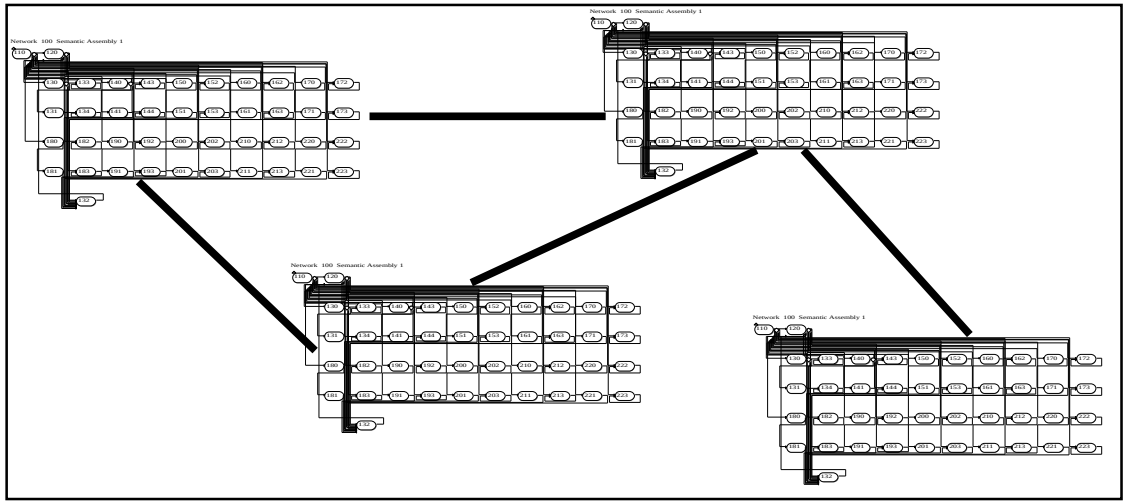
Computational Model: Semantic Processes



Psychological Model

Semantic/knowledge network represents concepts and associative links between concepts



Brain Model

Each concept in semantic network assigned to a neural assembly

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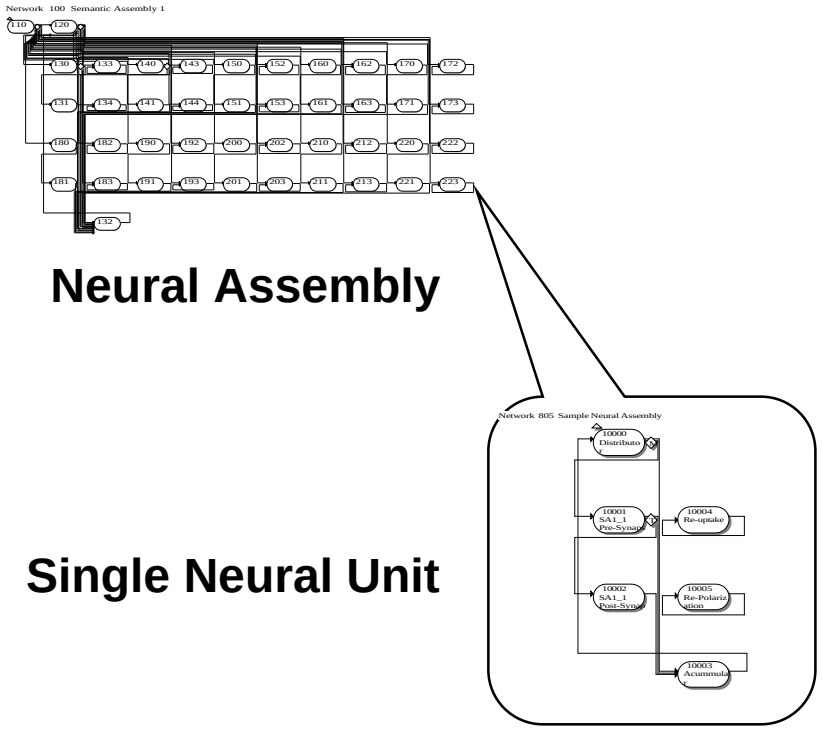
Neural Assemblies

Each neural assembly consists of a collection of neural units. Together, they possess the following properties:



Neural Assembly

Single Neural Unit

- **Oscillate in-phase with bursts from pacemaker**
- **Oscillate independently following extrinsic or intrinsic stimulus**
- **Differential thresholds for activation**
- **Activation a function of transmitter, reuptake, repolarization and metabolic factors**

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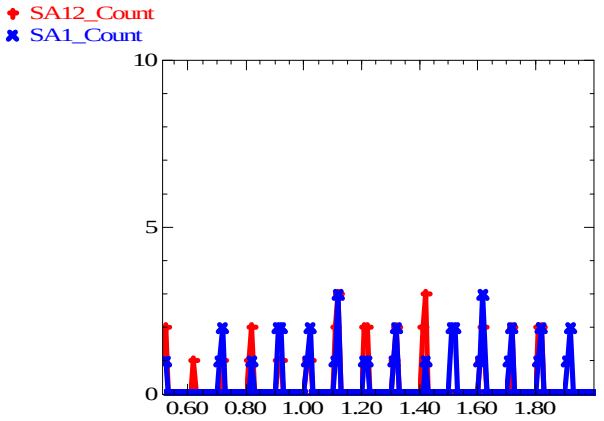
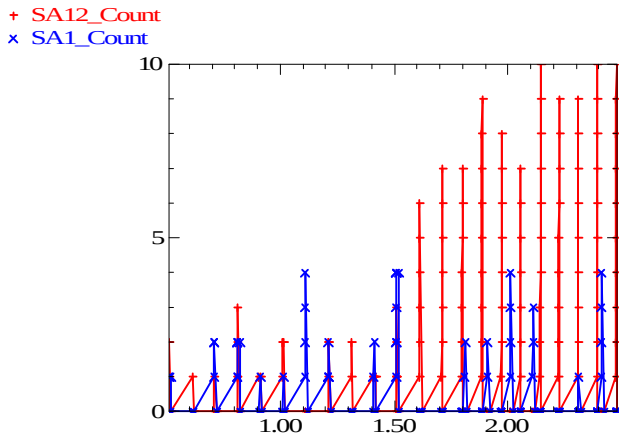
Properties of Semantic Processes

In absence of intrinsic or extrinsic stimulus, neural assemblies oscillate in-phase with pacemaker at low level of activation





Activation of assembly escalates in response to stimulation. Assembly oscillates independent of pacemaker.

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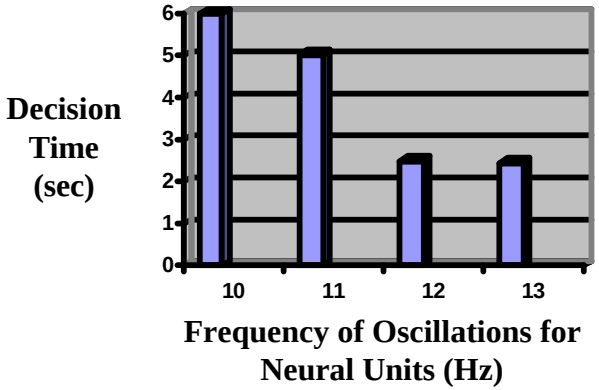
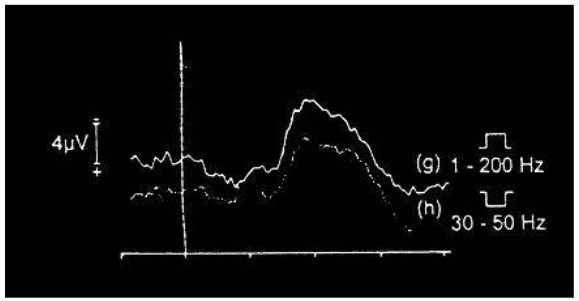
Properties of Semantic Processes

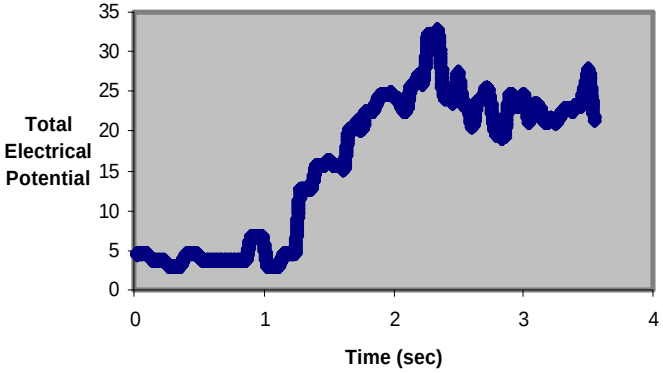
The rate of information processing corresponds to the dominant frequency in the 10-13 Hz Bandwidth



Actual Event-Related Potential



Simulated Event-Related Potential



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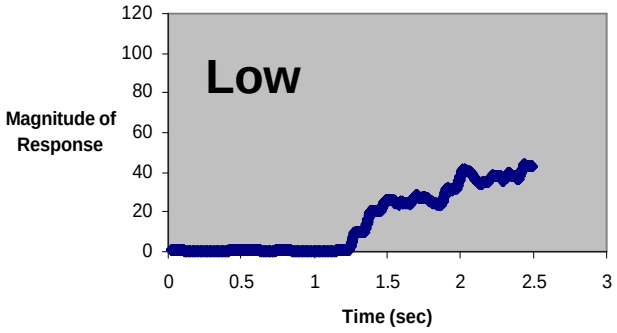
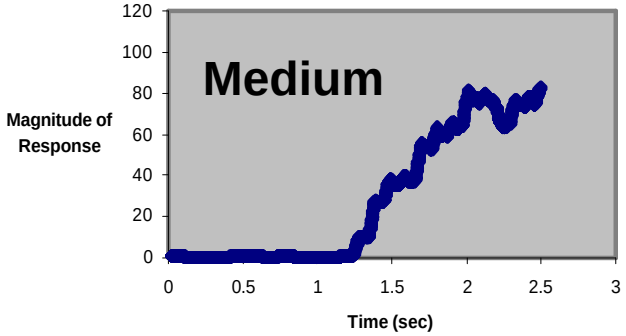
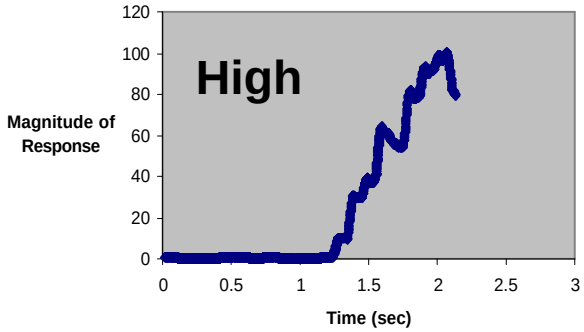
Properties of Semantic Processes

Magnitude of response increases in accordance with the degree of spreading activation







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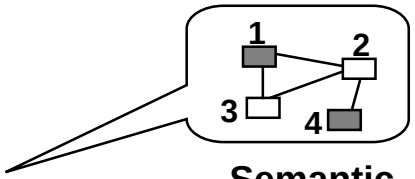
Computational Model: Episodic Processes

Template Matching

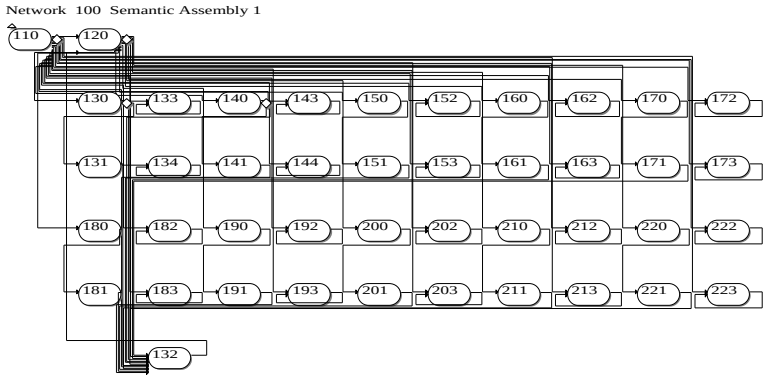
Situation	1	2	3	4
A	1	0	0	1
B	1	1	0	1
C	0	1	1	0
.	0	0	0	0



Semantic Network

<u>Psychological Model</u>

Pattern recognition based on activation of nodes in semantic network



<u>Brain Model</u>

Single neural assembly with previously described properties

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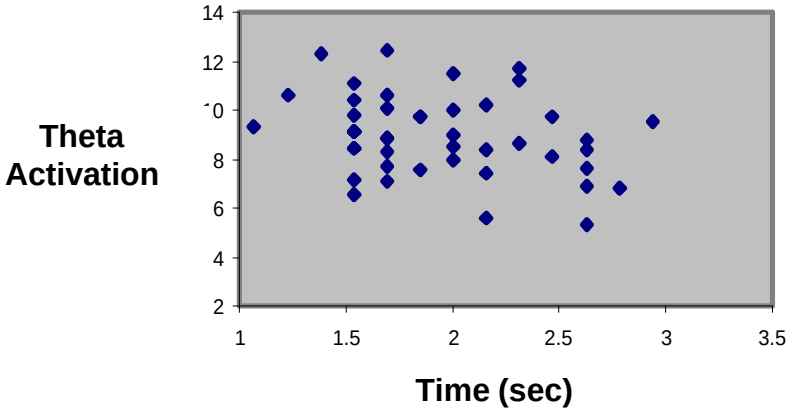
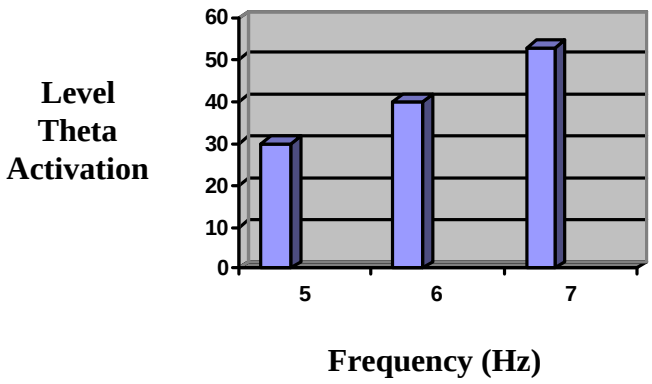
Properties of Episodic Processes

Cognitive performance is a function of the magnitude of activation in the theta bandwidth





Increase in frequency in theta bandwidth leads to increased activation in theta bandwidth (i.e., more units active)

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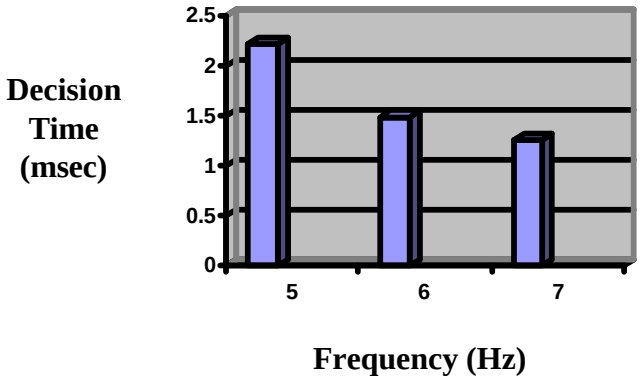
Properties of Episodic Processes

Cognitive performance inversely related to frequency of activity in the theta bandwidth



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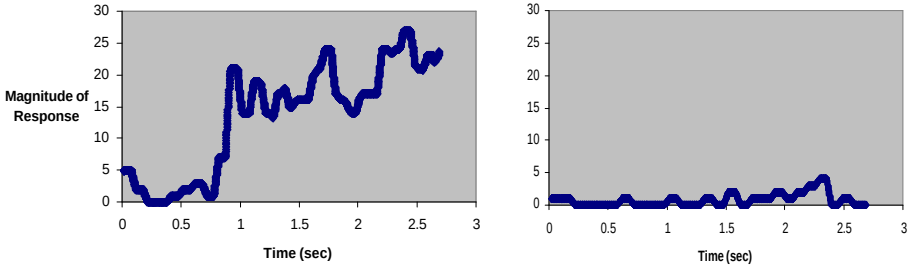
Emotions: Fear

Emotion leads to increased activation of neural assemblies corresponding to the stimulus event or situation associated with emotional reaction

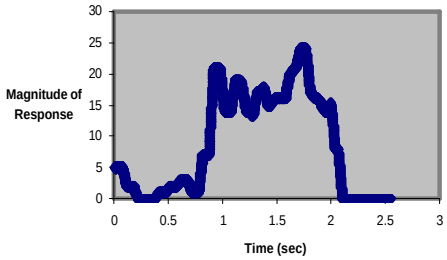


No association

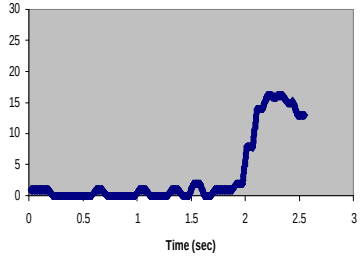
Association

Activation Observed in the Absence of Fear for Neural Assembles Associated with a Direct Threat Situation

Activation Observed with the same Neural Assembles Associated with a Direct Threat Situation Except that Fear Response is Elicited at Approximately 2 Seconds.



No association



Association

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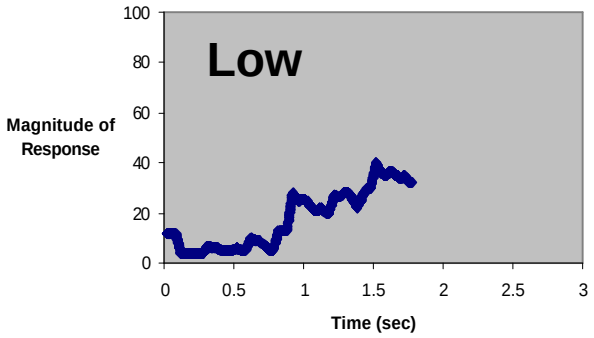
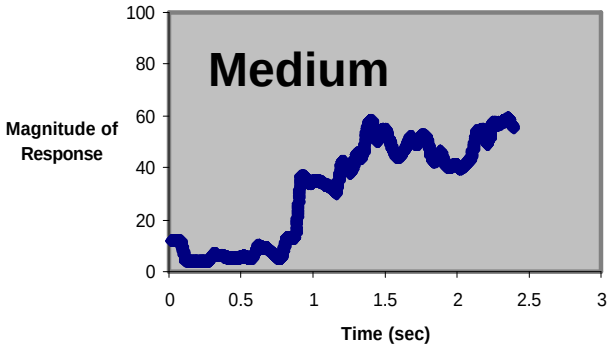
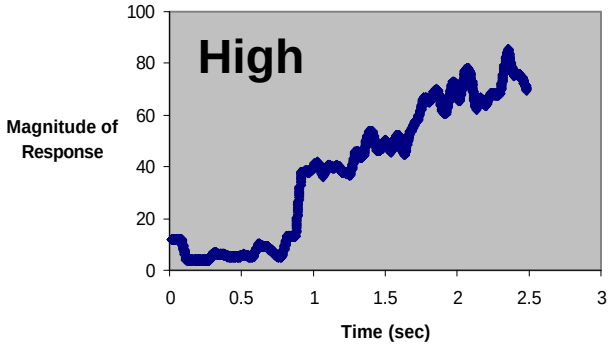
Emotions: Surprise

Magnitude of response increases in accordance with the degree of surprise associated with unexpected event







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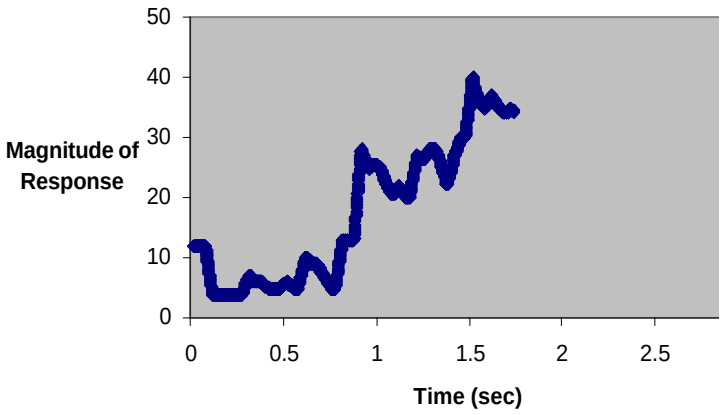
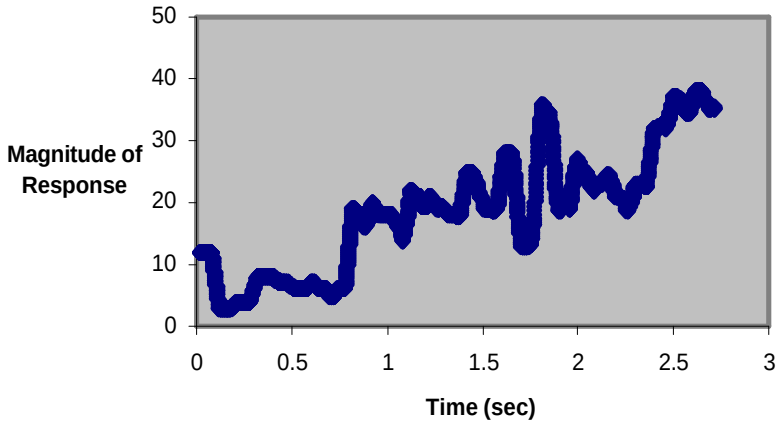
Metabolism

Adjustment to metabolic factors limits availability of individual units effecting overall pattern of activation.



Normal Blood Sugar



Severe Food Deprivation

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Other Factors

To date, we have demonstrated each of the following additional factors

- **Arousal**
- **Priming (e.g., recency effects due to training, reminders, etc.)**
- **Stress**
- **Expertise**
- **Personality (specifically, extroversion / introversion)**
- **Culture**

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Demonstration Problem

Sensor/Shooter Scenario

- **Based on vignette from Persian Gulf War featured on Discovery Channel**
- **Army Recon unit air-dropped into Iraqi territory with mission to report activity on roadway**
- **Unit compromised when detected by two little girls playing in the desert**
- **What do they do?**

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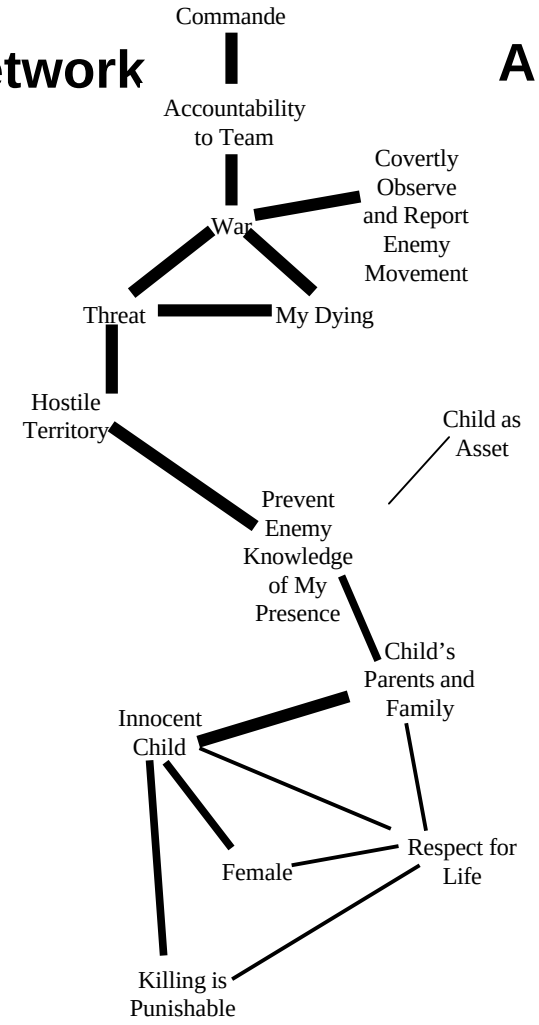
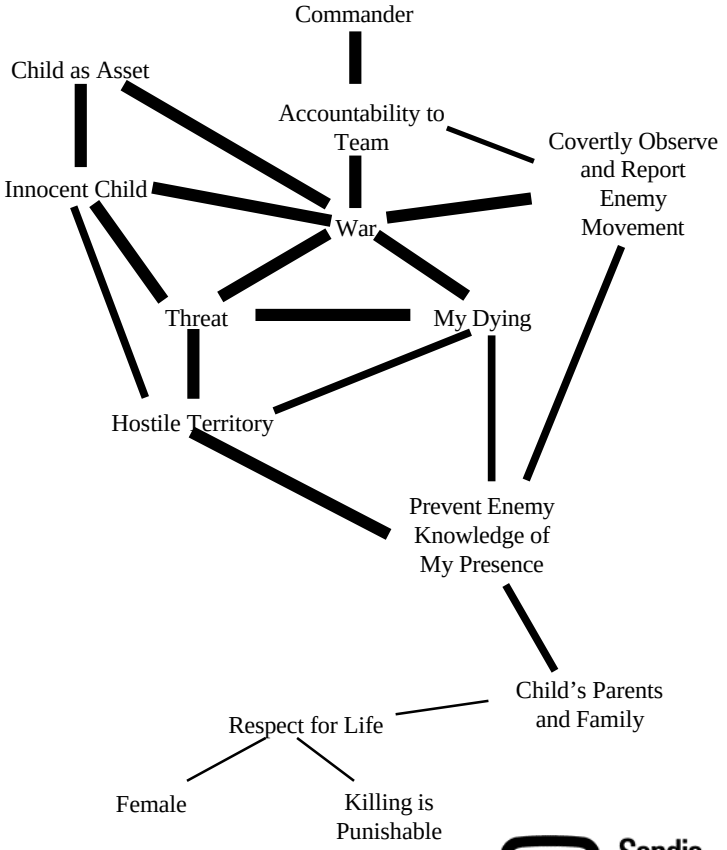
Alternative Semantic Networks

Original Network



Alternative Network



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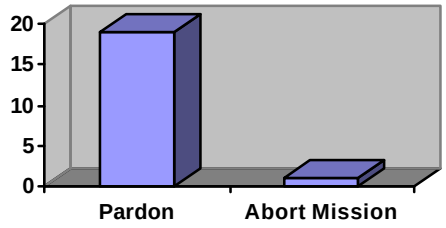
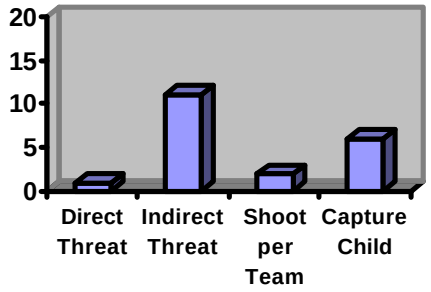
Culture Differences

Decisions Obtained with Repeated Simulations for Conditions Involving Different Semantic Networks and Levels of Priming

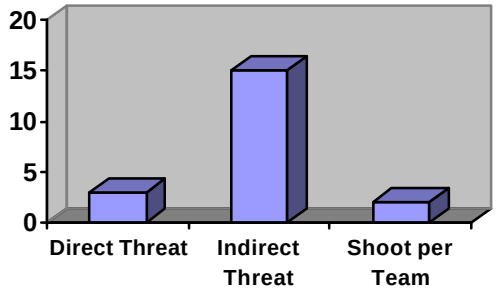
Original Network with No Adjustments



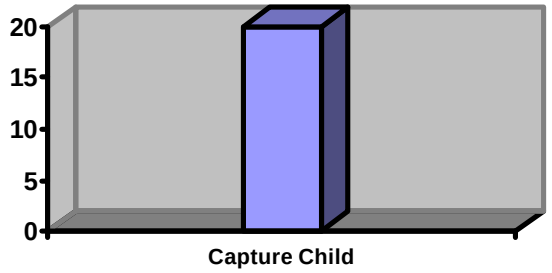
Original Network with Weak Priming for Indirect Threat



Original Network with Strong Priming for Indirect Threat



Alternative Network with No Adjustments



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FY01 Projects

- **Extensible Knowledge-Based Simulator Agents**
  (2 yr - Security/Law Enforcement Emphasis)

- **Endowment Simulator Agents with Human-Like Episodic Memory**
  (3 yr - Synthetic Human & Intelligent Machine Emphasis)

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Extensible Knowledge Representation

Objective: Develop a capability to readily model knowledge from different application domains while expanding capabilities of the cognitive model to accommodate dynamic simulation (i.e., multiple decisions across time) and group interaction

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Human-Like Episodic Memory

Objective: Develop the technology to endow synthetic humans and machines with the ability to operate and communicate on the basis of a lifetime of meaningful experiences, including story-based human-machine interfaces.

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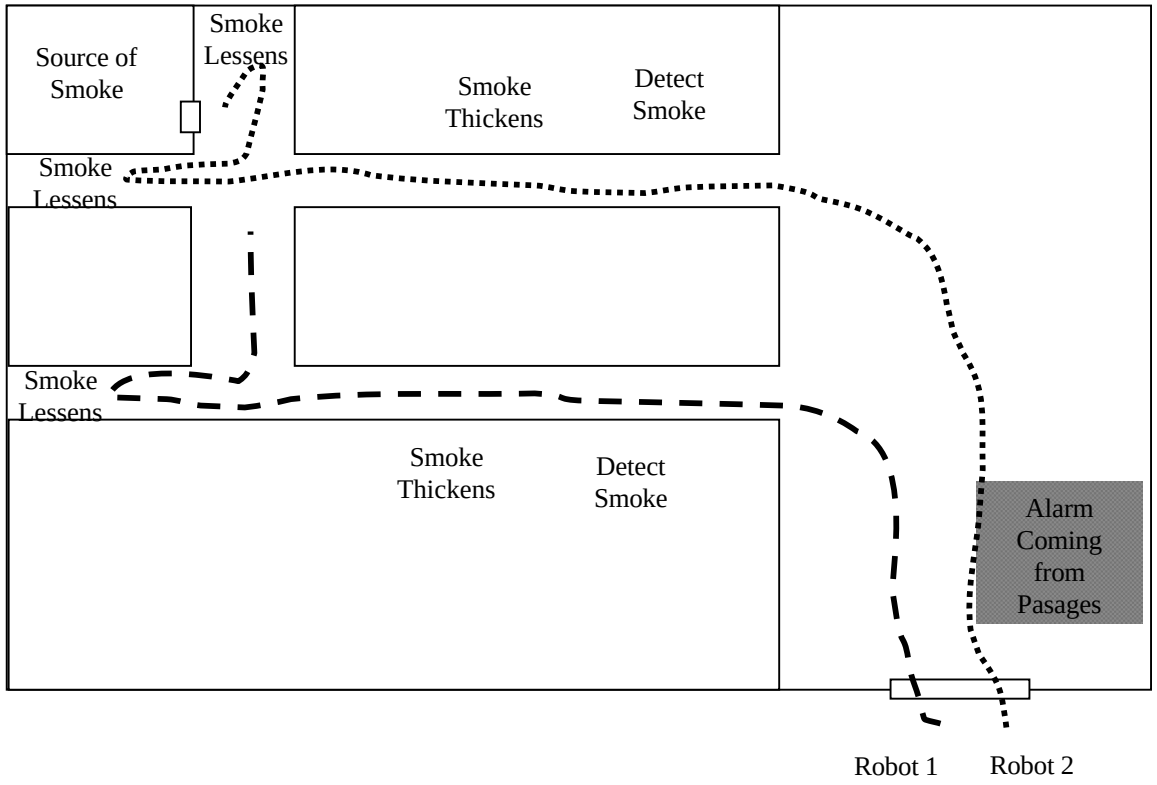
Demonstration Scenario



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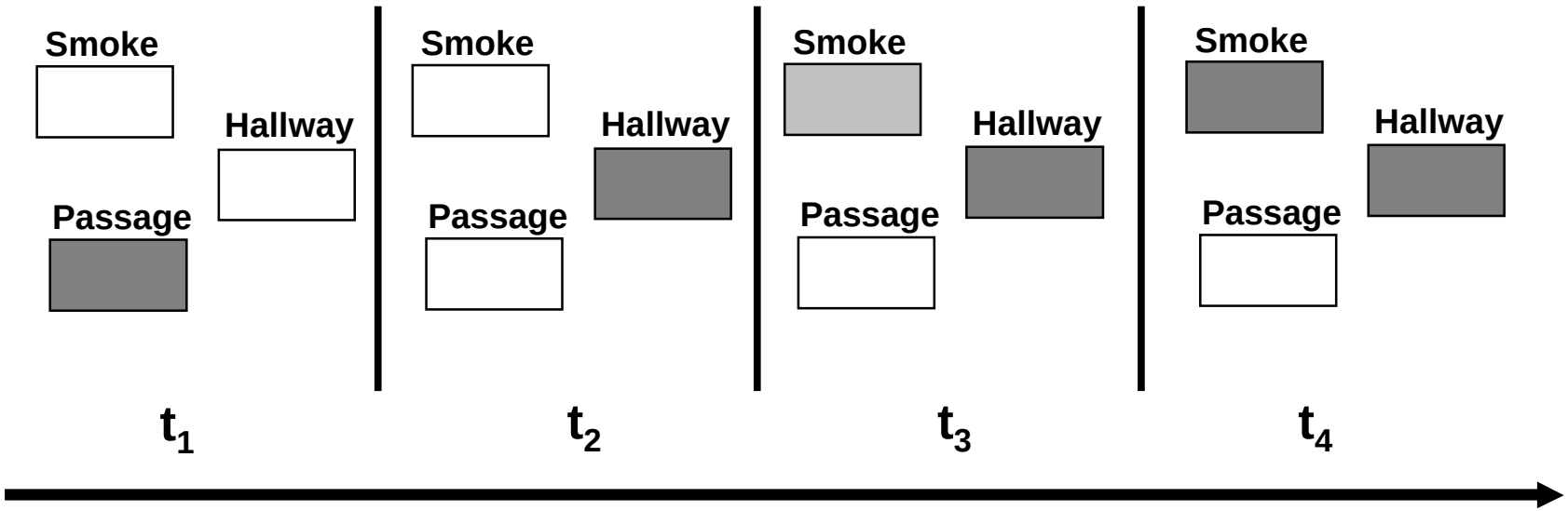
Semantic Activation Across Time

For a duration of time, there is a sequential progression in the patterns of concept activation



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Recognition of Schema based on Patterns of Semantic Activation

R1 Goes Down Hallway with Increasing Smoke

	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8	t_9	t_{10}	t_{11}	t_{12}	t_{13}	t_{14}	t_{15}	t_{16}
[illegible]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
R1 Smoke	0	0	0	0	1	2	3	4	4	3	3	3	4	4	4	5
R1 Passage	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0
R1 Hallway	0	0	1	1	1	1	1	0	1	1	1	1	0	0	0	1
R1 Intersection	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0
R2 Alarm	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
R2 Smoke	0	0	0	0	0	1	3	5	7	8	8	8	8	7	8	8
R2 Passage	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0
R2 Hallway	0	0	0	1	1	1	1	1	0	0	0	0	1	1	1	0
R2 Intersection	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1
R1–R2 Direction	1	1	0	1	1	1	1	1	1	1	0	0	0	1	0	0
R1-R2 Separation	1	1	5	5	5	5	5	5	5	5	5	5	5	5	5	4

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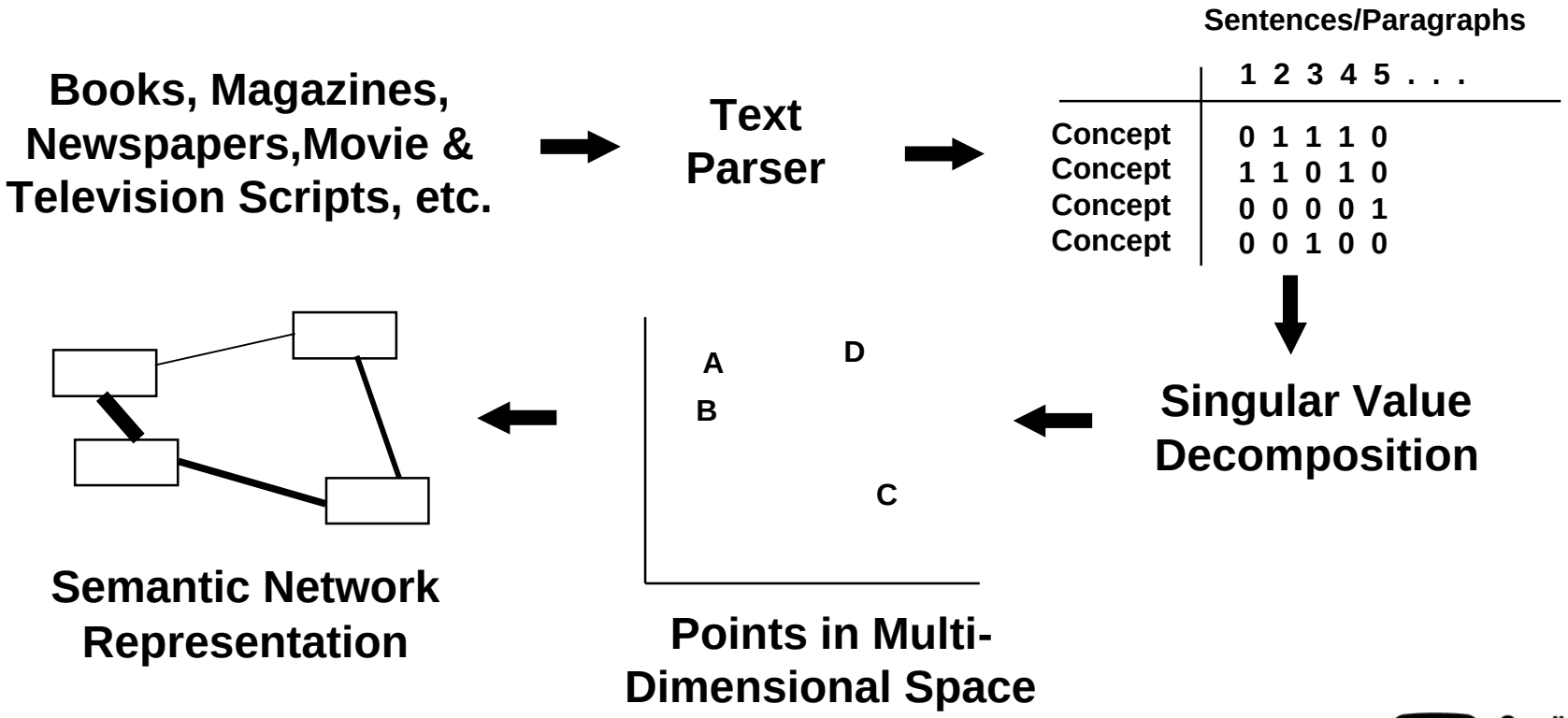
Episodic (i.e., Story) Representation Based on Sequence of Schema

1. Entered building
2. Searched for smoke, found no smoke
3. Selected path, passage into hallway
4. Followed path (search smoke)
5. Detected smoke
6. Followed path (smoke gradient), reached intersection
7. Sampled paths, found path with more smoke
8. Followed path (smoke gradient), reached intersection
9. Alerted (destination)
10. Followed path (destination)

Knowledge Representation Based on Latent Semantic Content Analysis

Customized knowledge structures based on domain, culture, knowledge of individual, etc.



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Conclusion

- Currently have the capability to model individual decisions based on naturalistic decision making, taking organic factors into consideration (e.g., arousal, emotion, culture)
- Initial capability to model dynamic sequences of behavior
- Developing capability for high fidelity synthetic humans that may be assigned a variety of attributes (e.g., background, experience, characteristics of known individual) and operate within an intelligent machine context.