SAND2007-7711C

BECCA

Overview

S-Learning

Rotary Robot

Reaching

Grasping

Context-Based Similarity

Natural Language Processing

Perception

Applications

BECCA—A Brain Emulating Cognition and Control Architecture

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- BECCA is a biomimetic approach to achieving human-like reasoning, perception, learning, and movement control in machines
- Capabilities
  - Learning complex, unmodeled systems and patterns (data fusion)
  - Predicting future events based on prior experience
  - Identifying novel patterns and concepts
  - Generalizing knowledge and applying it to unfamiliar situations (symbolic reasoning)
- It has two core algorithms
  - S-Learning
  - Context-Based Similarity

Operational Diagram

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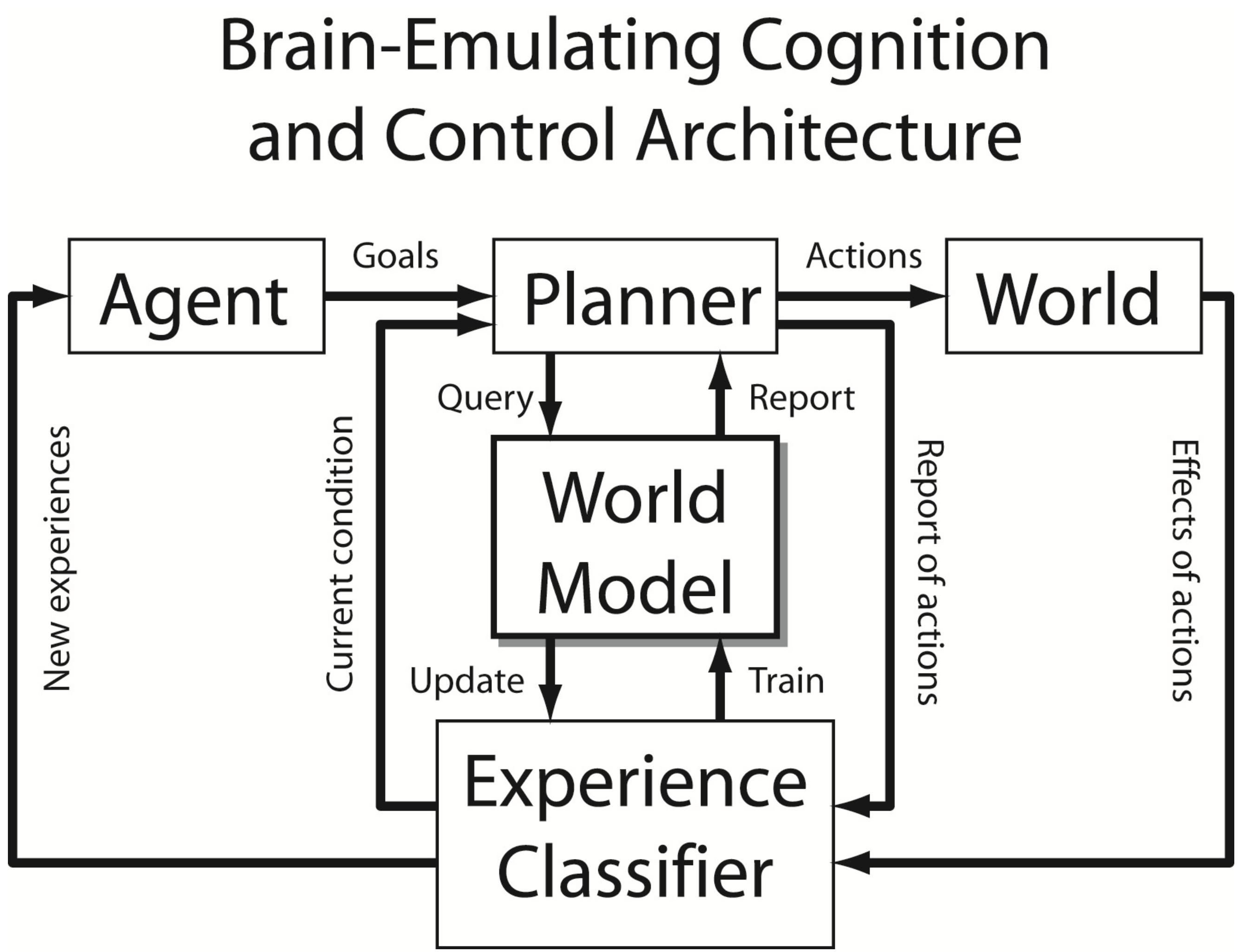

Working Assumptions

- Sensor and control information
  - are passed in "episodic" fashion, quantized in time,
  - are discretized in magnitude,
  - are treated as categories, i.e. extrapolation and interpolation does not occur explicitly.
- Allows very general application

S-Learning Algorithm

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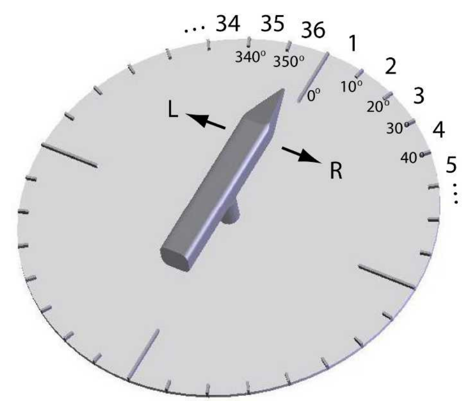
- S-Learning (*sequence* learning)
  - records observed sequences and uses them
    - to make control decisions and
    - predictions about future events
- Algorithm outline
  - 1. If a sequence ends in a goal, remember it.
  - 2. If a sequence correctly predicts a goal, strengthen it.
  - 3. If a sequence incorrectly predicts a goal, weaken it.

S-Learning: Rotary robot

- Simulation of a one degree-of-freedom rotary pointer robot,
  - Sensor quantized in 10º increments
  - Movement by 10º increments
- S-Learning demonstrated the ability to learn and predict hard nonlinearities
- S-Learning performed optimally even in the presence of
  - Scrambled sensor conditions
  - Gain reversals
  - Stochastic movement errors
  - Random time delays
- *No explicit model of the system was provided*—its workings were discovered by S-Learning



S-Learning: Reaching simulation

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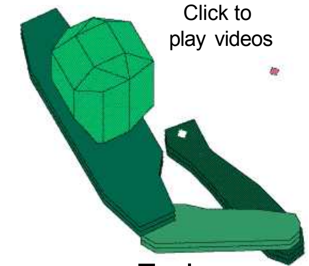
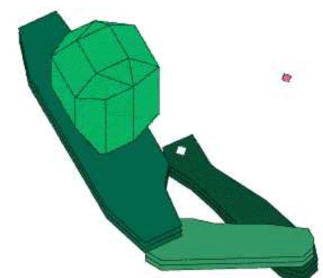
- Two degree-of-freedom robot reaching simulation
  - Approximately human parameters used for inertia. movement characteristics, and sensing capabilities
- Robot learned to reach a fixed target at an arbitrary position in the plane
- Demonstrated ***generalization***
  - Learning in one task was applied to a second task
  - This, despite the complete separation of the sensory representations of the two tasks
- *No explicit model of the system was provided* —its workings were discovered by S-Learning

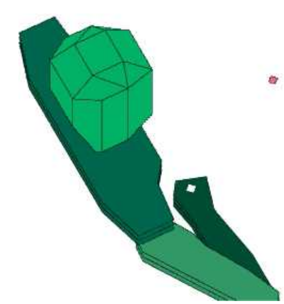
Click to play videos



Early



Intermediate

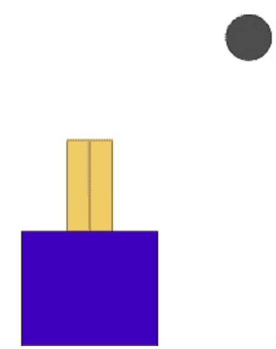


Mature

S-Learning: Grasping simulation

- Three degree-of-freedom robot grasping simulation with rich sensors:
  - Coarse vision
  - Coarse position
  - Contact pressure
- Robot learned to reach a fixed target at an given position in the plane
- Learned to coordinate grasp with motion to grab target
- *No explicit model of the system was provided* —its workings were discovered by S-Learning

Click to play video



Context-Based Similarity (CBS)

For key event, ε, find λ_ε (all ρ_ε).

↓

For each ρ_ε, find $\tau_{\alpha\omega}$.

↓

Similar events, σ_ε, are the combined set of all $\tau_{\alpha\omega}$.

Definitions:

$\boldsymbol{\varepsilon}$ *Key event(s)*. The subjects of the comparison. This can be one or more events.

$\boldsymbol{\rho}_\varepsilon$ *Key pattern*. Any pattern containing ε.

$\boldsymbol{\alpha}$ *Prefix*. The portion of $\boldsymbol{\rho}_\varepsilon$ that preceeds $\boldsymbol{\varepsilon}$.

$\boldsymbol{\omega}$ *Postfix*. The portion of $\boldsymbol{\rho}_\varepsilon$ that follows $\boldsymbol{\varepsilon}$.

i.e.: $\rho_\varepsilon = [\alpha\ \varepsilon\ \omega]$

$\boldsymbol{\lambda}_\varepsilon$ *Key library*. The set of all ρ_ε.

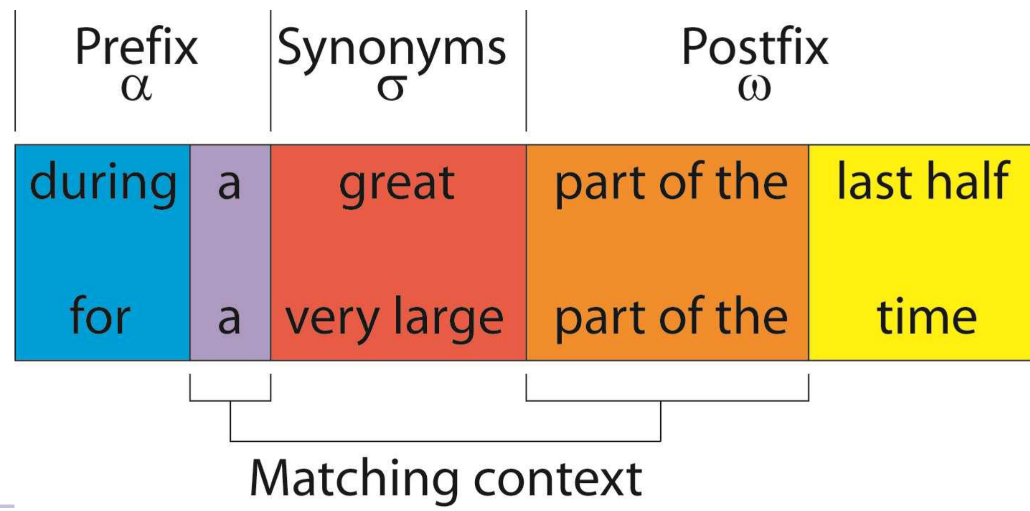
$\boldsymbol{\tau}_{\alpha\omega}$ *Term set*. The set of all ε occurring between a given α and ω.

$\boldsymbol{\sigma}_\varepsilon$ *Synonym set*. The set of events similar to ε.

- States that occur in a given context are related.
  - The semantic content of a state or event is defined by its surroundings

Context-Based Similarity (CBS)

- Underlying concept: Events are similar if they occur in identical contexts.
  - *Context* refers to the surrounding events that precede and follow a given event of interest.
- CBS finds the word “great” and the phrase “very large” to be similar because they are preceded and followed by the same word(s), i.e. they are in identical contexts



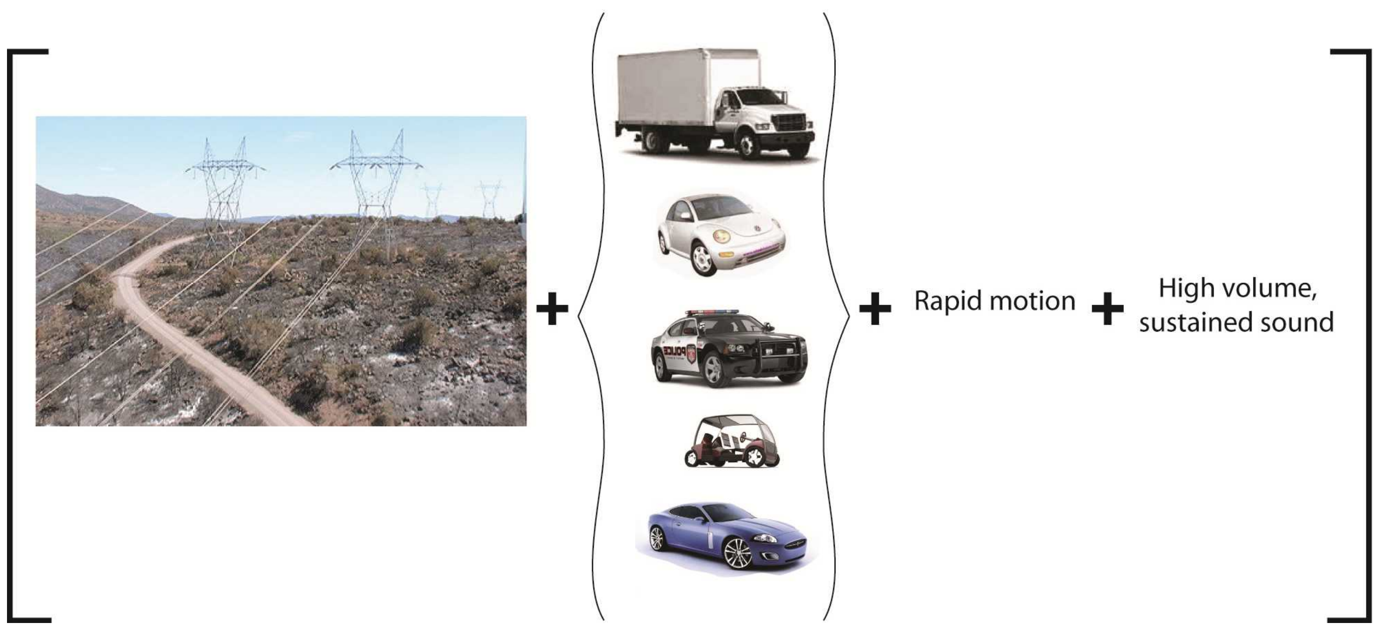
CBS: Natural Language Processing

- After reading 25 million words, CBS performed synonym extraction (finding sets of words that occurred in contexts identical to a seed word)
- No part-of-speech tags were given
  - In fact, CBS did not do anything that was specific to English, text, or language in general. It would have handled position and force data the same way.
- Plausible synonym groups were created
- Illustrates bootstrapped association of categorically separate inputs

seven	large	sugar	feet	father	road
five	great	flour	face	mother	river
two	small	fruit	heart	wife	street
four	considerable	butter	head	son	table
three	certain	salt	side	head	fire
ten	very large	water	house	life	hill
twelve	good	mace	lips	voice	head
fifteen	very small	mear	work	face	house
twenty	vast	cream	hands	heart	room
fifty	larger	brandy	back	name	lake

CBS: Concept formation

- Formulating the concept of the object <vehicle> by compiling specific examples
- Repeated sequences of 1) a static video background, 2) a dynamic video component created by a moving vehicle, 3) detected motion, and 4) detected sound allow the “synonym group” or *concept* of <vehicle> to be formed.



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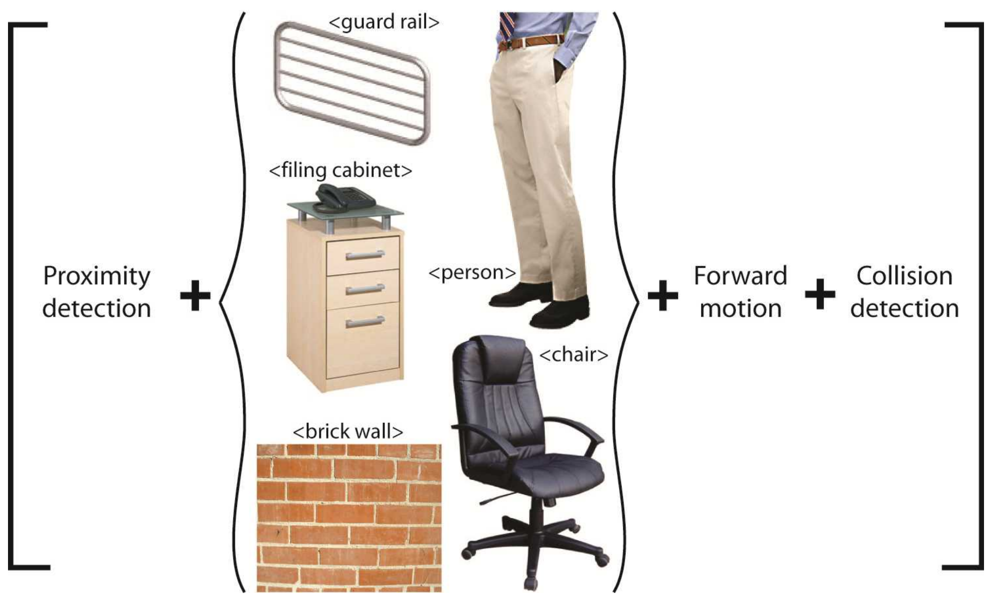
CBS: Advanced concept formation

- Formulating the higher-level concept <barrier> using previously developed concepts
- Repeated sequences of 1) a proximity detection event, 2) a instance of one of several previously discovered concepts, 3) forward motion, and 4) collision detection allow the meta-concept of <barrier> to be formed.



Operational Diagram

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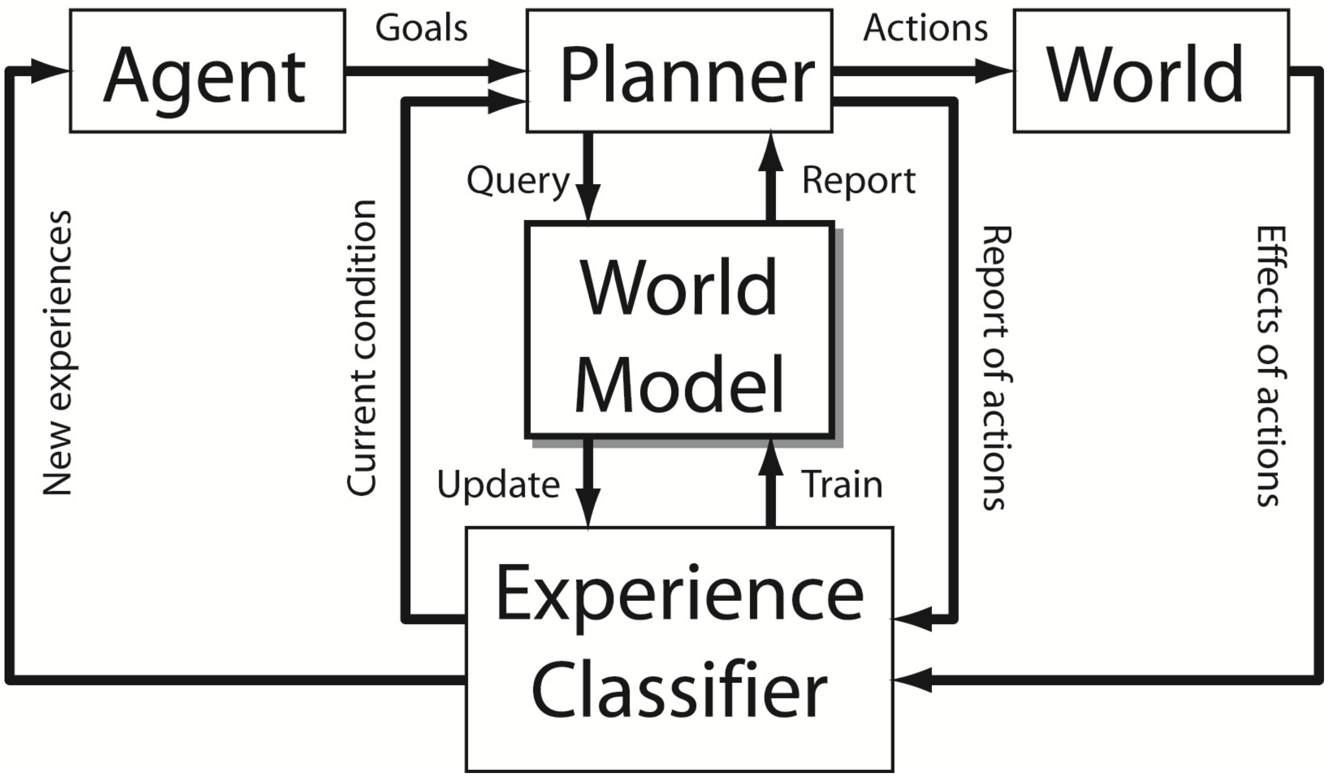
Brain-Emulating Cognition and Control Architecture



Humanoid robot control

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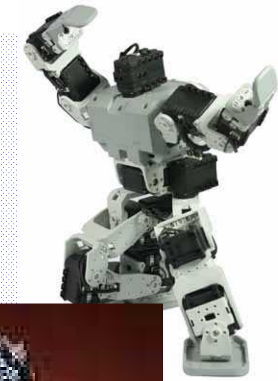
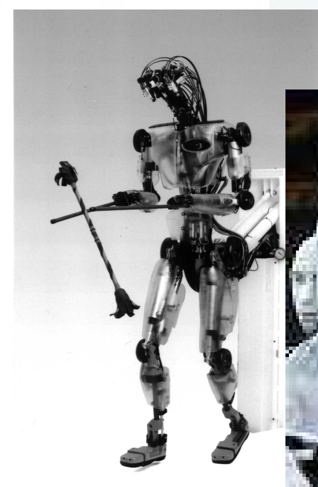
- Physically interact with humans
- Learn to manipulate unfamiliar objects
- Acquire spoken language
- Learn complex perceptuo-motor tasks
- Create high-level abstractions
- Make predictions about future events
- Use reasoning to achieve goals
- Solve poorly-posed problems
- Generalize experience to novel situations








Multi-vehicle cooperative control

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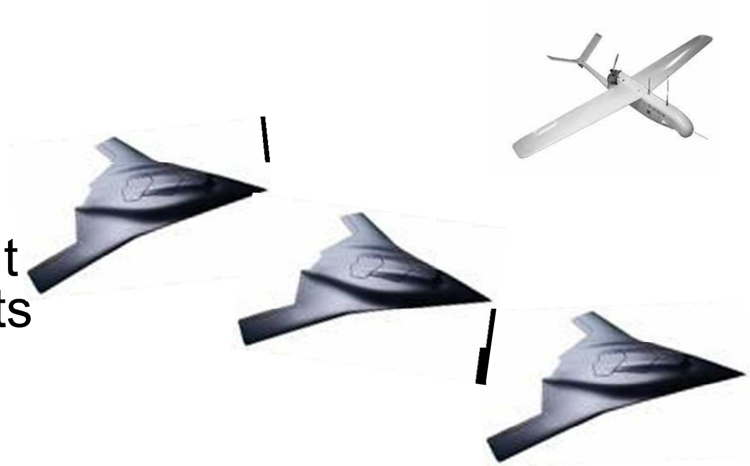
Applications

- Learn from experience
  - Individual vehicles
  - The cooperative as a whole
- Make predictions about unfamiliar environments
- Create conceptual symbols
- Find cross-domain patterns
- Use symbolic reasoning to interpret complex data
- Explore hypothetical situations



Multi-media data mining

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- Make predictions
- Create conceptual symbols
- Identify arbitrary patterns in large multi-modal data sets
- Use symbolic reasoning to interpret complex data
- Explore hypothetical situations
- Identify unusual or “red flag” situations