The Soar Cognitive Architecture
Towards Human-Level Intelligence

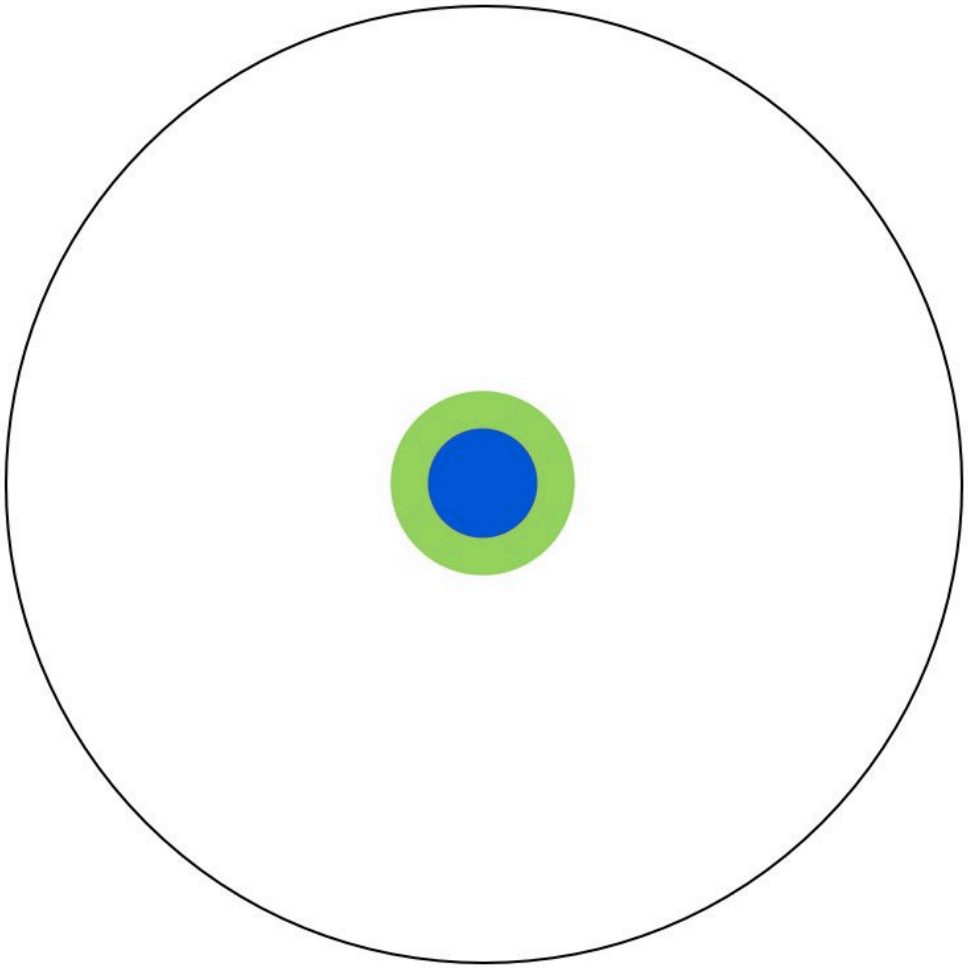
Nate Derbinsky

MSaiL

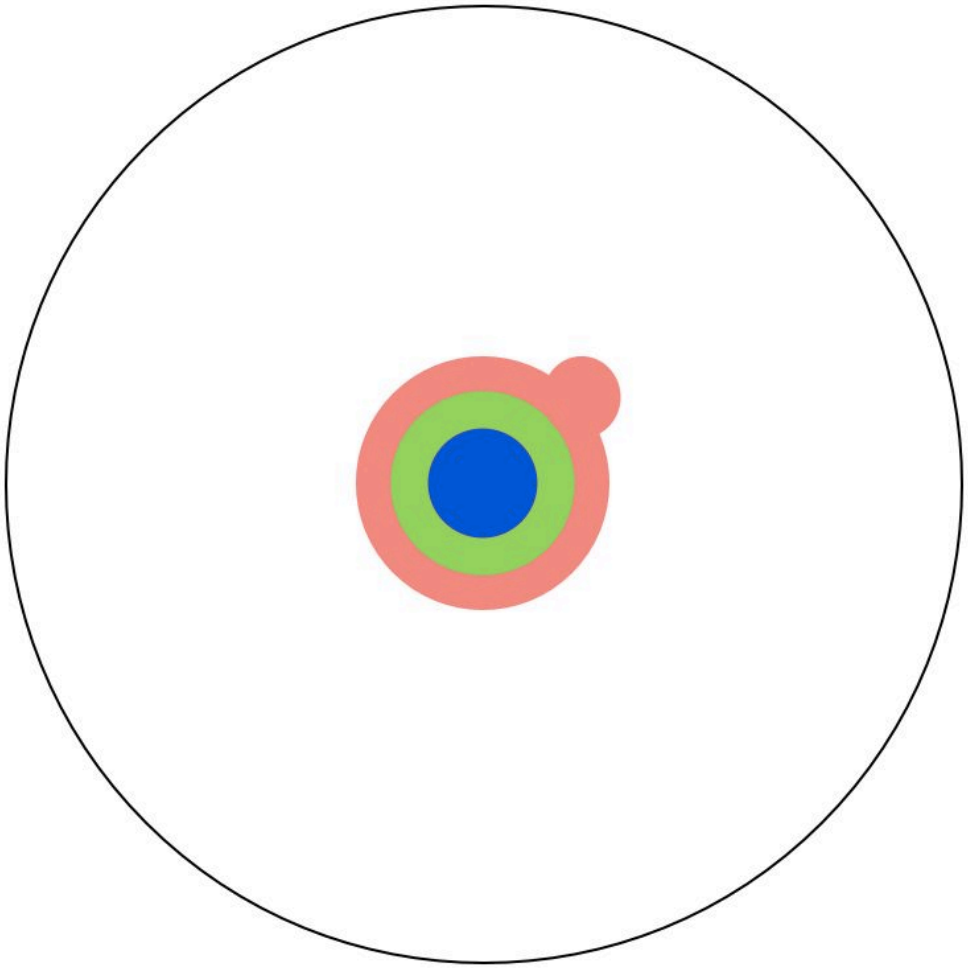
A Short Guide to Grad School…

http://matt.might.net/articles/phd-school-in-pictures/

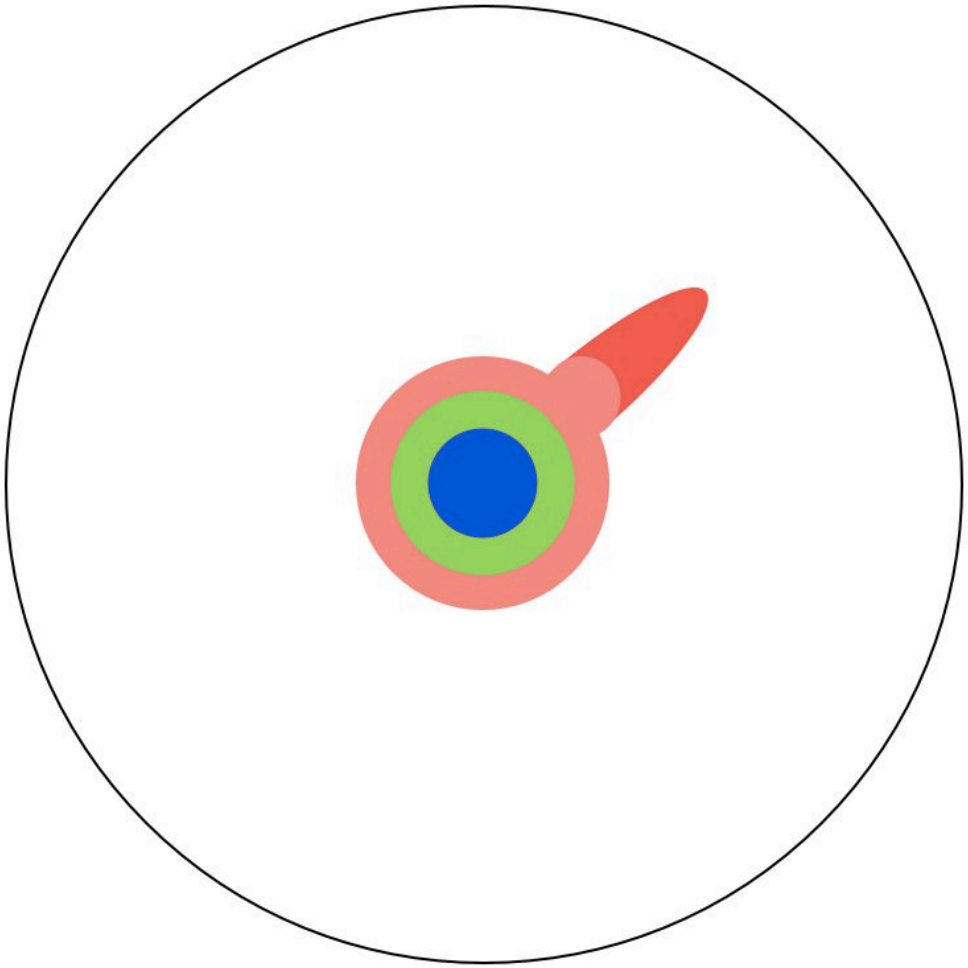
High School…



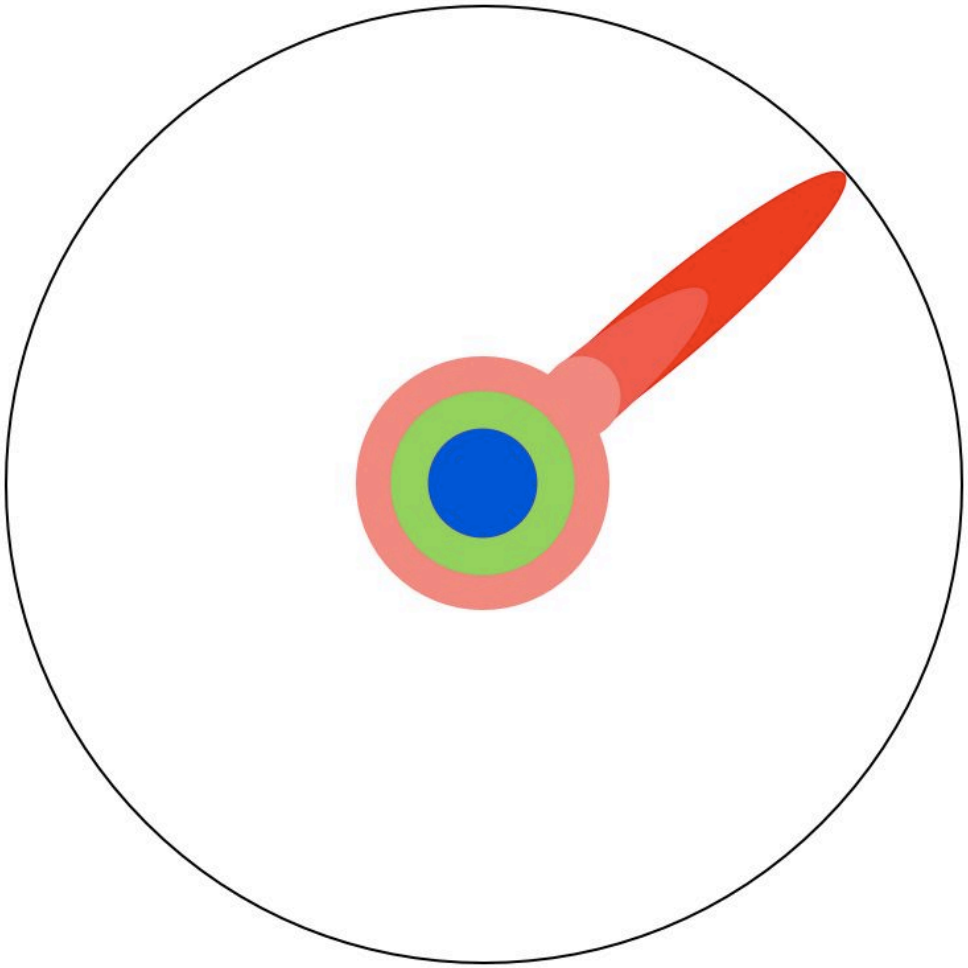
Specialization in College…



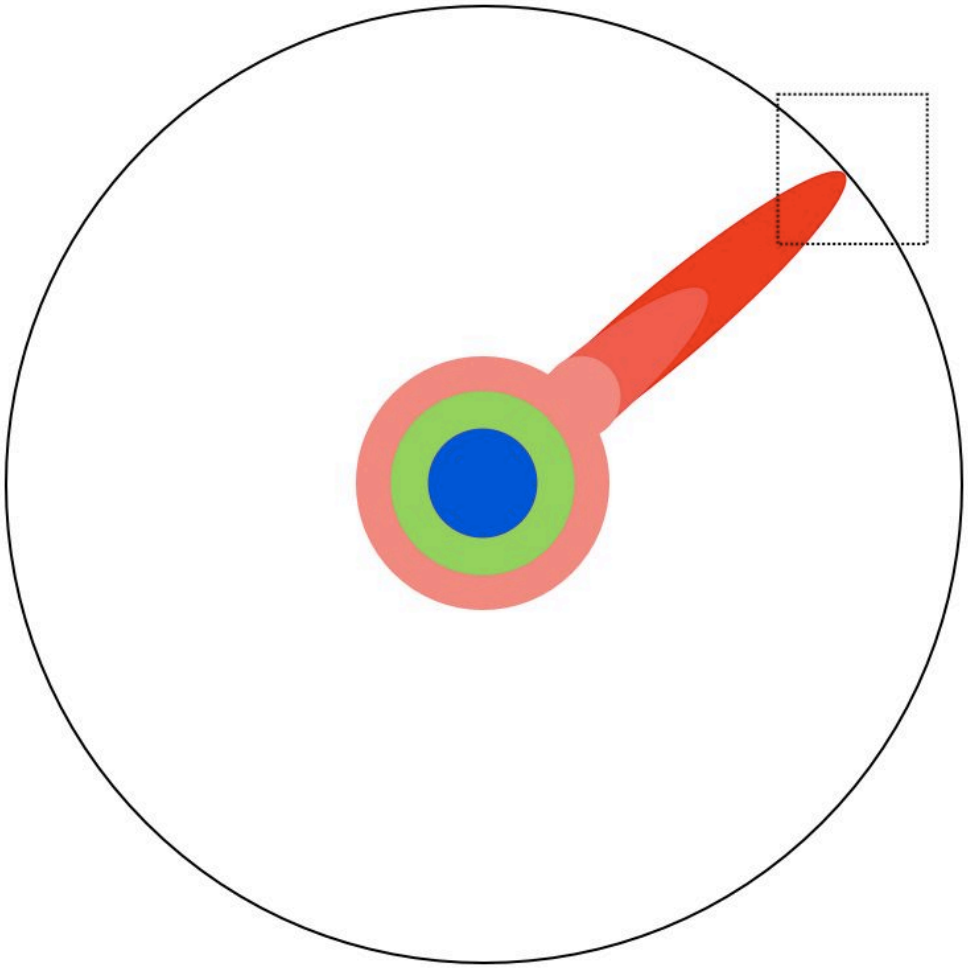
A Master's Deepens that Specialty…



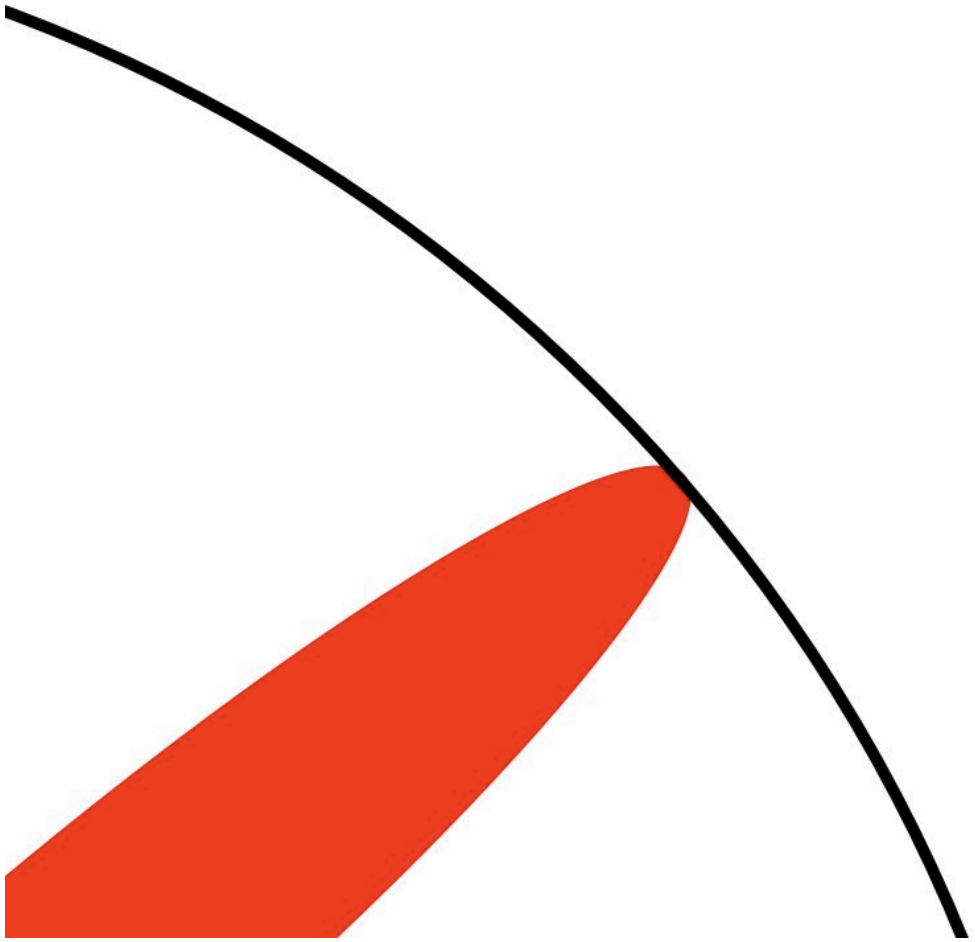
Reading Research Papers…



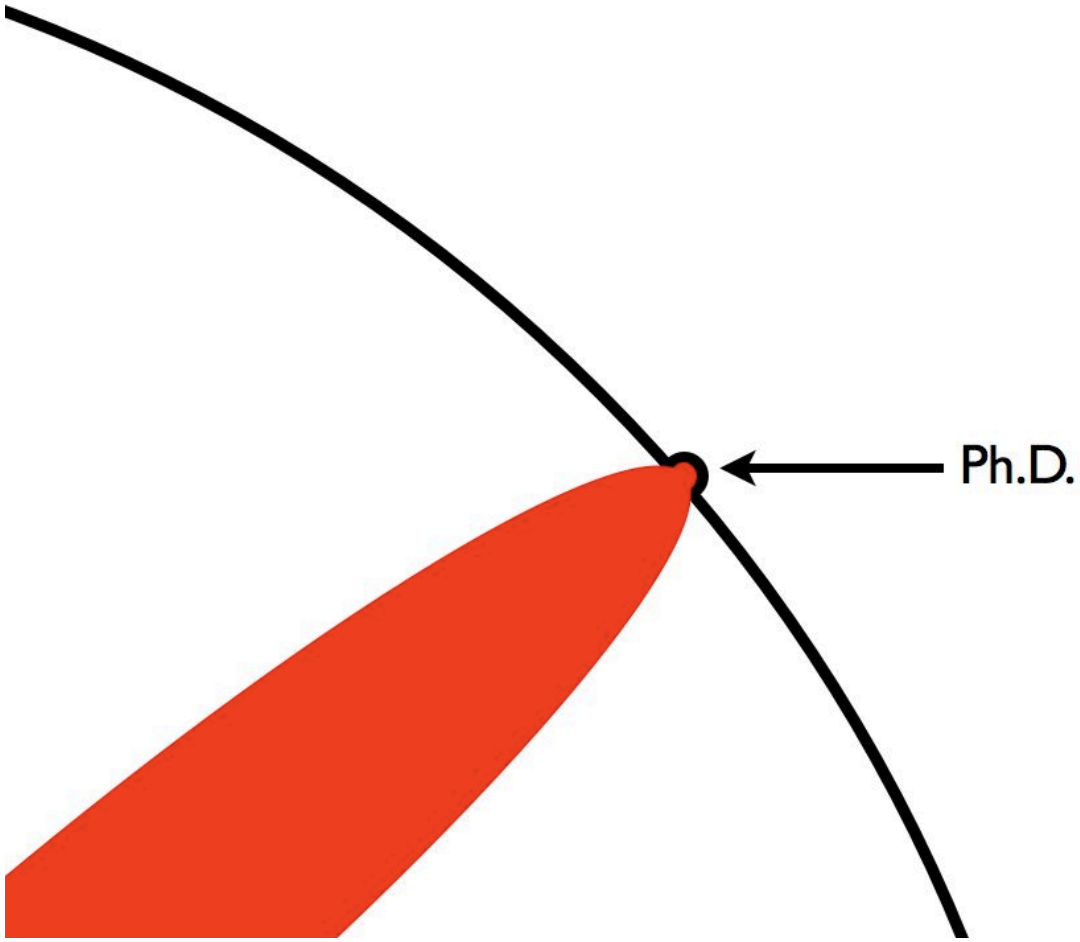
Once at the Boundary, Focus…



Push for a Few Years…

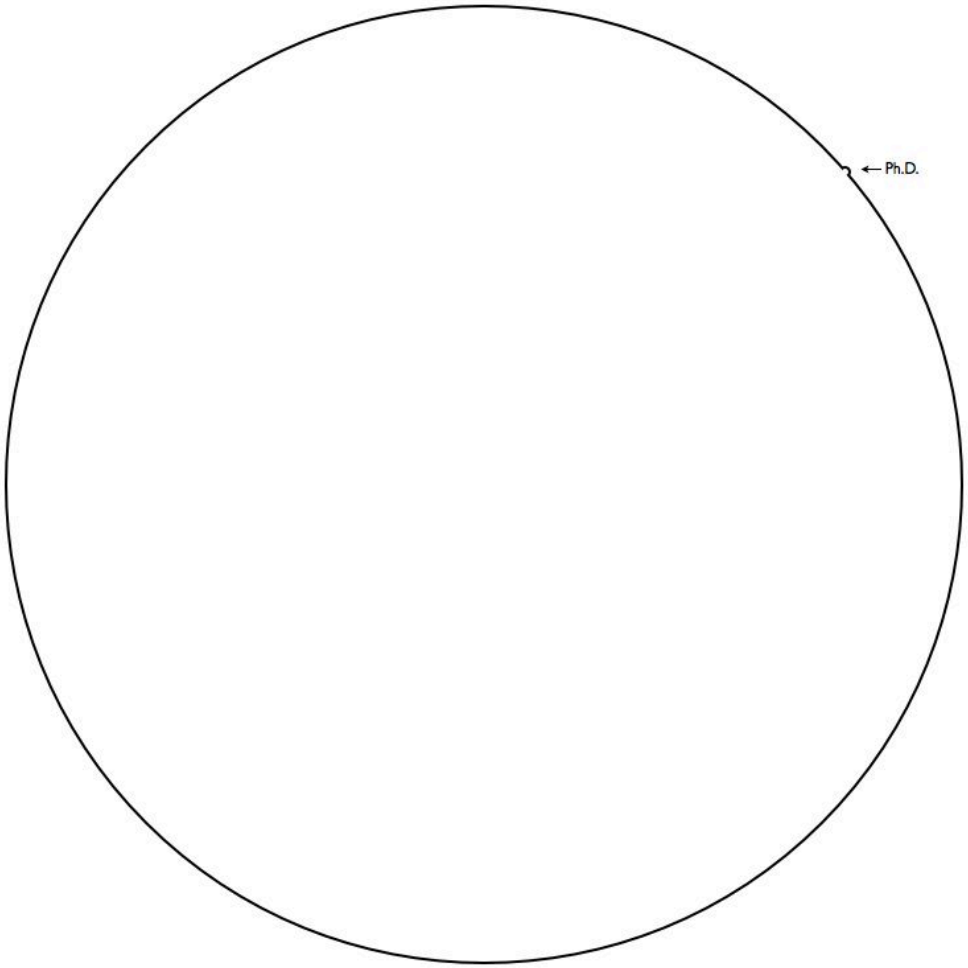


Until the Boundary Gives Way…

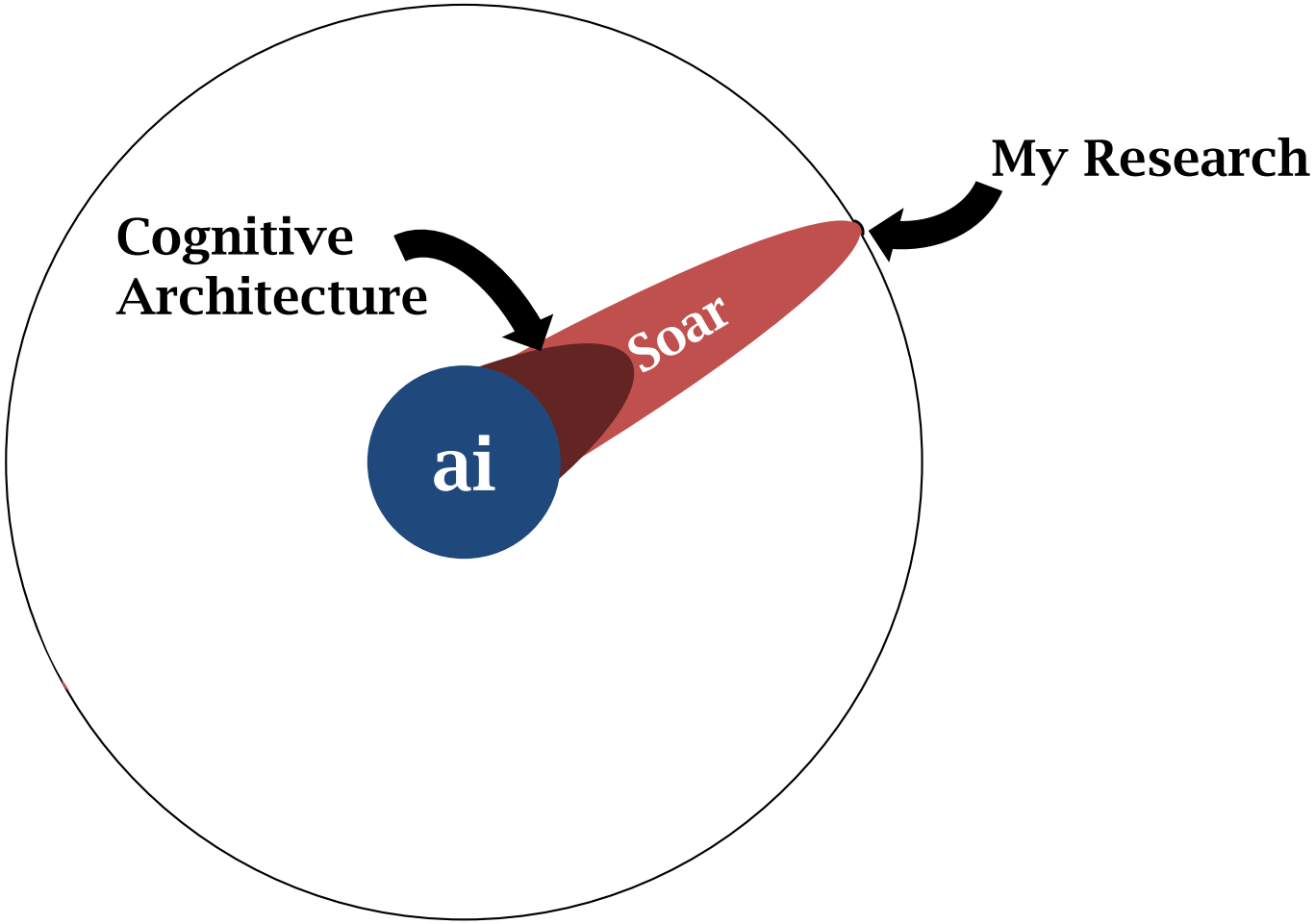


Grad Student World View

The Big Picture



Talk Outline



AI Strengths

- Reasoning
- Planning
- Extracting patterns
- Machine translation
- Games

…

AI Strengths

- **Reasoning**
- Planning
- Expanding patterns
- Machine translation
- Games
- …

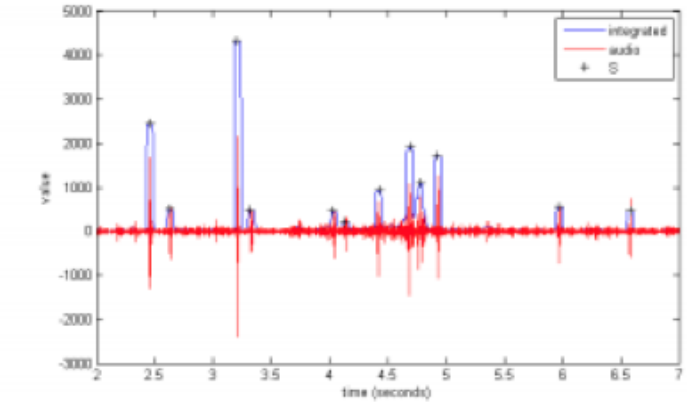
Example: Cyc (cyc.com)

- >500K concepts, 5M facts, 1M rules
- Hybrid forward/backward inference (EECS 492/543)
- Applied to anti-terrorism, cyber-defense, disaster contingencies, …

Step 1. Hypothetical Hacker sends an e–mail message to shandra.cyc.com
Step 2. Hypothetical Hacker lures the user of shandra.cyc.com to a particular website
Step 3. Hypothetical Hacker contructs a data string longer than the memory buffer for Real Player version 7.0 can handle
Step 4. Hypothetical Hacker sends the data string to Real Player version 7.0 running on shandra.cyc.com
Step 5. Hypothetical Hacker overflows the memory buffer for Real Player version 7.0 running on shandra.cyc.com
Step 6. Hypothetical Hacker installs a sniffer program on shandra.cyc.com
Step 7. Hypothetical Hacker waits for an entry of a computer password
Step 8. Hypothetical Hacker sniffs the login information for a Cycorp LAN Windows NT user account on the Cycorp LAN Windows NT account system
Step 9. Hypothetical Hacker uses hacker computer to log in remotely to a Cycorp LAN Windows NT user account via shandra.cyc.com
Step 10. Hypothetical Hacker downloads MSIEXEC Exploit onto shandra.cyc.com
Step 11. Hypothetical Hacker runs MSIEXEC Exploit on shandra.cyc.com
Step 12. Hypothetical Hacker gets access to a Cycorp LAN Windows NT system account

AI Strengths

- Reasoning
- Learning
- Natural language translation
- Games
- …
- **Extracting patterns**



Example: AI-D (ai-d.org)

- Predict food shortages, post-disaster need, disease propagation, …
- Distributed medical diagnosis
- Voice-based services for illiterate populations

AI Strengths

- Reasoning
- Extracting patterns
- Machine translation
- ...
- **Games**

Example: Players

- Chess, Checkers, Poker, Jeopardy…

Example: Game Theory

- Applied to markets, auctions, P2P, and security/privacy




AI Assumptions

- Reasoning
- Planning
- Extracting patterns
- Machine translation
- Games

…

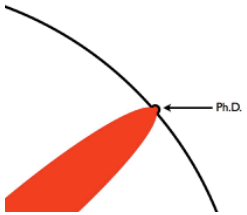
Single, well-defined task

Typically narrow in data type, amount, and learning

Short-term

Next Generation Tasks

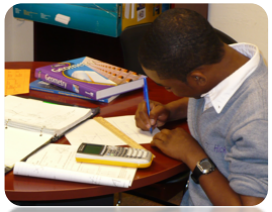
- Cognitive Robotics
  - Long-term exploration
  - Search-and-rescue
  - Synthetic teammates (military, medical, …)
  - Personal assistants (home, office, tutors, …)
- Scientific Knowledge Discovery

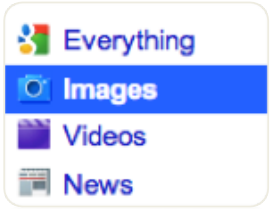


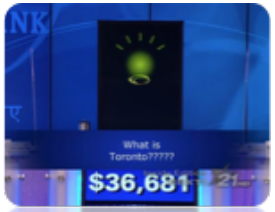
- Resource Management (food, transport, …)

Goal: Human-level AI

- Autonomous
- Long-term (and reactive)
- Multiple tasks
- Comprehensive learning (vs. laborious programming)
- Multi-modal perception and knowledge
- Robust (vs. optimal)







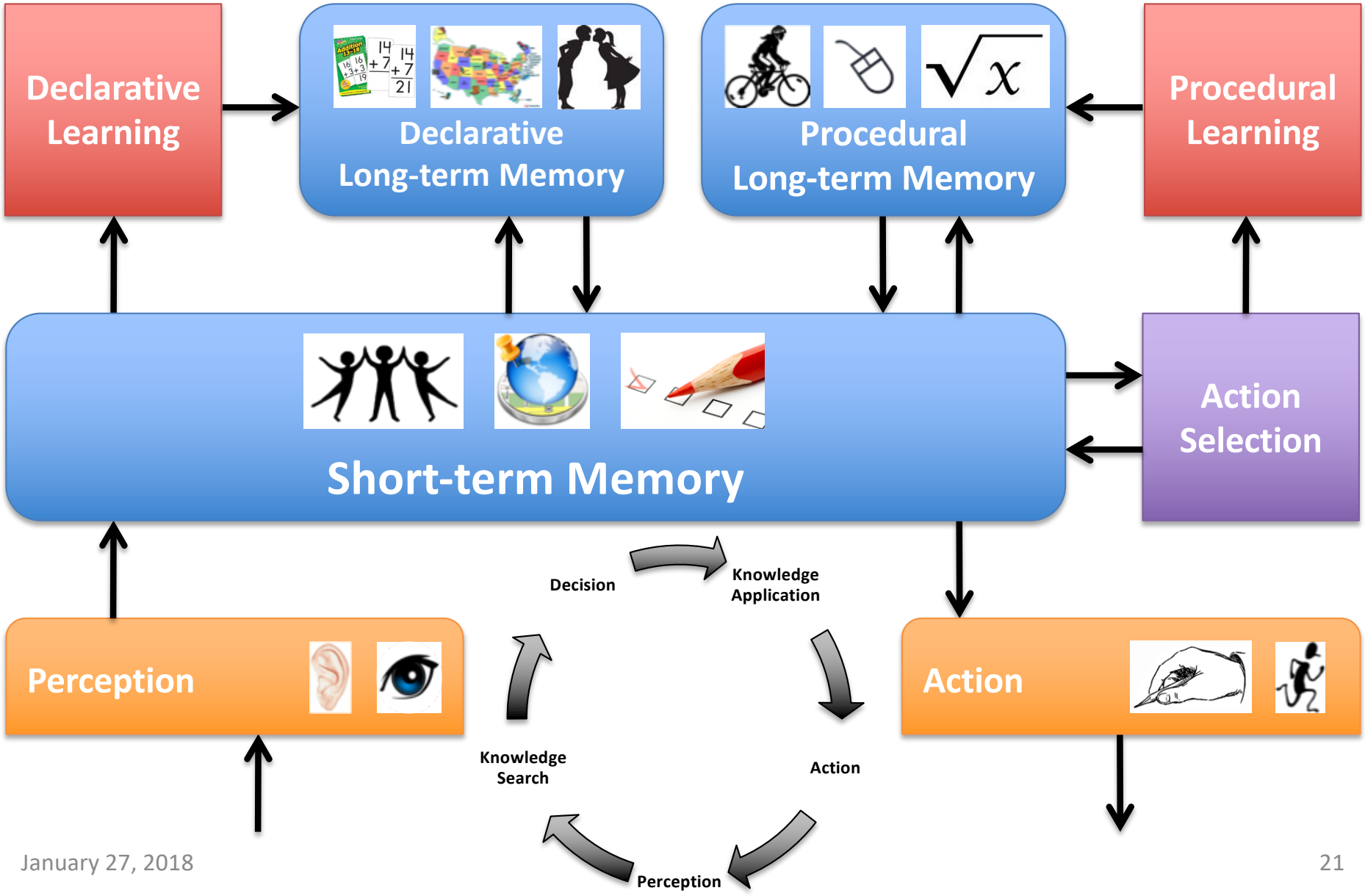
Approach: Cognitive Architecture

Goal. Develop and understand human-level intelligence across a diverse set of tasks and domains

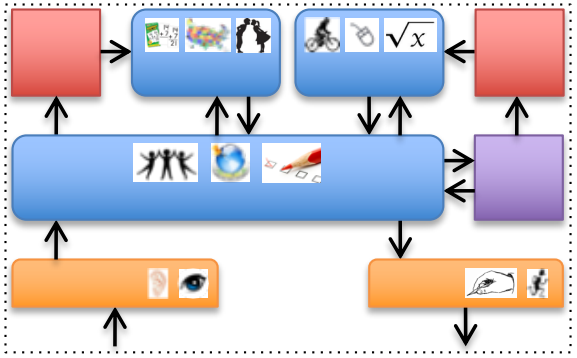
Specification of those aspects of cognition that remain constant throughout the lifetime of an agent

- Memory systems of the agent's beliefs, goals, experience
- Knowledge representation
- Functional processes that lead to behavior
- Learning mechanisms

Prototypical Architecture



Agent Definition



Architecture (fixed)

Knowledge (dynamic)

Common Research Goals

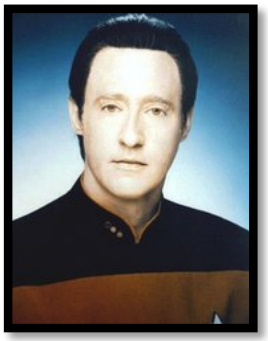
Biological Plausibility

Leabra

Psychological Plausibility

ACT-R
CLARION
EPIC

Agent Functionality

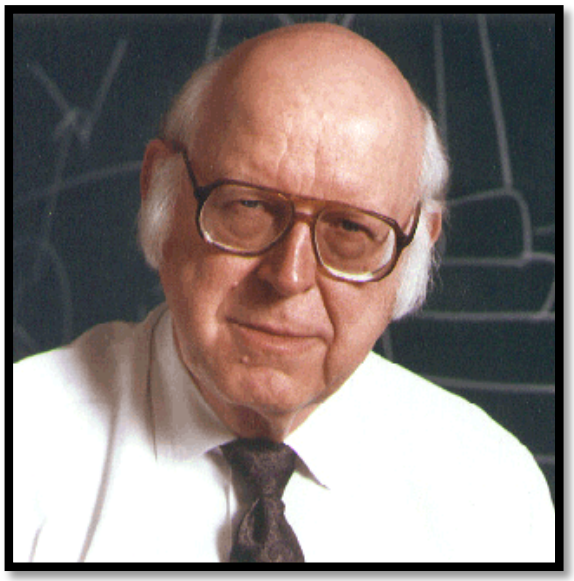


Companions
ICARUS
LIDA
Soar

The Soar Cognitive Architecture

Created in 1982 by…

John Laird
Professor
Michigan



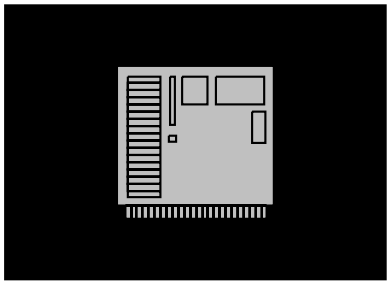
Allen Newell
Founder of AI
CMU

Paul Rosenbloom
Professor
USC, ICT

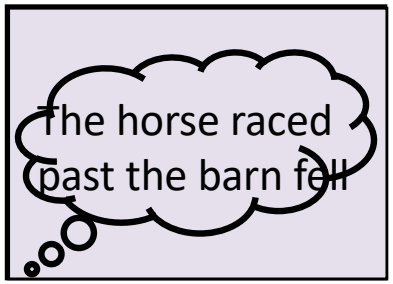
Distinctive Characteristics

- Efficiently brings to bear large amounts of knowledge
- Diverse mechanisms that support general problem solving methods
- Public distribution and documentation
  - Major operating systems (Windows, OS X, Linux)
  - Many languages (C++, Java, Python, …)

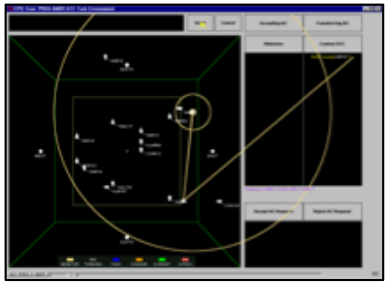
Select Applications (1)



R1-Soar
Computer Configuration

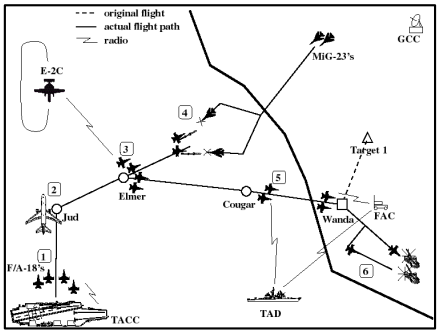


NL-Soar
Language Processing

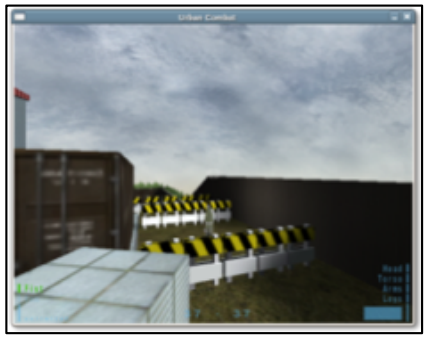


Amber EPIC-Soar
Modeling HCI

ICT Virtual Human
Natural Interaction, Emotion



TacAir-Soar
Complex Doctrine & Tactics



Urban Combat
Transfer Learning

Soar Quakebot
Anticipation

Haunt
Actors and Director

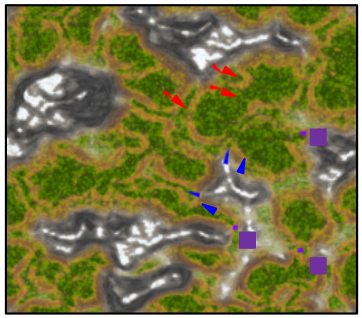
Select Applications (2)

MOUTbot

Team Tactics & Unpredictable Behavior

SORTS

Spatial Reasoning & Real-time Strategy

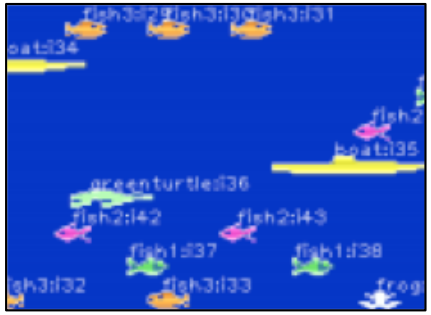


Simulated Scout

Mental Imagery

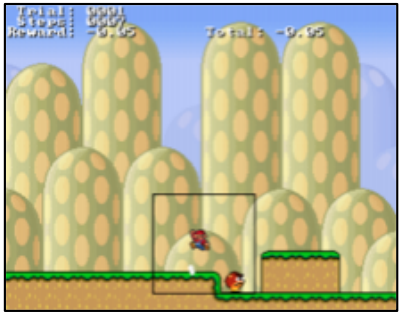
Splinter-Soar

Robot Control



ReLAI

Mental Imagery & Reinforcement Learning

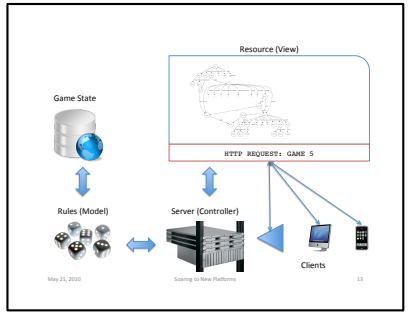


Infinite Mario

Hierarchical Reinforcement Learning

iSoar

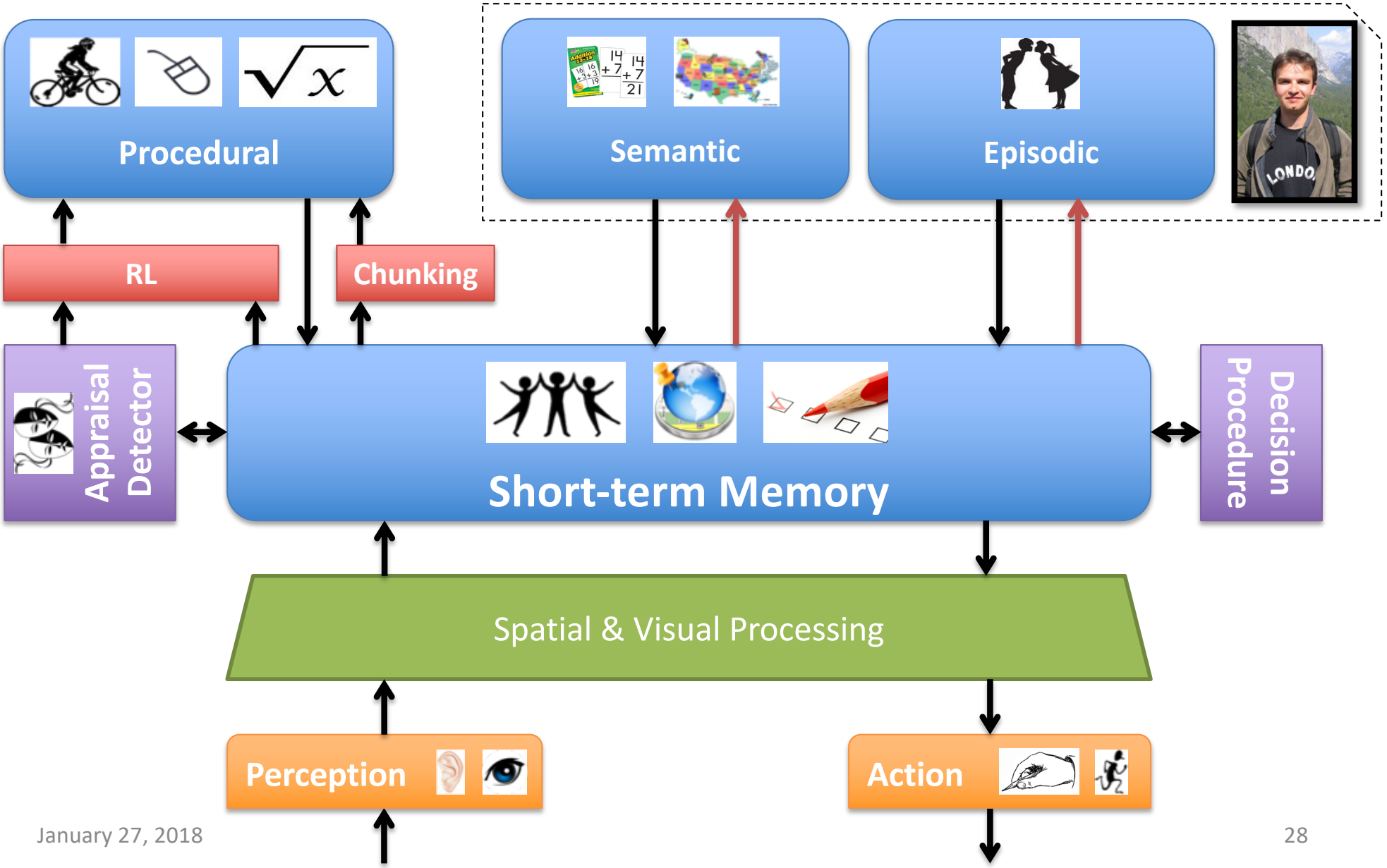
Mobile Reinforcement Learning



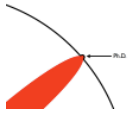
RESTful Soar

Web-based Gameplay, Probabilistic Learning

The Soar Cognitive Architecture

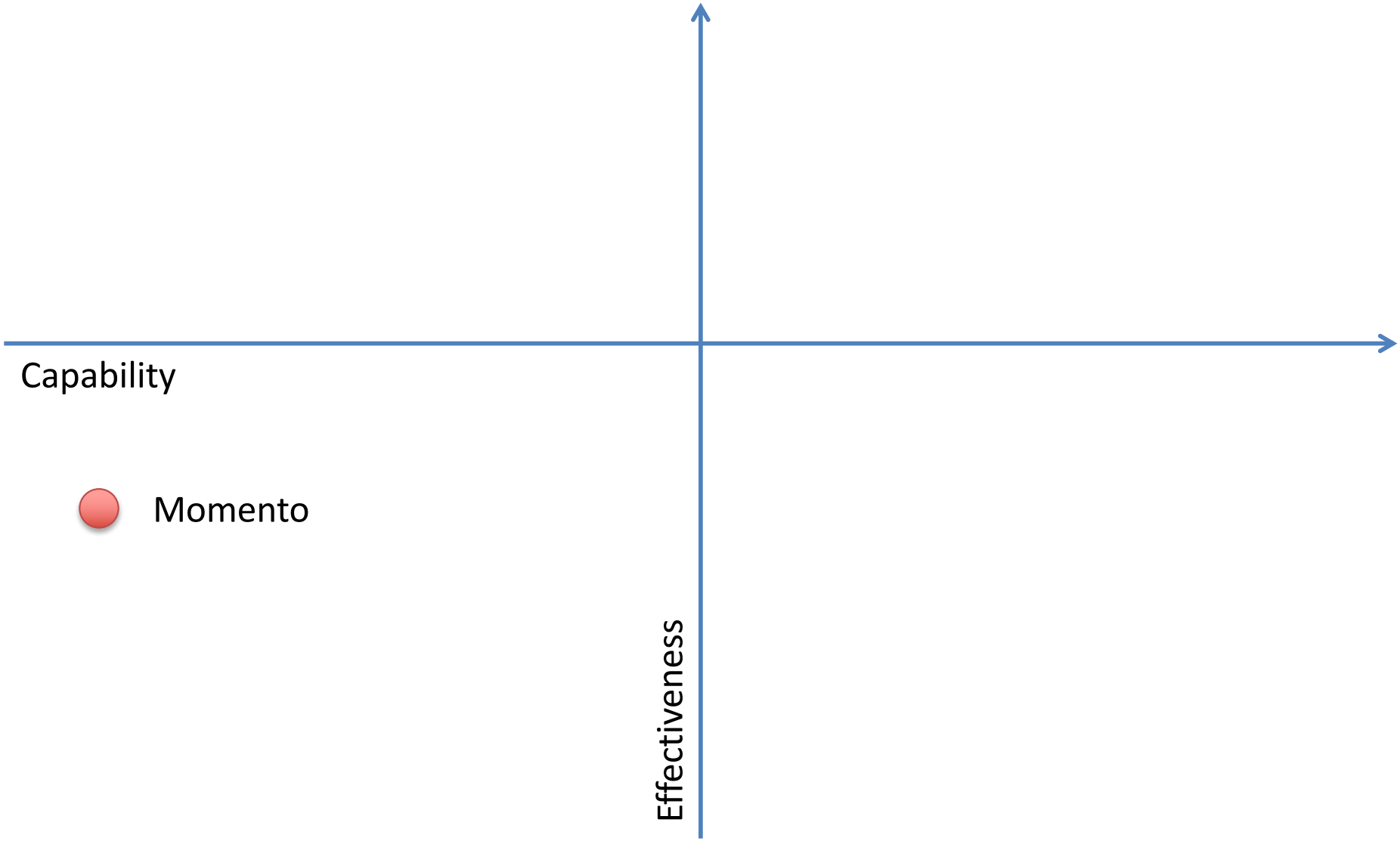


My Research



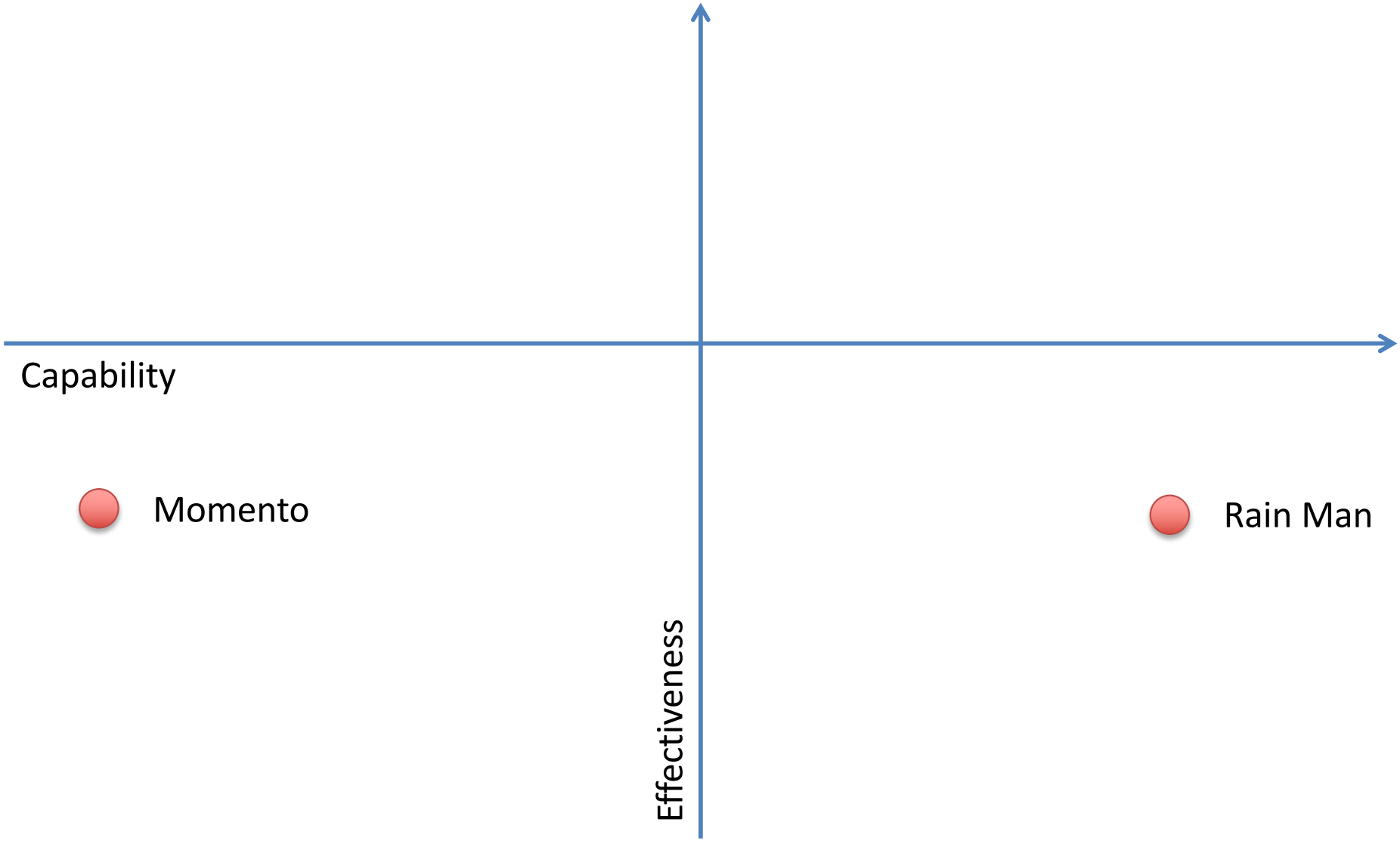
Goal. Explore and evaluate long-term declarative memory systems that are effective and efficient across a variety of tasks

Effective Memory



Momento (2000)

Effective Memory

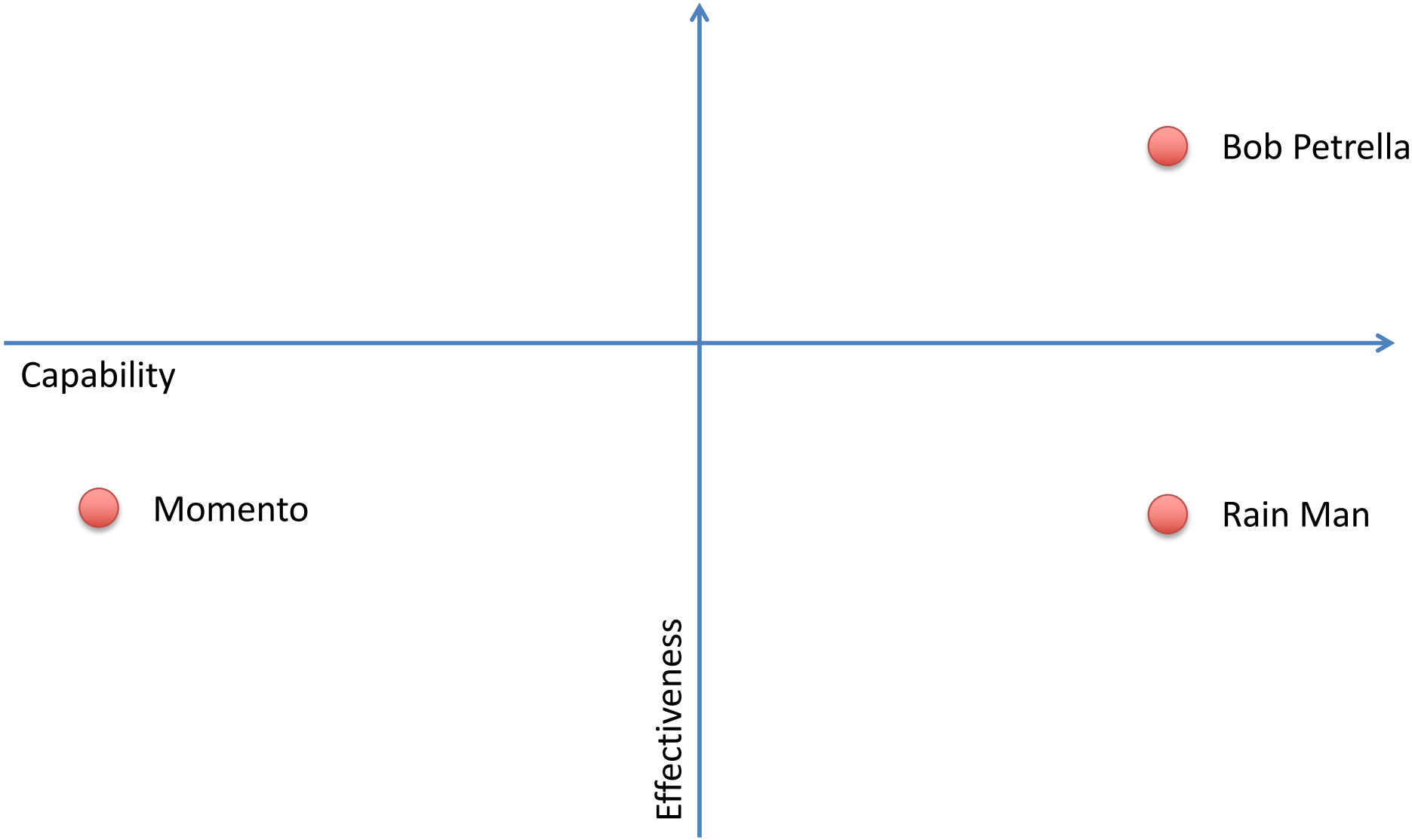


Kim Peek

- American Savant
- “Photographic” memory
- Developmental disabilities
  - Autistic in movie

Rain Man (1988)

Effective Memory

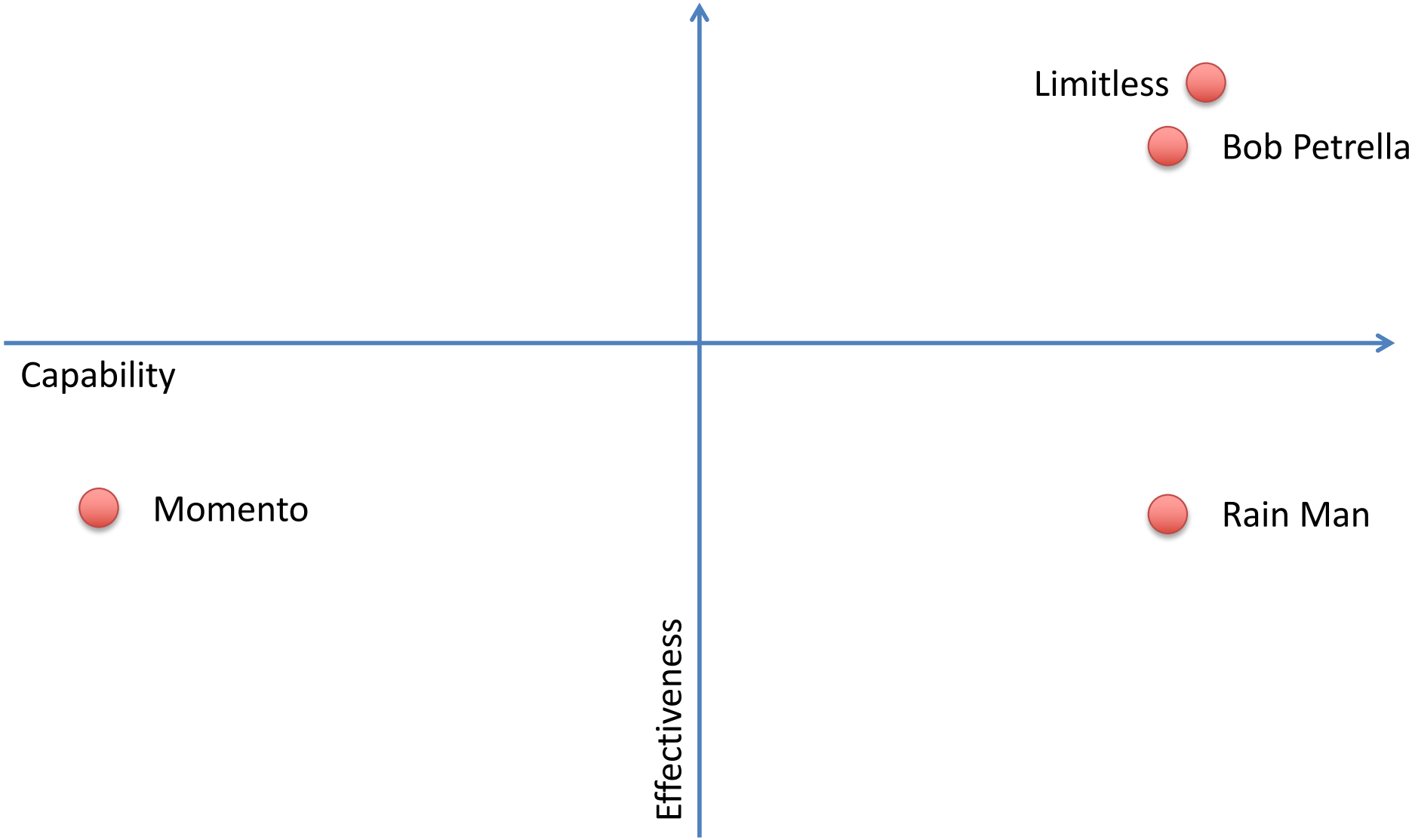


Bob Petrella

- Fourth person diagnosed with superior-autobiographical memory
- 58, lives in LA, works as producer for the Tennis channel

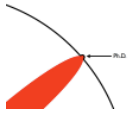
CBS News, 60 Minutes (2010)

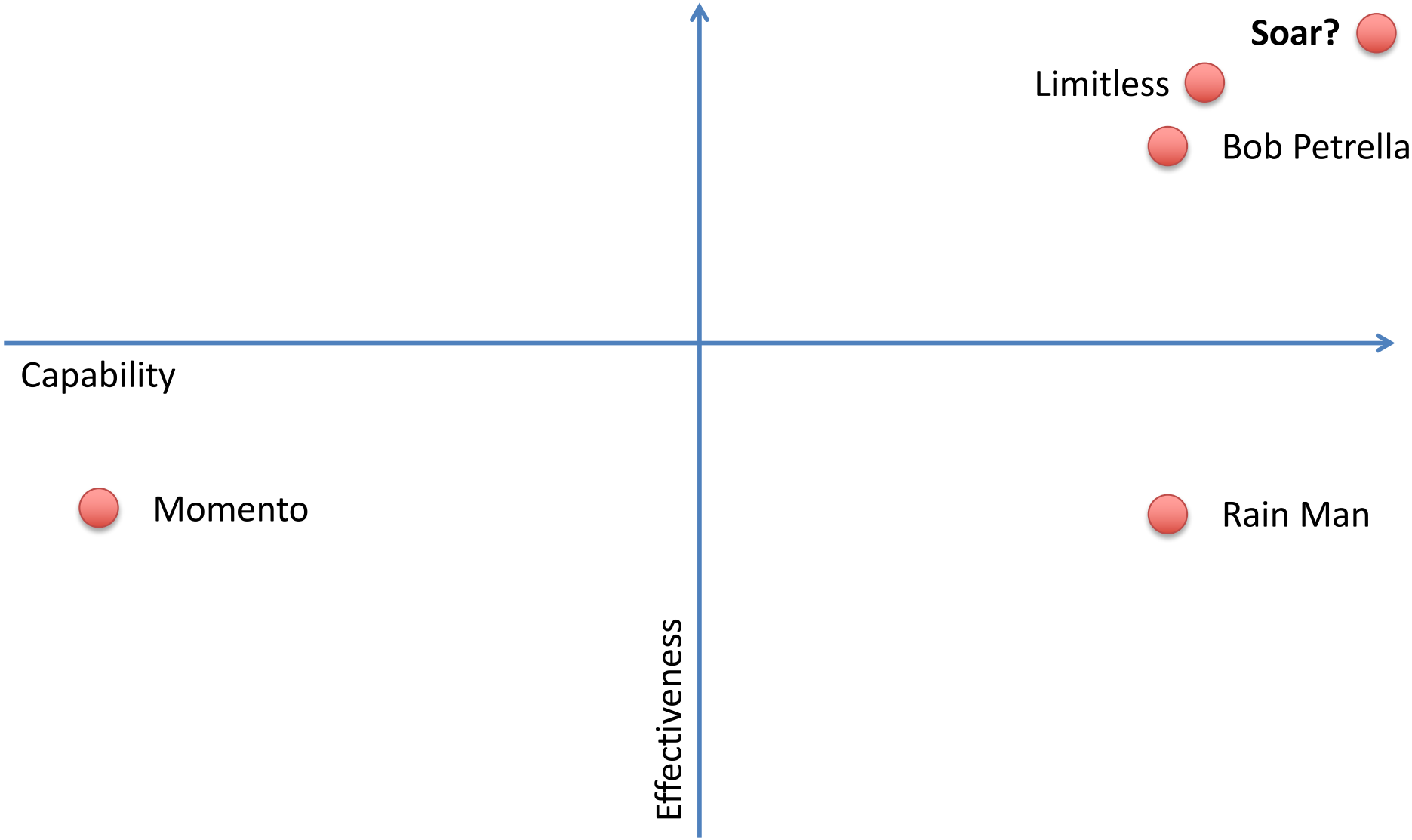
Effective Memory



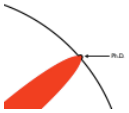
Limitless (2011)

Effective Memory





Ex. Cognitive Capabilities



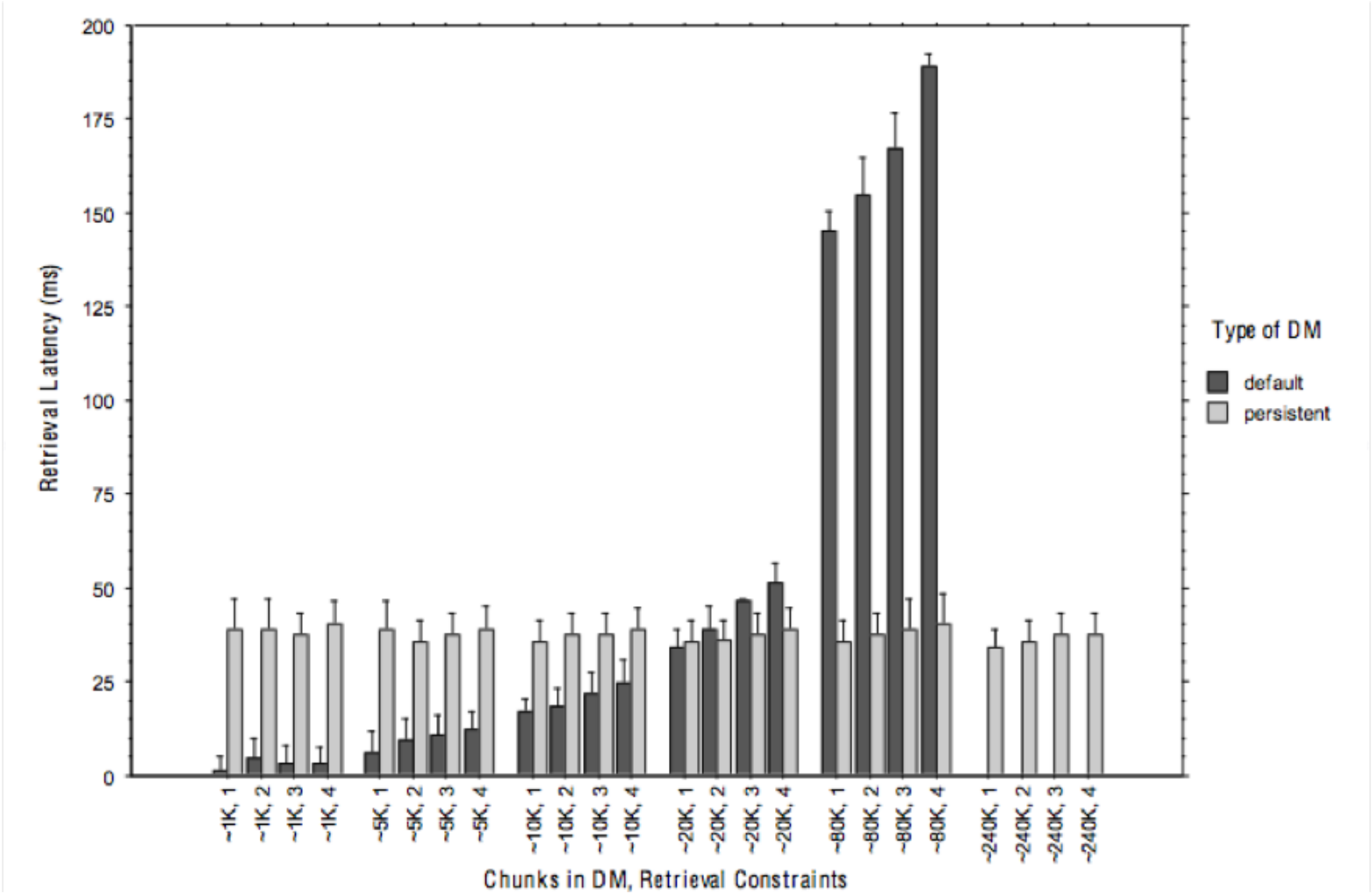
Virtual Sensing (Nuxoll & Laird, 2007)

Expands agent sensing beyond immediate perception via access to details of past situations

Action Modeling (Laird et al., 2010; Xu & Laird, 2010)

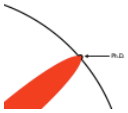
Informs predictions about the result of actions in present or future situations based upon prior experience

SMem: Capability vs. Efficiency



[Douglass et al., ICCM 2009]

SMem: Efficient Implementation



Approach

- Inverted Index (EECS 485)
- Statistical Query Optimization (EECS 484)
- Heuristic Search (EECS 492)

Results

- Over 100x faster queries on 3x more data[1]
- Stable and efficient for real-world tasks (robotics[2] & mobile music[3])
- Cognitively inspired and empirically functional biases[4]

Future Work

- Explore additional capabilities
- Evaluate on more tasks & data

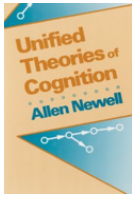
1. [Derbinsky, Laird, Smith; ICCM 2010]
2. [Laird, Derbinsky, Voigt; BRIMS 2011]
3. [Derbinsky, Essl; NIME 2011]
4. [Derbinsky, Laird; AISB 2011]

Getting Involved

Download Soar (soar.googlecode.com)

- Binaries & source available
- Manual & tutorials
- E-mail support

Readings



- Unified Theories of Cognition
- Soar group publications

Soar Workshop (sitemaker.umich.edu/soar)

- Tutorials, talks
- Attendees from around the world

Thank You :)

Questions?