Variability in Human Behavior Modeling

Robert Wray
Soar Technology

John Laird
University of Michigan

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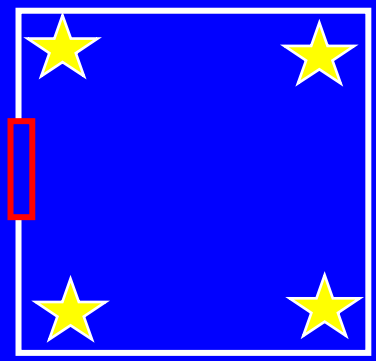
Variability

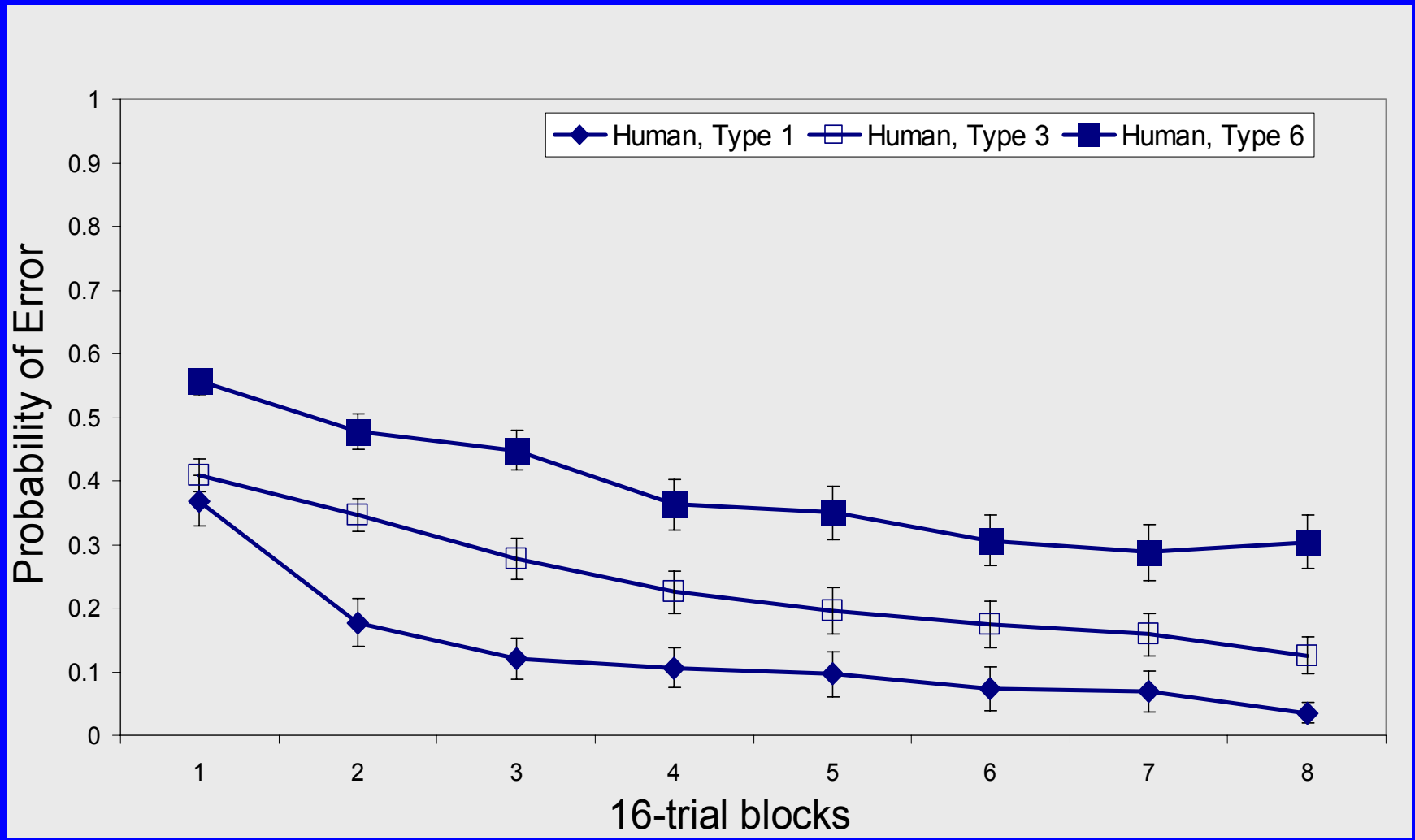
- Definition: differences in observed behavior when entities are placed in essentially same situation
  - "essentially": identical at some level of abstraction
    - Intercepting a bogey vs.
      intercepting a bogey at specific range, heading, ROE, etc.
    - Physical agents:
      Always differences at quantum and cellular levels
    - M&S applications: Observer point-of-view
- Goals:
  - This talk: What is variability, why it's of interest, progress made using Soar to explore variability
  - Long-term: tools & techniques for realistic variability in human behavior representation (applied focus, goals)

MOUTBots:
Intelligent, realistic opponents for virtual reality training



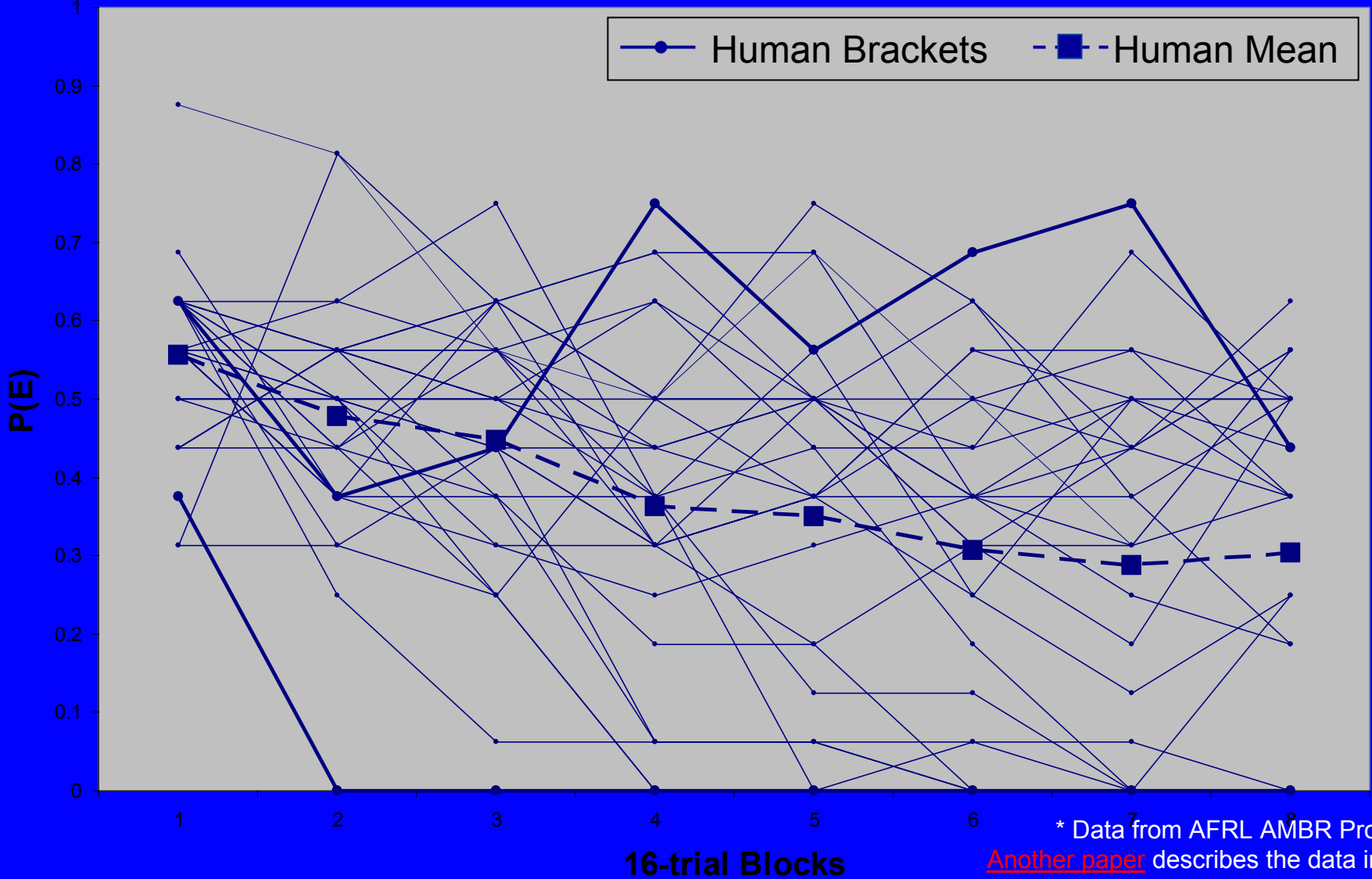
* Intelligent Opponent MOUTBot details

Variability in Human Behavior



* Data from AFRL AMBR Program.
Another paper describes the data in detail.

Variability in Human Behavior



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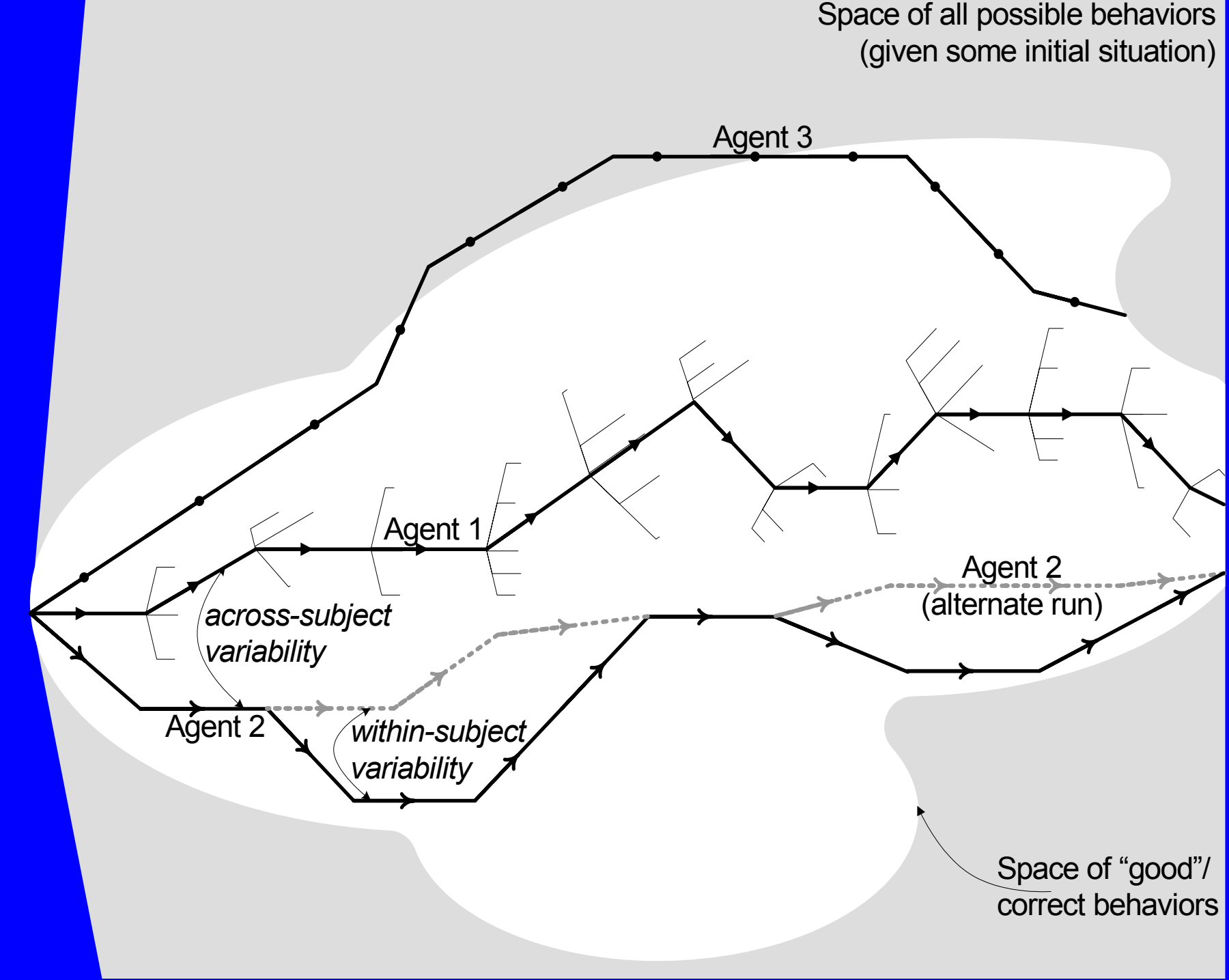

Space of all possible behaviors
(given some initial situation)
Agent 3
Agent 1
Agent 2
(alternate run)
across-subject
variability
Agent 2
within-subject
variability
Space of “good”/
correct behaviors

Properties of Variability

- Does not imply correct/incorrect, novice/expert
  - Behavior can diverge from and converge to correct behavior
  - Expert and novice behavior will be variable
- Variability does not exclude determinism
  - Non-observable features can be used/imputed to explain differences (e.g., “behavior moderators”)
- “Chaotic”
  - Small differences in individual decisions can lead to large divergence in overall behavior
  - Few options at each decision can lead to variable behavior
- Should not be arbitrary
  - Variability must reflect actual human behavior

Sources of Human Variability

Physical Differences	Mental Differences
Perception (Visual acuity)	Differences in available knowledge
Level of fitness & health	Training/Education/Experience
Dexterity	Culture/Religion/Class
Physiological state (hunger/fatigue)	Self-knowledge
↥ Arousal & Emotion ↧	
↥ “Intelligence” (e.g., memory capacity) ↧	
↥ Personality ↧	

Within-subject variability

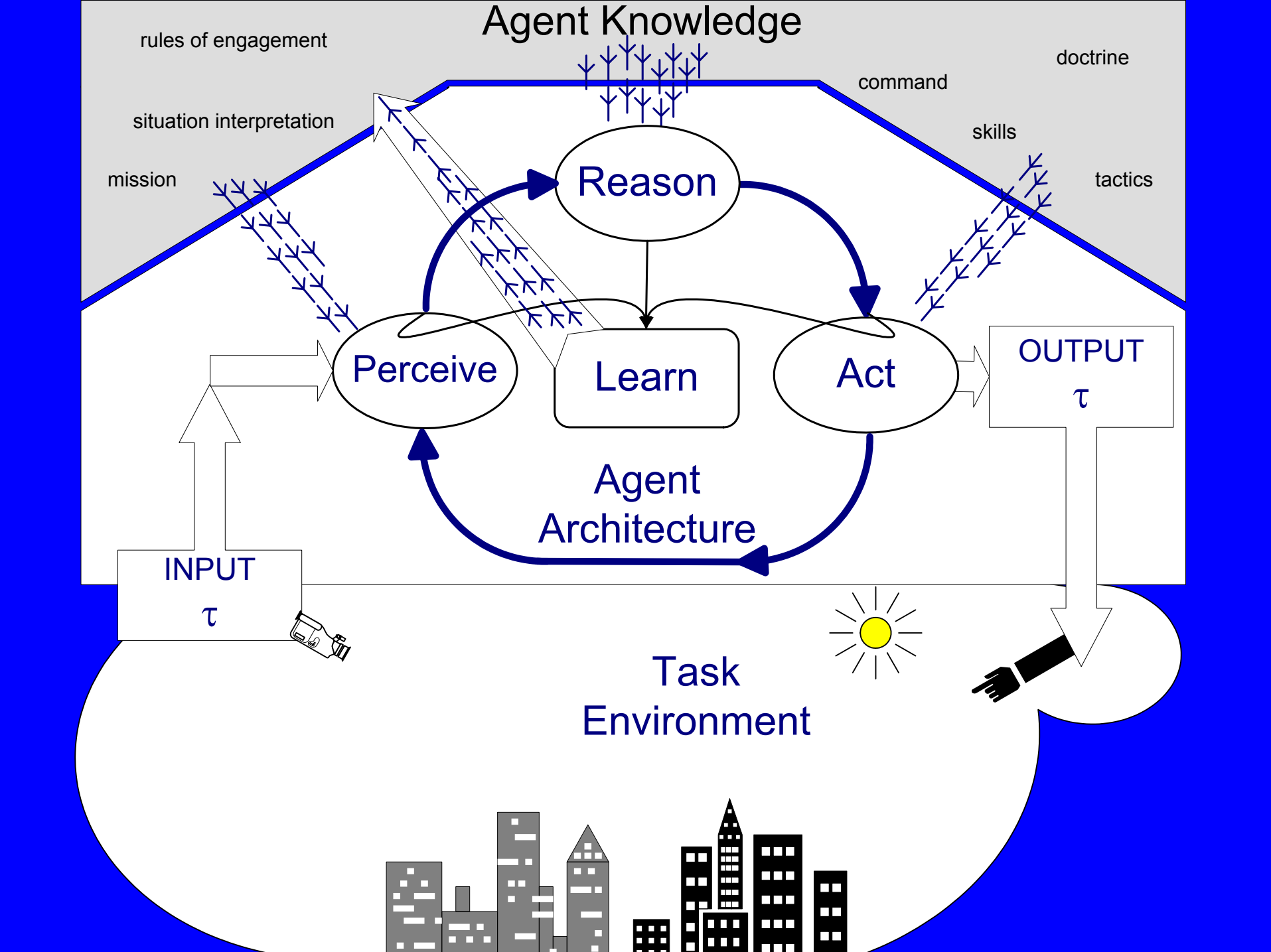
- Single entity does something different in the same situation
  - (“same situation” includes temporal distinctions)
- Example sources
  - Physical: Perception/dexterity differences (fatigue)
  - Mental: Learning/experience (“fool me once….”)
- Role in HBR
  - Domains with episodic structure
  - Human users often do not have repeated interactions with the same entities

Across-subject variability

- Different entities do different things in the same situation
- Example sources
  - Physical: Dexterity (marksmanship)
  - Mental: Training (novice vs. expert)
- Role in HBR
  - Critical importance:
    Limit gaming, increase unpredictability, enhance motivation
  - Produce realistic, observable patterns for training

Solution Requirements

- Realistic, individual-level variability in behavior
  - "Correct" variability (not arbitrary behavior)
  - HBRs should capture individual-level behavior
    - Soldier 1: tactic A (always)
    - Soldier 2: tactics A/B (50%/50%)
    - Soldier model: choosing tactic A 75% of the time would not produce individual-level behavior
  - Simple noise/probability distributions over options alone insufficient/incomplete for across-subject variability


Agent Knowledge
rules of engagement
doctrine
command
situation interpretation
skills
mission
tactics
Reason
Perceive
Learn
Act
OUTPUT
τ
Agent
Architecture
INPUT
τ
Task
Environment

Possible Approaches

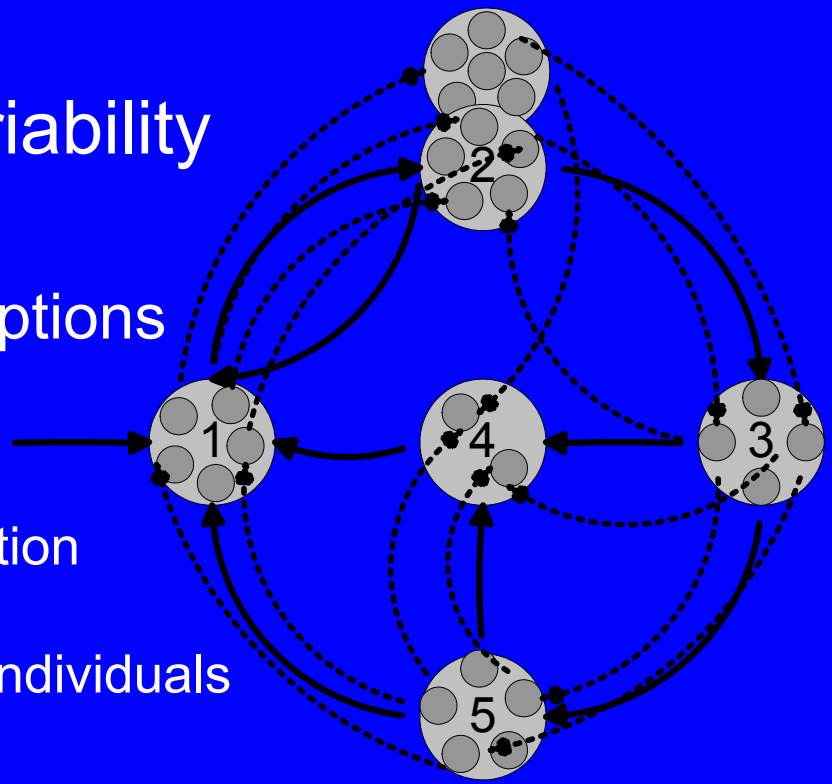
- Model knowledge differences
  - Soldier A model/Soldier B model
  - Limitations: time & cost (*n* HBRs vs. 1 HBR)
- Model divergence via learning
  - "basic" soldier that learns to be soldier A or B
  - Limitations:
    - basic soldier model, arbitrary variability
- Model sub-cognitive sources of variability
  - Example: emotions model facilitates different responses to a stimulus based on arousal profile
  - Limitations: basic science, interactions, cost

Possible Approaches (2)

Architectural support for variability

Strawman:

- Explicitly represent more options within a single model
- Variability parameters
  - Distributions for option selection (within-subject variability)
  - Profiles (random seeds) for individuals (across-subject variability)



- Normative approach – not descriptive!!

Architectural Support

- Advantages:
  - Variability development costs amortized over many applications
  - More complete domain knowledge representations
  - Less dependent on basic science advances in learning/modeling sub-cognitive factors
  - Potential “API” for interfacing sub-cognitive process models with HBRs
- Potential limitations (empirical questions):
  - Small fraction of total variability can be achieved via option selection
  - Determining variability profiles (for realistic behavior) will be overly labor-intensive
  - Computationally efficient functions cannot capture dynamic changes to variability parameters

Current Progress in Soar

- Extended indifferent preference semantics
  - Associate weight/“unnormalized” probability with indifferent preference
    - (<s> ^operator <o> = 30)
    - Achieved by overloading binary indifferent preferences
  - Default value of indifferent preference: 50
    - Value likely should be context dependent?
  - Selection:
    - Sort preferences as in standard Soar 8
    - If all candidates indifferent, normalize weights and choose candidate from (0,1] distribution
    - (Soar 8: choose randomly with equal probability)
  - No re-decision due to changes in weights alone

Current Progress (2)

- Weighted indifferent enables within-subject variability
  - Controlled
    - User determines/sets distributions (not emergent!)
    - Integrated with other preferences (> beats + deterministically)
    - Represent declaratively for easy manipulation
  - Context sensitive
    - Attack-with-grenade (general attack): low
    - Attack-with-grenade (tactically appropriate): high
- Initial step towards across-subject variability
  - Declarative representation facilitates alternate sets of weights

Conclusions

- Variability is a requirement for HBRs
- Architectural approaches
  - + Potential:
    Controlled, tailorable, inexpensive variability
  - – Future work: Evaluate this potential

Conclusions (Soar)

- Current Soar solution
  - \+ Controlled variability
  - \+ Computationally trivial
  - \+ fully backwards compatible
  - \+ support for within- *and* across-subject variability
  - – Open questions:
    - Where is the data to support specific weights?
    - Can weights be learned? Appropriate weights?
    - How much variation can be achieved without modeling knowledge differences?
  - – Normative, not descriptive approach (inconsistent with Soar theory?)