Computational Rationality

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Summer School 2017

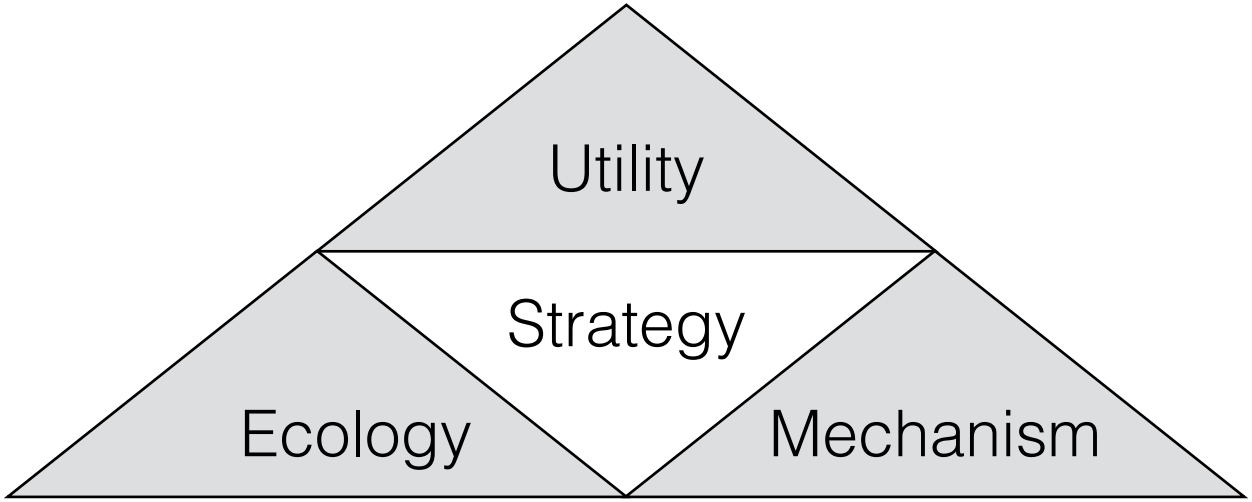
Plan

- **Background**
- **Computational rationality**
  - exploration v exploitation
  - multi-arm bandit & Google maps
- **Reinforcement learning 1 (Markov Decision Processes)**
  - menu search; using a vending machine
- **Reinforcement learning 2 (Partial Observability).**
  - human decision making; using a vending machine

What is a human?


adidas

Computational rationality



adaptation

bounds

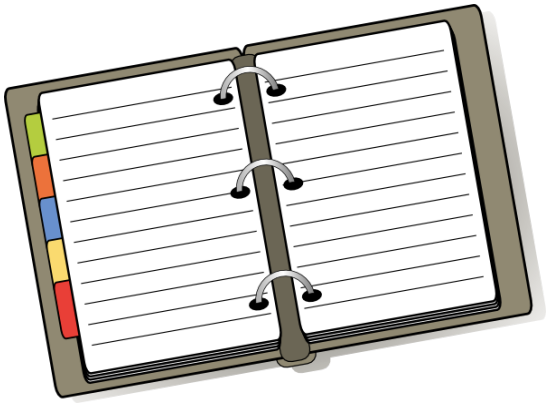
alternatively…

Charman and Howes (2003): Journal of Experimental Psychology: Applied

adaptation

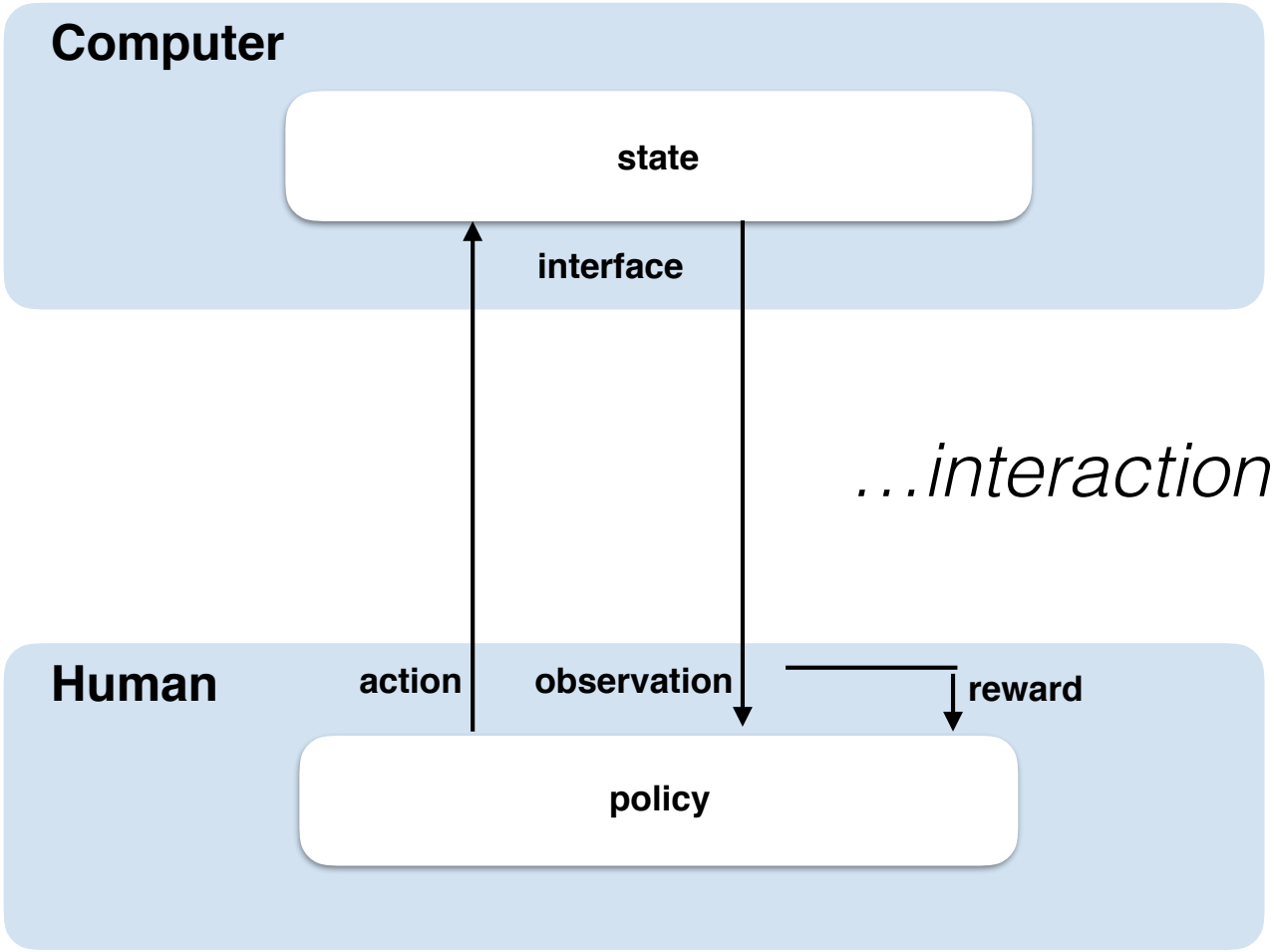
bounds

Sarah 9.30
Peter 10.00
Simon 11.00
Andrea 15.00
Jean 15.15
David 1530
Iain 1600
Julie 1630
Wayne 1700
Satinder 1730
Rachel 1900



Howes et al (2015) *Cognitive Science*

Can we predict interaction?

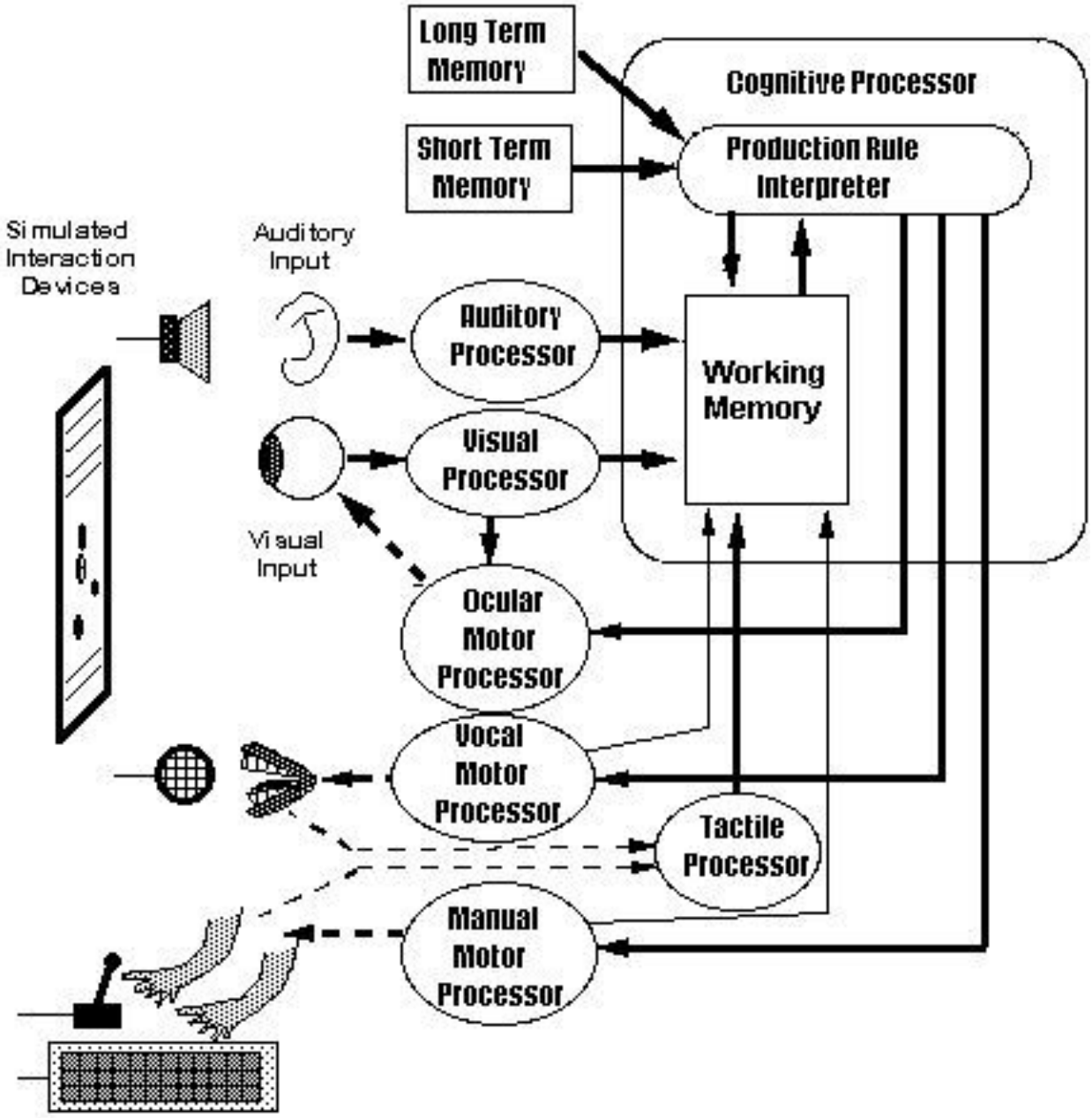


why model?

- **Explanation**: avoid being hacky, ad hoc, and trial-and-error.
- **Design**: Design is infinite, users are not… good design is bounded.
- **Optimization**: Algorithms can design user interfaces, attacking very hard problems, if it is informed by understanding of how a user may behave in the context of a particular UI.

History of Cognitive Modeling in HCI and Human Factors

- Fitts's Law
- Control Theory
- GOMS and KLM
- cognitive architectures (ACT-R and EPIC)
- adaptive interaction



The EPIC cognitive architecture

cognitive architectures

- **Strengths**
  - broad descriptive power
  - extremely flexible
- **Weaknesses**
  - require to be reprogrammed for every new task
  - often requires fitting to outcome data.
  - too flexible

The dangers: Over-fitting and mistaking adaptive strategy for fixed mechanism.

As observed by Tanner & Swets (1954), Newell (1973), Meyer & Kieras (1997).....

visual search is adapted…

Find the blue speech bubble

+

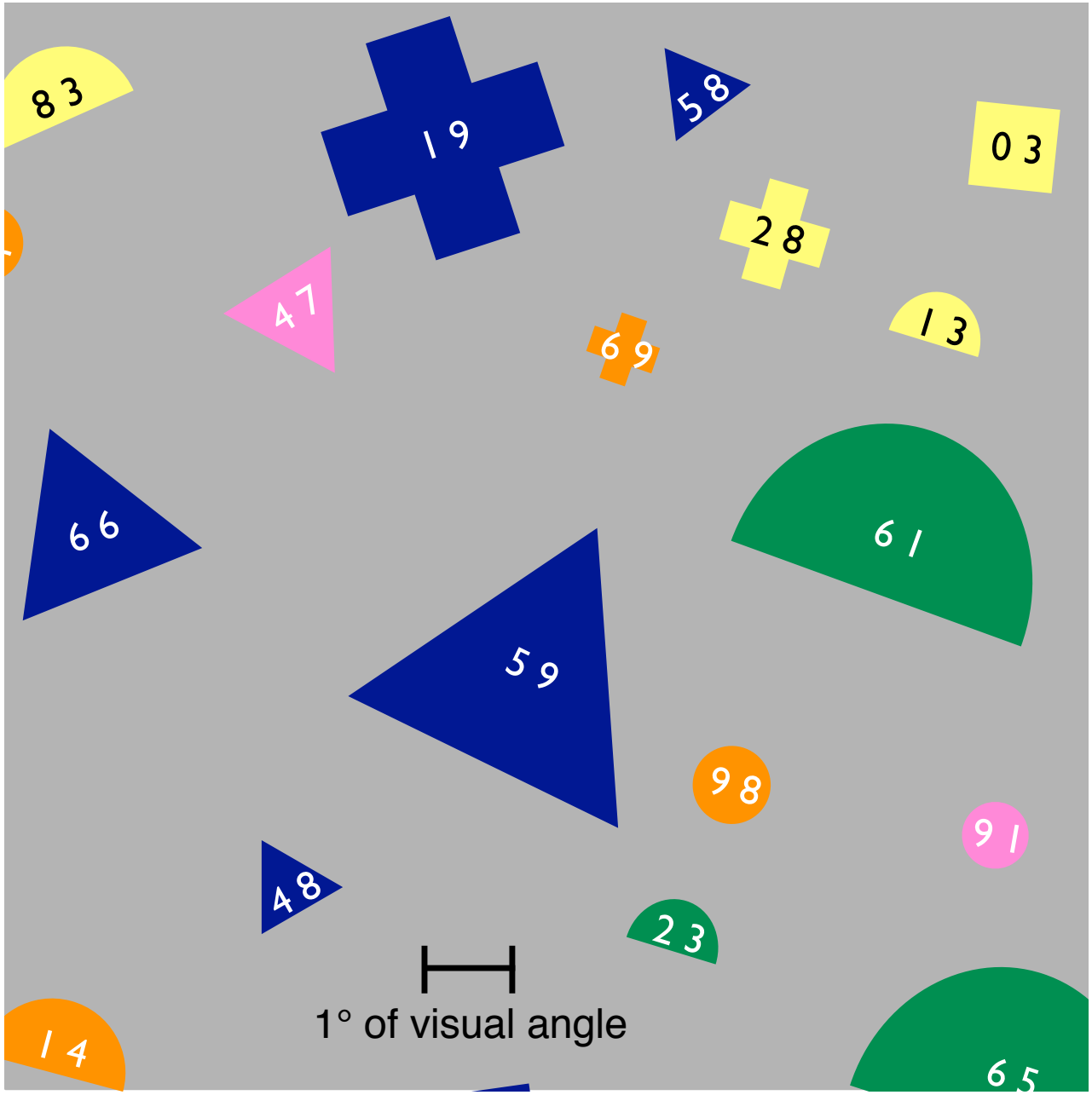

AT&T
12:58 PM
86%
Messages
TerryWhite
Photos
Camera
Remote
Maps
Weather
Google Voice
Clock
Learn CS
App Store
On the Go
Settings
Echofon
Facebook
Reeder
Phone
Favorites
Mail
Productivity


AT&T
12:58 PM
86%
Productivity
Notes
Calendar
Contacts
Softphone
CardStar
Reminders
Global Wi-Fi
Signature
VIP Access
TextExpander
Safari
Light

adapted to prior

http://wel.cs.manchester.ac.uk/studies/saswat/images/guardian_dynamic.jpg

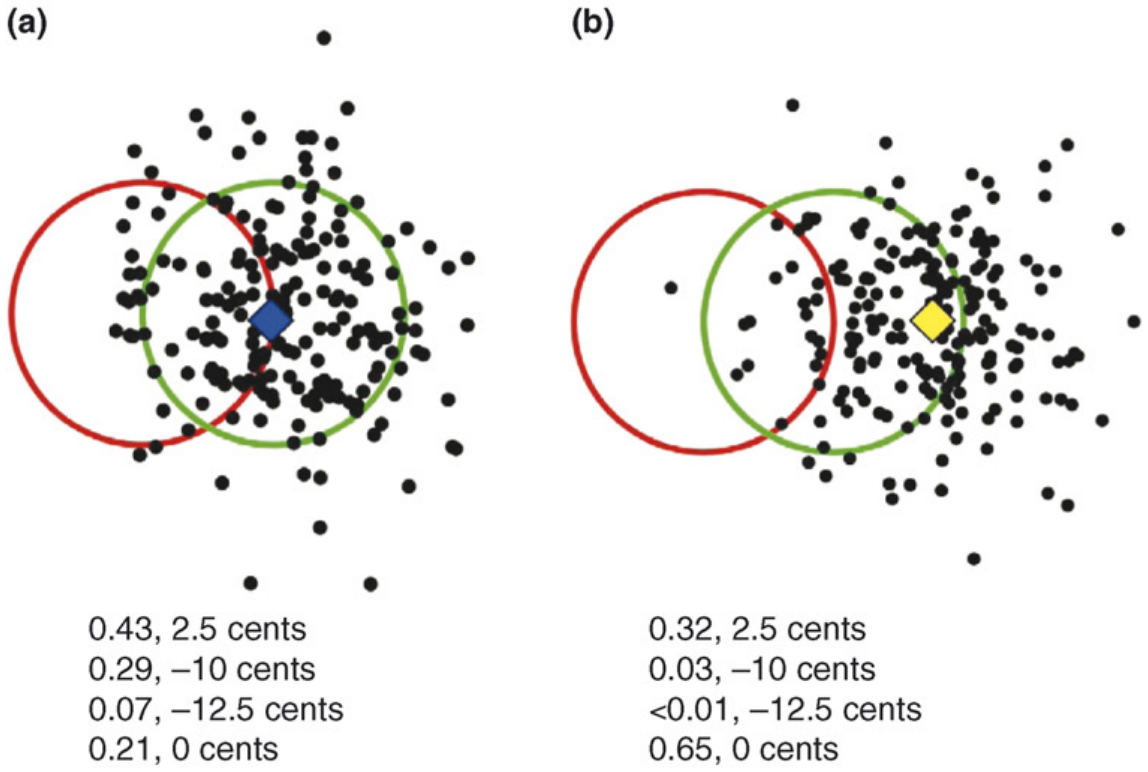
adapted to processing constraints

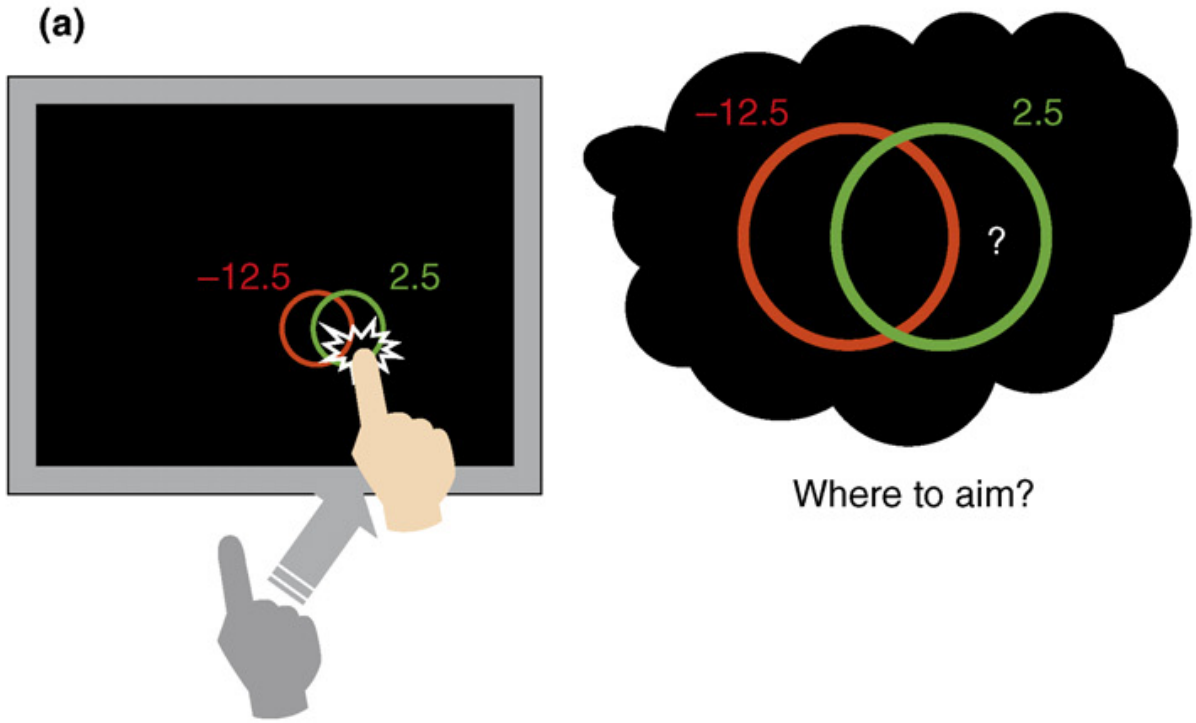


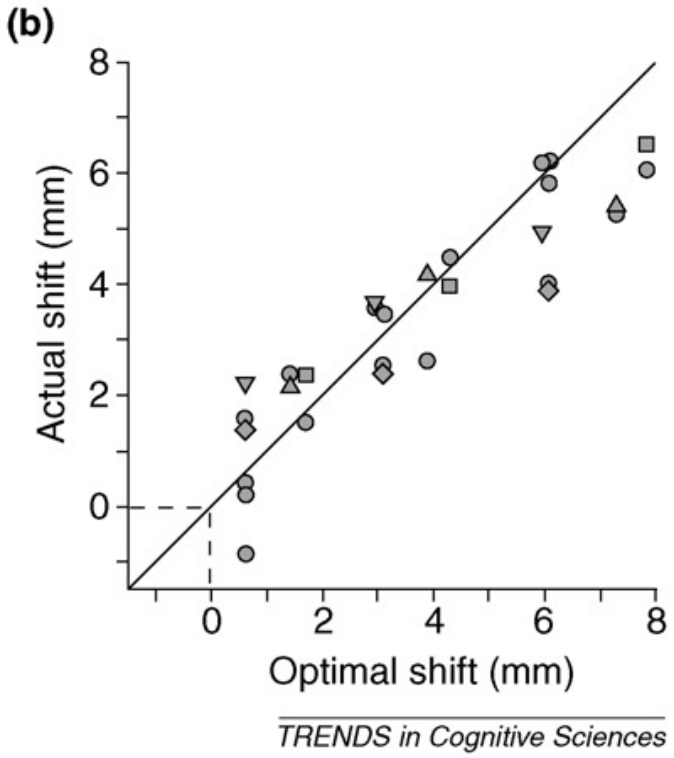
Parafoveal vision

- focus on the red "C" of the word "Cognitive" on the right. Can you read the words on the left most white book?
- Move your eyes one book to the left? etc.
- Notice how acuity for books to the left increases as your eyes move to the left.
- Also notice that you can attend to somewhere other than where you are fixated.

motor processing also adapted Maloney et al. (2009)…




(a)
−12.5
2.5
−12.5
2.5
?
Where to aim?

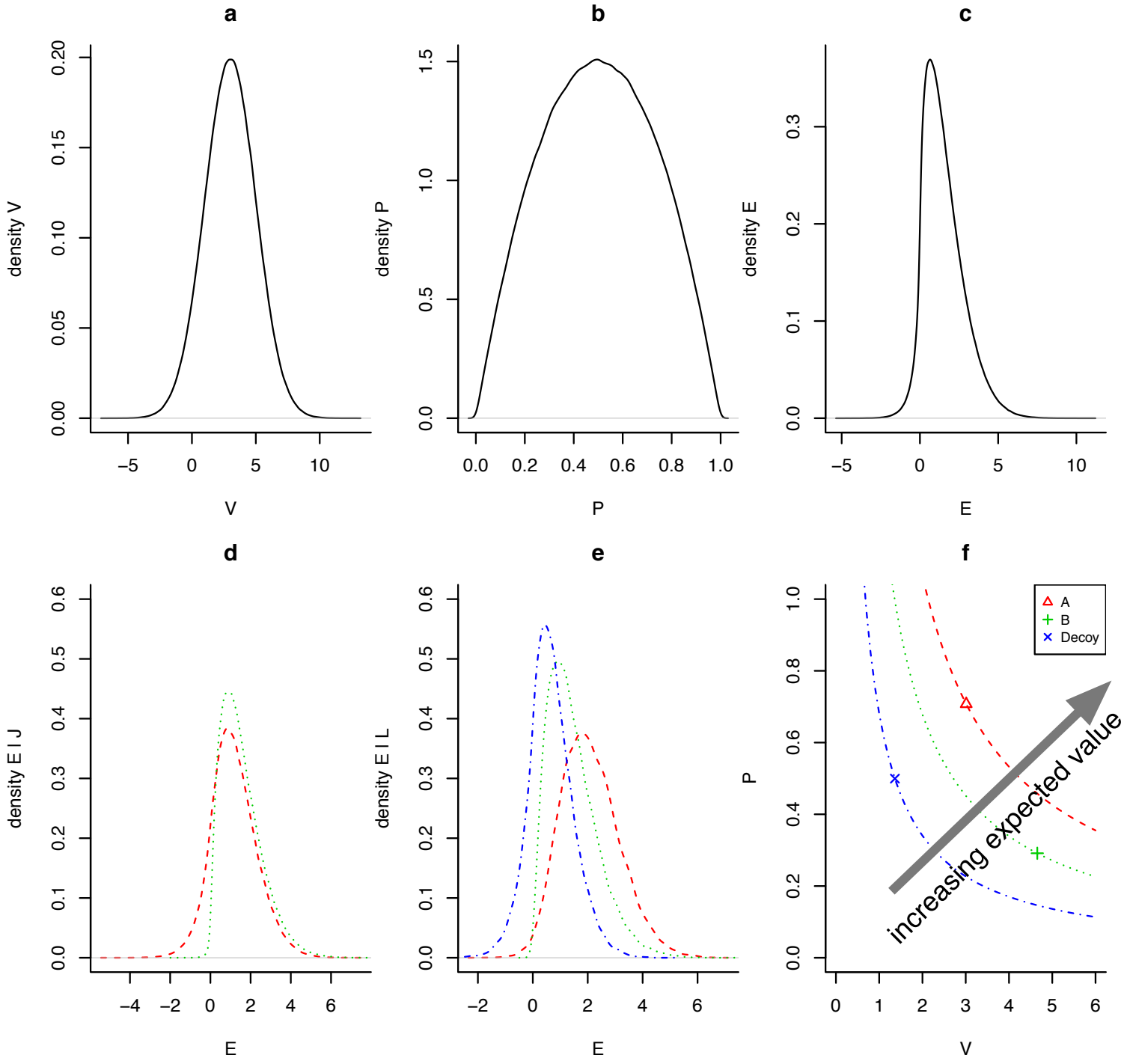

(b)
Actual shift (mm)
Optimal shift (mm)
0
2
4
6
8
TRENDS in Cognitive Sciences

memory… is adapted to needs probability…

Schooler and Anderson (1989)

decision making is adaptive…

Howes et al. (2016)…


a
b
c
density V
density P
density E
V
P
E
d
e
f
density E I J
density E I L
P
E
E
V
A
B
Decoy
increasing expected value

Collaboration is adaptive

Bolton et al. (2004) — collaboration is adaptive.

Figure 1 The Buyer-Seller Encounter

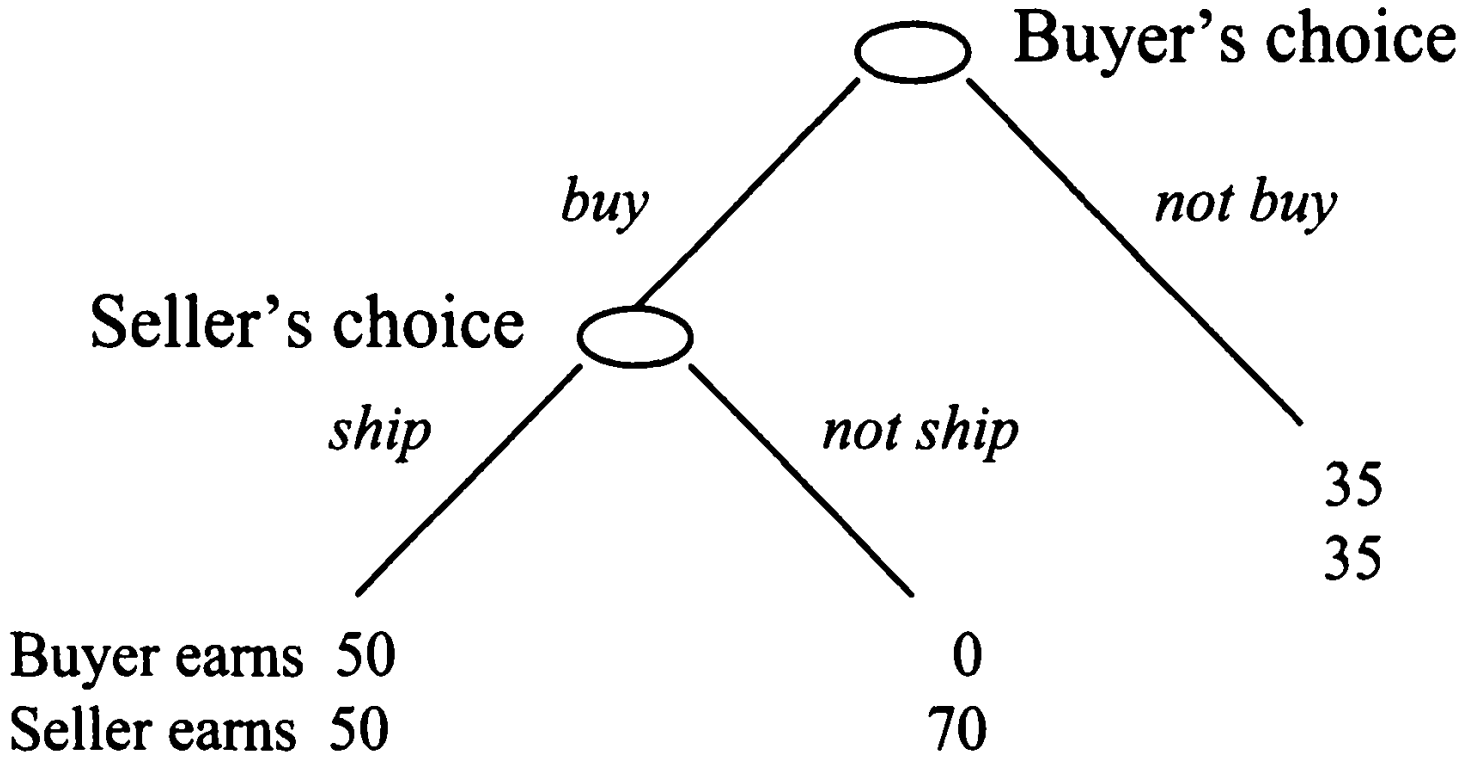
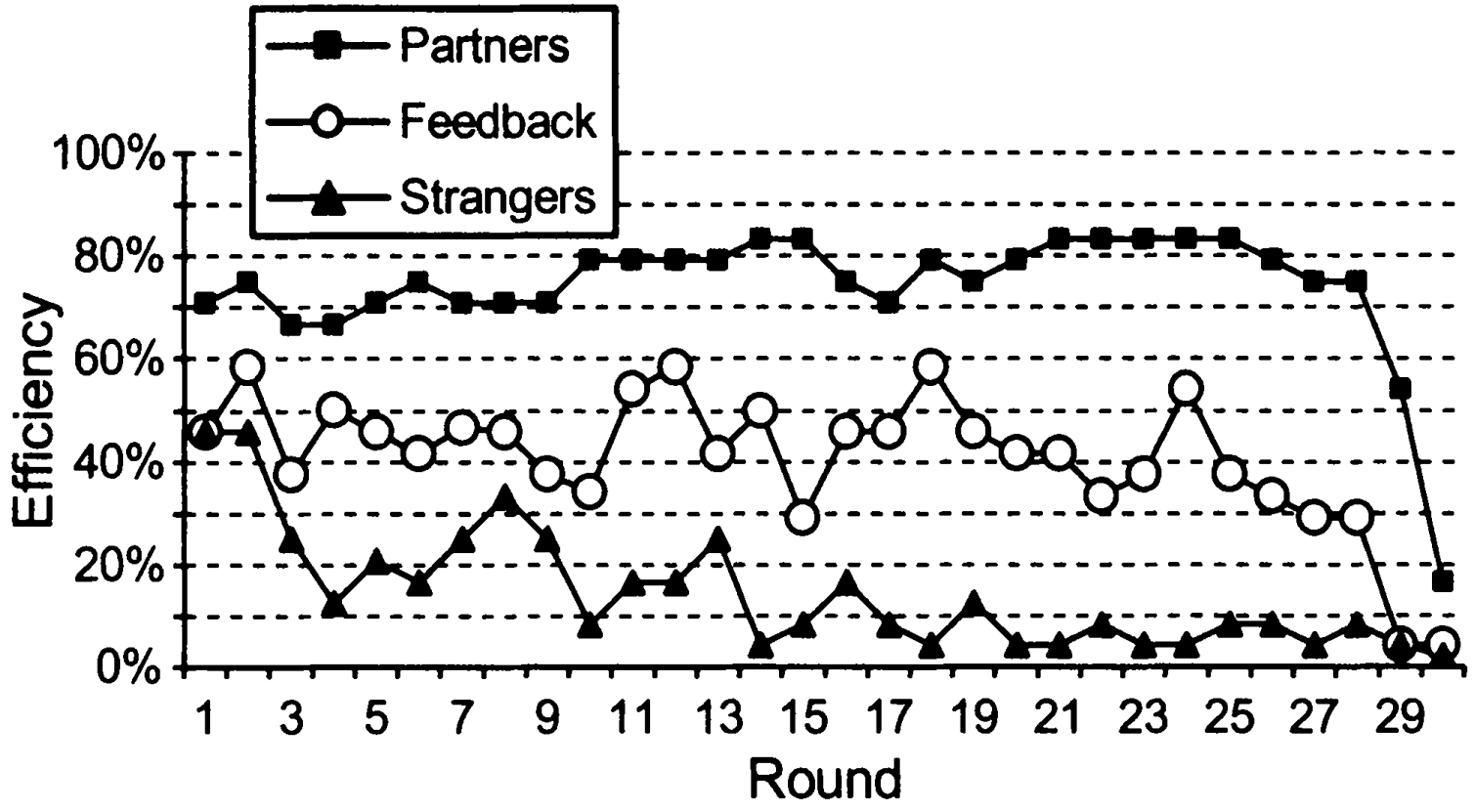


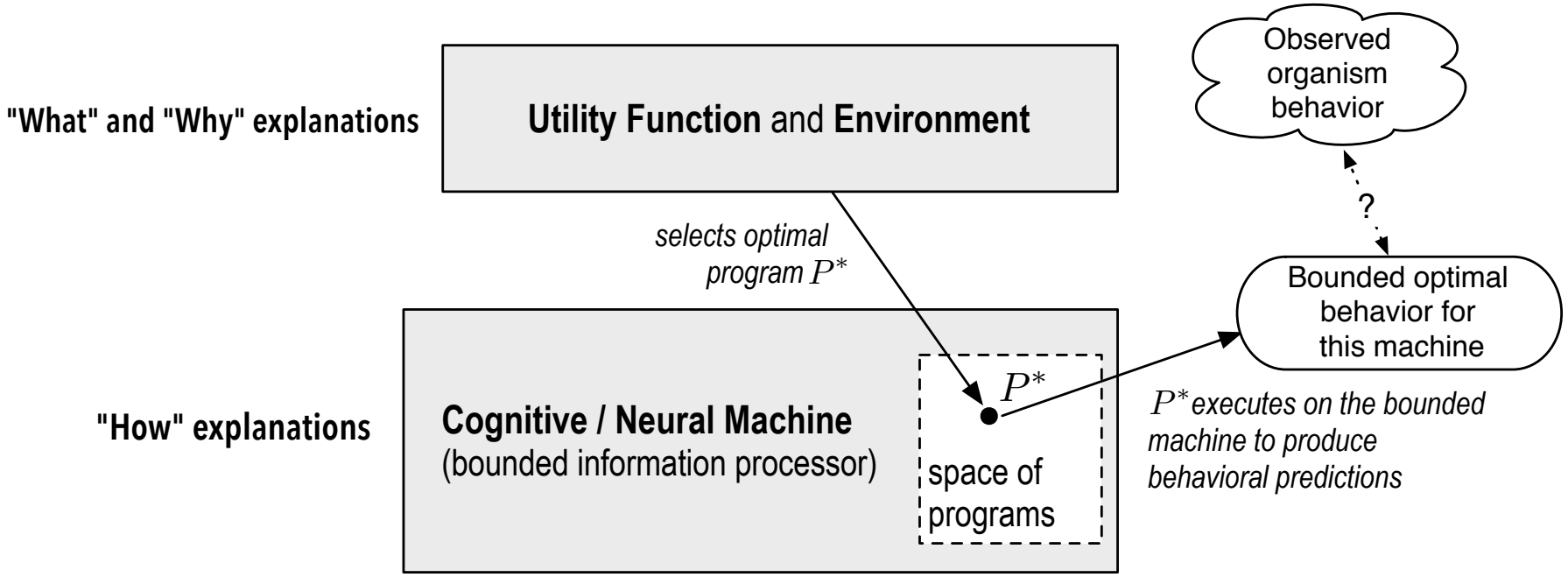
Figure 2 **Efficiency Measured as How Often the Gain from Trade Is Realized, by Round**



Questions:

- What is a good value of epsilon for modeling the human results?
- If epsilon-greedy is what people are doing then why do they not use a more effective learning rate? One which learns faster and reaches a higher plateau?
- What other constraints might be bounding the human performance?
- Is it possible to perform better by changing epsilon during learning?
- What would happen for decks that vary over time?
- Could this model be used to model individual differences?

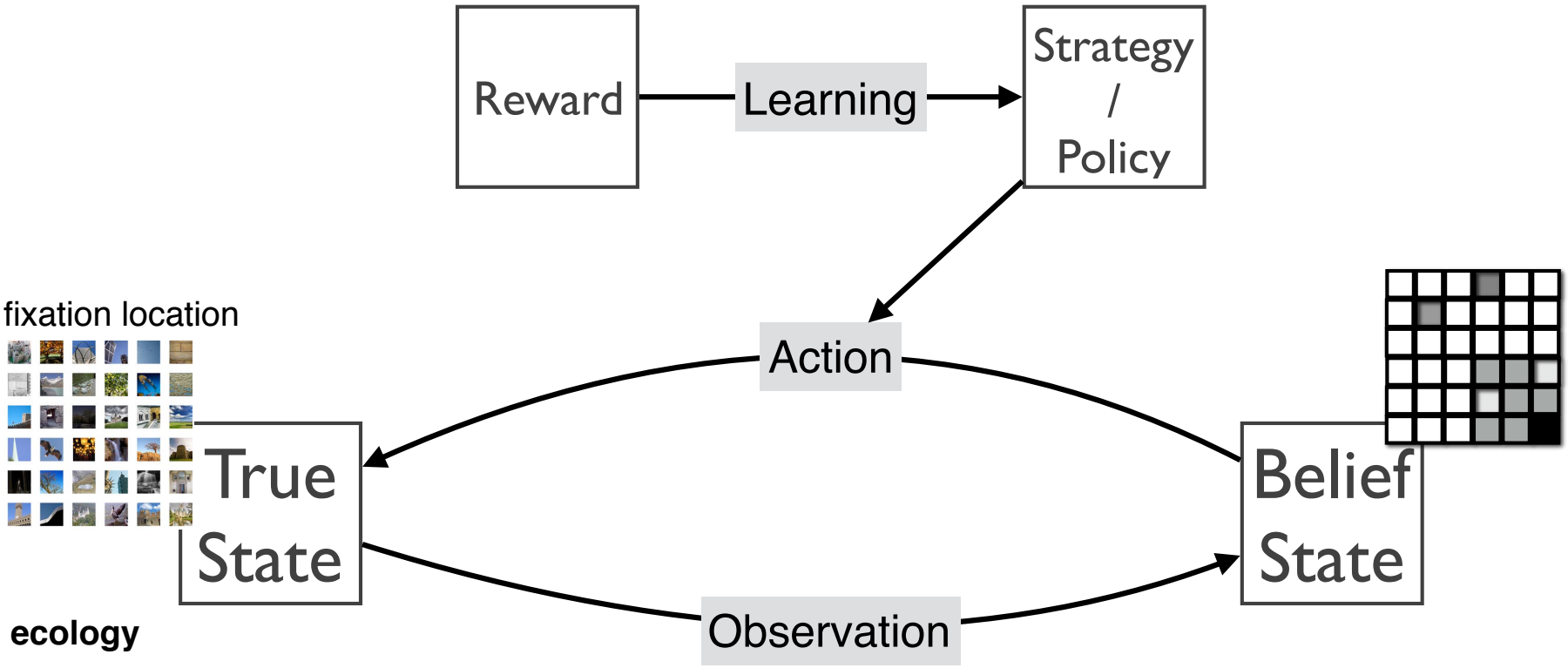
computational rationality



Lewis, R. L., Howes, A., & Singh, S. (2014). Computational Rationality: Linking Mechanism and Behavior Through Bounded Utility Maximization. *Topics in cognitive science, 6*(2), 279-311.

Howes, A., Lewis, R. L., & Vera, A. (2009). Rational adaptation under task and processing constraints: implications for testing theories of cognition and action. *Psychological review, 116*(4), 717.

A POMDP for visual search



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References

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Reading

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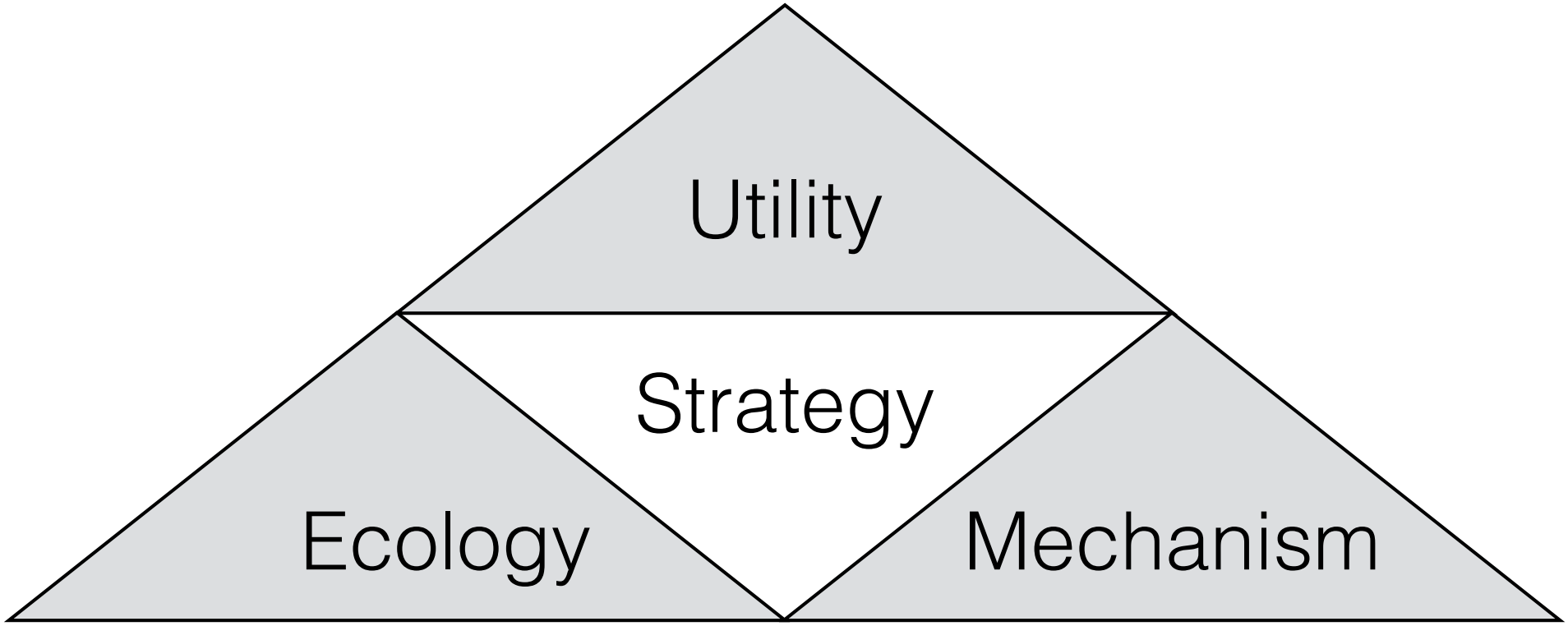
- Lewis, R. L., Howes, A., & Singh, S. (2014). Computational rationality: Linking mechanism and behavior through bounded utility maximization. *Topics in cognitive science, 6*(2), 279-311.

End.

What is a computational model?

- A means of explaining human behaviour.
- Desirable properties:
- Prediction
  - Does not require fitting to what you are predicting.
  - Does not have to be rebuilt for each new design.
- Unambiguous
  - Not open to different interpretation.
  - Independent of the theorist.

Computational rationality



connections

- Control theory for humans (Murray-Smith)
- Probabilistic modeling of text entry (Kristensson)
- Unsupervised learning (Williamson)

- Howes, A., Lewis, R. L., & Vera, A. (2009). Rational adaptation under task and processing constraints: implications for testing theories of cognition and action. ***Psychological review****, 116*(4), 717.

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