Childhood Is Evolution’s Way of Performing Simulated Annealing: A life history perspective on explore-exploit tensions.

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Why Childhood?: Longer Childhood, Bigger Brain, Smarter Animal
Human Brain
Development of Connections (Synapses)

Adapted from P. Huttenlocher et. al. (1979-1997)
THE THEORY THEORY 2.0

Learning Probabilistic Causal Models from Statistical Data

• Gopnik & Wellman, Psychological Bulletin, 2012

• Gopnik, Science, 2012
Unanswered Questions

• How do children learn higher-order causal “framework theory” principles as well as specific causal relationships?
• Are there developmental differences?
• How do children search through all the possible hypotheses?
Inferring Abstract Laws
Lucas, Gopnik & Griffiths, 2014, *Cognition*

- Framework theories
- Hierarchical Bayes-nets (Griffiths & Tenenbaum, 2007)
- The blessing of abstraction (Goodman, 2010)
Which objects are blickets?

Is D a blicket? Is E a blicket? Is F a blicket?
What if you also saw these events?
Which objects are blickets?

Is D a blicket? Is E a blicket? Is F a blicket?
“Or” Training

“And” Training

Test
Functional Form Procedure: “OR” and “AND” Test

Trial

D  D  D  E

D + F  D + E + F  D + F
Functional Form Procedure: “OR” and “AND” Conditions

Which of these should we use to make the machine turn on?

- CIRCLE
- DIAMOND
- BALL

Intervention Question
“BASELINE” Intervention Results:
Percentage of Single vs. Multiple Object Interventions

- **Children:** N = 22
- **Adults:** N = 26
“OR” Intervention Results:
Percentage of Single vs. Multiple Object Interventions

Children: N = 25
Adults: N = 28
“AND” Intervention Results:
Percentage of Single vs. Multiple Object Interventions

**
Intervention Choices for 6- and 7-year-olds: “AND” Condition

- One Multiple
  - 4- and 5-year-olds (N = 25)
  - 6- and 7-year-olds (N = 24)
  - Adults (N = 28)
When Younger Learners Do Better Than Older Ones

• Learning traits versus situations as causes for action (Seiver et al. *Child Development*, 2013.)


• Learning multiple uses for a tool, Defeyter and German, 2003

• Learning non-native speech contrasts, Kuhl. Werker
Disadvantages of Frontal Control

• Thompson-Schill et al., 2009
Why the developmental differences?
Two Possibilities

Gopnik, Lucas, & Griffiths, *Current Directions in Psychological Science* (In press).
Different Accumulated Knowledge

• Learned prior for “OR” or “Traits” leads to bias
Different types of search and sampling

• Sampling as a solution to the search problem in computer science: Markov Chain Monte Carlo, Particle Filters

• Sampling in adults: Vul & Pashler, 2008
Sampling in Cognitive Development


Exploitation vs. Exploration

Low-temperature search
Quick to settle on high-probability answer
May miss low-probability answer

High-temperature search
Slow to settle on high-probability answer
More likely to find low-probability answer
Experimentation, Exploration and Explanation
Simulated Annealing

• Early High-Temperature Search followed by later Low-Temperature Search
Conclusion

Childhood is evolution’s way of performing simulated annealing.
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- Elizabeth Seiver
- Noah Goodman

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