Nativism, Empiricism, and Cognitive Development

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Warm up for the “Origins of Knowledge” Debate
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Critical Questions

• Where does knowledge about the world come from?

• Is there enough information in the input to guarantee stable and veridical representation of the input?

• What are the basic “building blocks” or elements of cognition?

• And where do more general categories come from?
  ▪ Things, events, and properties
  ▪ Number, space, and time
Where do the objects come from?

• How do we recover objects in cluttered visual scenes?
• How do we segregate overlapping objects?
• How do we establish continuity and coherence of occluded objects?
• How do we individuate and enumerate objects?
These questions have more than 2000 years of intellectual history

• Plato and Aristotle

• Empiricists and Rationalists

• Associationism and Gestalt Psychology

• Piaget and Chomsky

• More recent debates…. 
Possibility 1. Innate Knowledge

- Input is too underconstrained and compatible with multiple hypotheses. Yet people somehow converge on the same set of hypotheses.

- Therefore, there must be some a priori domain-specific knowledge (constraints, assumptions, beliefs or biases) on what is possible and what is not.
Possibility 2. Rich Input – Powerful Learning Mechanisms

- The argument that input is impoverished has little empirical value (psychologists, philosophers, and linguists have done very little to actually analyze the input)

- There is no need to postulate innate knowledge: Rich input and powerful learning mechanisms may yield stable and coherent knowledge
Historical Arguments for Innate Knowledge

• There is not enough information in the input. Therefore, input alone cannot guarantee stable coherent knowledge. Structure has to come from within.
Example 1: Wasserman’s Study

Training
Wasserman’s Study

Training
Wasserman’s Study

Testing
Wasserman’s Study

Testing
Wasserman’s Study

Testing
Humans

Pigeons
Example 2: Quinn’s Study

- 3-4 month-old young infants can easily learn a category of cats that excludes dogs, but not of dogs that excludes cats.
FAMILIARIZATION

Cat 1 vs. Cat 2
Cat 3 vs. Cat 4
... 
Cat 11 vs. Cat 12

TEST

Dog 14  Cat 14

FAMILIARIZATION

Dog 1 vs. Dog 2
Dog 3 vs. Dog 4
... 
Dog 11 vs. Dog 12

TEST

Dog 14  Cat 14
• So there is structure in the input

• And structure matters for learning!

• Therefore, one cannot make a “not enough information” argument without systematically analyzing the input.
Historical Arguments

• There is not enough information in the input.

• Evolution favors quick start of important cognitive functions.
It is not the strongest
of the species that
survives, nor the most
intelligent that
survives. It is the one
that is the most
adaptable to change.

Charles Darwin
Historical Arguments

• There is not enough information in the input.

• Evolution favors quick start of important cognitive functions.

• Analytic knowledge

• Absence of a precise learning account of some core competencies
Both positions are plausible

- None of the positions could be eliminated on the basis of a priori arguments
- Both positions are internally consistent
- And therefore the debate has to be solved empirically
- The study of cognitive development may generate important empirical arguments
What is at stake now?

• No one advocates pure genetic determinism or pure tabula rasa possibility.

• Also, no one disputes the role of genes or the role of learning.

• So what is advocated by nativism and empiricism today?
Nativism in Cognitive Development

• Hardwired rather than learned representations in some “core” domains (object, number, space, actions, and social partners)

• Dedicated input analyzers in these domains

• Early onset of competence in core domains
What might be the case for nativism?

- Experimental or correlational genetic evidence?
- Precise models of how genes could code for core knowledge?
- Precocious infants?
Is there a problem with the “precocious infant” argument?

- Little information about the mechanism
- Inability to solve the grounding problem
How will one recognize innate ideas in a messy input?

- Suppose that knowledge of numbers (or objects) is innate

- How does one map contrast and color (retinal information) onto abstract notions of set cardinality?

- Grounding problem is an exact inverse (and is no easier to solve) than the abstraction problem
Is there a problem with the “precocious infant” argument?

• Little information about the mechanism
• Inability to solve the grounding problem
• Impossibility to reach a firm conclusion that knowledge in question is not learned
  ◆ 3.5 month-old has 800 hours of waking time, which is 48,000 minutes, 3 mil seconds and 3-6 mil eye movements
• Demonstration rather than explanation. Open for alternative interpretations
Three Examples

• Object
• Number
• Space
Case 1: Objects

Kellman & Spelke (1983): 4-month-olds look longer at the broken rod
What about neonates?

Slater et al (1996): Neonates look longer at the complete rod
And 2-month-olds?

Johnson & Aslin, 1996; Johnson, 2004: 2-month-olds succeeded only in the easy condition, but not in the difficult condition.
Moral

• Object perception clearly exhibits development

• While it is possible to come up with a innate account, there is no need to

• Initially object perception requires support from multiple features: the size of the gap, edge alignment, and common motion
Case 2: Number

Wynn (1992): 5-month-olds look longer at the impossible outcome
Case 2: Number

Clearfield & Mix (1999): 6.5-month-olds relied on contour lengths, not on number.
But there is more! Many other continuous variables correlate with the number

- Contour Length
- Surface Area or Volume
- Density
- Spatial Frequency
- Timing

In fact, Mix et al (2002) did not find a single study that controlled all these cues!
Moral

• Similar to object perception, number may require support from multiple features: mass, spatial extent, density, spatial frequency, and time.
Case 3: Space

Hermer & Spelke, 1996: Geometric Module?
Adding a distinct landmark did not help

Spelke: Encapsulated geometric module
Questioning the modularity

Cheng & Newcombe (2005)

No use of landmarks

Use of landmarks
Orientation without geometry?

Toddlers Succeed

Toddlers fail

Huttenlocher and Lourenco (2007)
Lessons from the 3 case studies

- There was little support for nativism
- What is more important, in all these cases, participants were successful when “deep” features were supported by surface features.
Are there alternatives to nativism?

- Nativism seeks to uncover how “deep” features (e.g., objects, numbers, etc.) are detected despite “surface” variance.
- In contrast, alternatives seek to uncover how perceptual “surface features” may support the detection of “deep features.”
- One idea is that coherent co-variation of surface and deep features is the key.
Distinct Asynchronously Developing Learning Systems?

- The cortico-striatal system (early onset) exploits coherent co-variation and it is based on “compression”
- The Frontal-MTL (late onset) system is based on “selection” and does not need coherent co-variation
Adapted from Ashby, et al, 1998
Coherently co-varying structures can be learned spontaneously by a compression-based system.
Structures lacking coherent co-variation require the involvement of a selection-based system.
Distinct Systems of Learning?
## Properties of the Systems

<table>
<thead>
<tr>
<th>Compression-based System</th>
<th>Selection-based System</th>
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<tbody>
<tr>
<td>Is based on many to one cortico-striatal projections</td>
<td>Depends critically on the prefrontal cortex</td>
</tr>
<tr>
<td>Exploits massive statistical redundancy in the input</td>
<td>Enables focusing on few highly predictive and regular dimensions</td>
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<td>Supports non-deliberate, implicit learning</td>
<td>Supports more deliberate, explicit learning</td>
</tr>
<tr>
<td>May not require error-signal</td>
<td>Depends critically on error-signal</td>
</tr>
<tr>
<td>Exhibits early onset and is likely to be present across a variety of species</td>
<td>Exhibits late onset and is likely to be present in species with relatively developed prefrontal cortex</td>
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<td>“Chokes up” when there is massive irrelevant variance in the input</td>
<td>Can resist irrelevant variance in the input</td>
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Developmental Asynchrony of the Compression-based and Selection-based systems

- Prefrontal Cortex (PFC) critical for the selection-based system comes on-line relatively late
- It exhibits the slowest maturational course, with some structures not reaching maturity until the late adolescence
Rostrolateral cortex – exhibits immaturity even at 8-11 years of age.
A mechanism of early learning?

• The most critical components of the selection-based system are immature early in development

• Therefore, learning by compression seems like a good candidate for a mechanism of early learning

• The compression-based system is good at extracting patterns of co-variation
Early learning by compression

Evidence from successes and failures of infant learning
Successes and failures of infant category learning

• Participants: 8- and 12-month-olds

• Category learning task
Overview of the Paradigm

Test_4

......

Test_1

......

Fam_1

......

Fam_2

......

Fam_1

Time
Dense Category

Training Items
Sparse Category

Training Items
Testing Pair
Results

• Attention optimization scores were calculated for each trial

\[
\text{(Looking to relevant features/M – irrelevant features/N)} \frac{\text{Total looking (relevant + irrelevant)/M+N}}
\]

• Values > 0 indicate more looking to relevant and values < 0 indicate more looking to irrelevant.
Attention Optimization: Dense Category

Attention Optimization: Sparse Category

Novelty Preference

Proportion Looking to Novel

Dense | Sparse
Learning succeeded only when there was coherent co-variation, but failed otherwise.
Success and failures of infant learning of complex contingencies
Multiple Correlations Condition
Participants:
12- and 14-month old infants

60 sec of accumulated looking

60 sec of accumulated looking
Test Phase

30 sec of accumulated looking per test item

Testing: Context 1

Testing: Context 2

Same

Switch

New
Infants Succeed

Looking Time (Msec)

- Same: 11500
- Switch: 15000
- New: 15500
Reduced Number of Correlations
Familiarization

Participants:
12- and 14-month old infants

Context 1

60 sec of accumulated looking

Context 2

60 sec of accumulated looking
Infants Fail

Looking Time (Msec)

- Same: 11500
- Switch: 11350
- New: 15000
Similar to category learning, infants succeeded only when there was “coherent co-variation” in the input.
Can infant learn unobservables?

• Yes, but only if there is enough support from co-varying perceptible features.

• The ability to focus on abstract features while ignoring surface variance requires selectivity and inhibitory control that develops well into preschool years.

• But I do not have time to talk about it today.
So, where do we stand?

• Previous 2000 years failed to resolve the debate

• The 70 years of molecular genetics brought surprisingly little evidence favoring nativism

• There is little support for nativism in cognitive and infant development research

• I hope that advances in neuroscience, developmental science, animal learning, computational modeling, and robotics will favor the learning account of the origins of knowledge

• Is nativism going extinct?
Thank you!