Nativism, Empiricism, and Cognitive Development

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Warm up for the “Origins of Knowledge” Debate
April 2010

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)

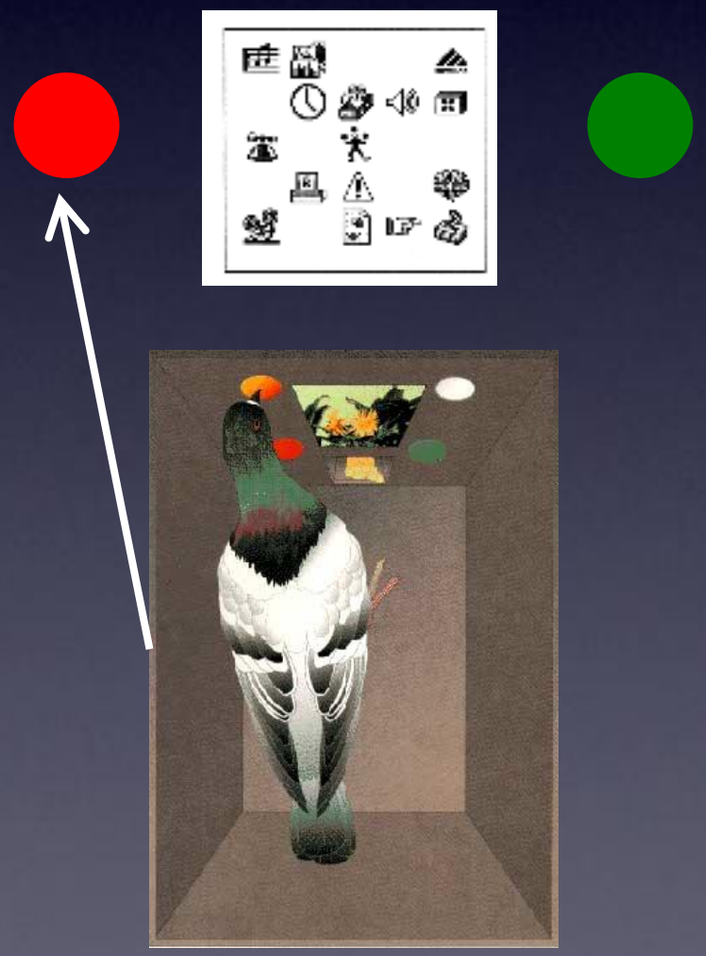
- There is no need to postulate innate knowledge: Rich input and powerful learning mechanisms may yield stable and coherent knowledge

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.

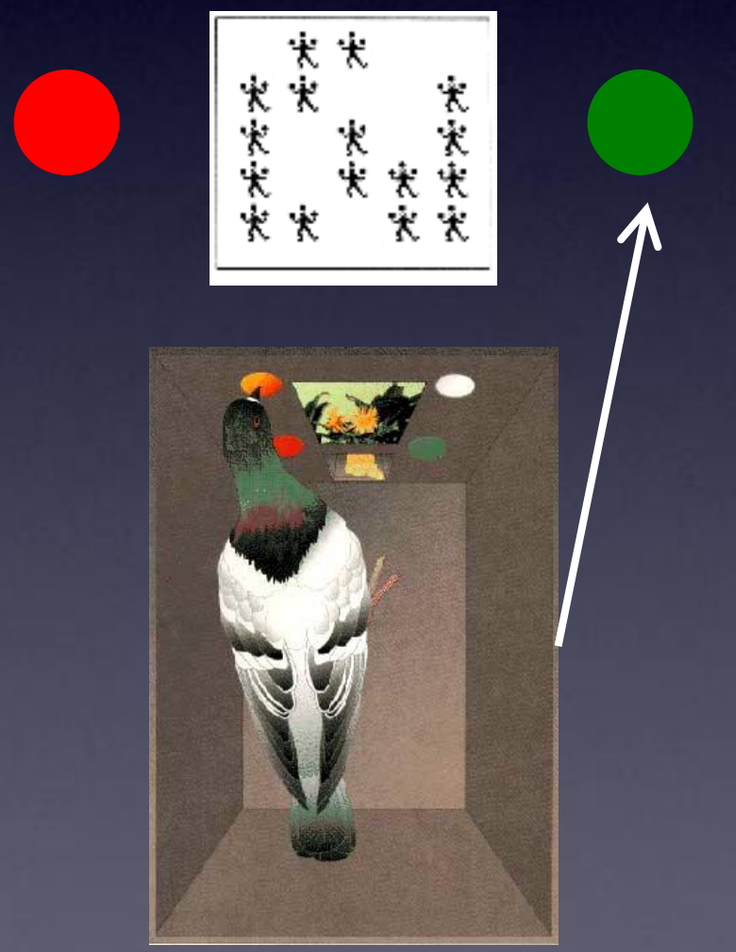
Example 1: Wasserman's Study

Training



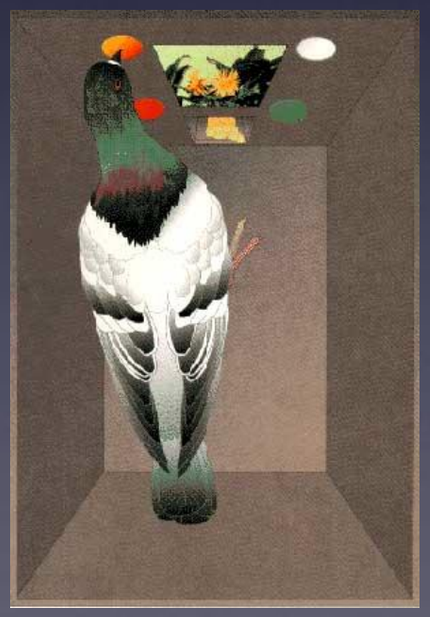
Wasserman’s Study

Training



Wasserman’s Study

Testing



Wasserman’s Study

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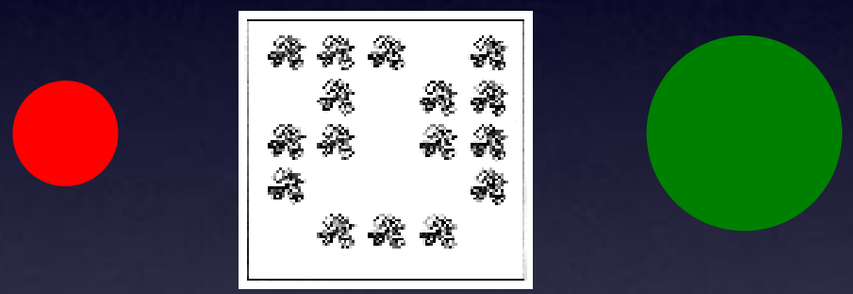
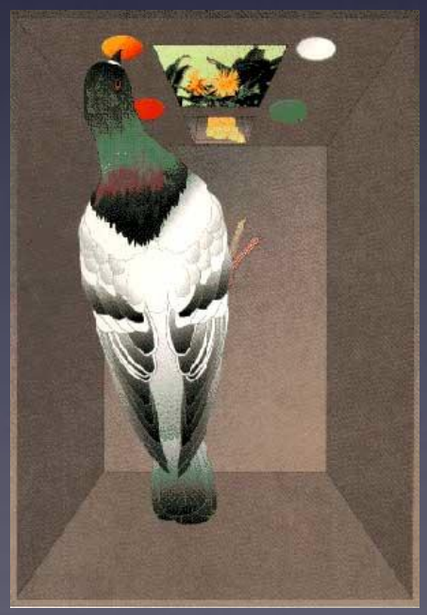
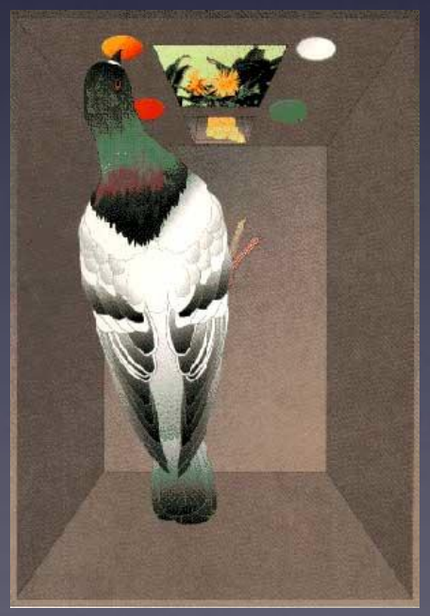




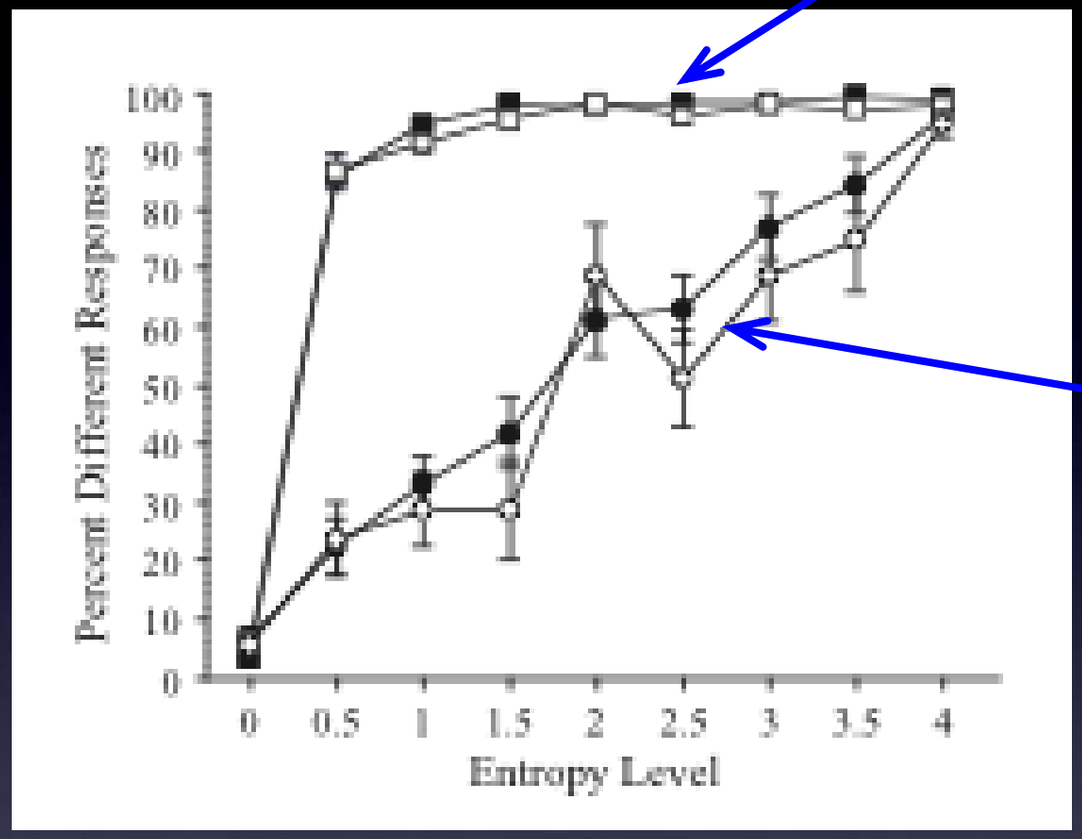
Wasserman’s Study

Testing



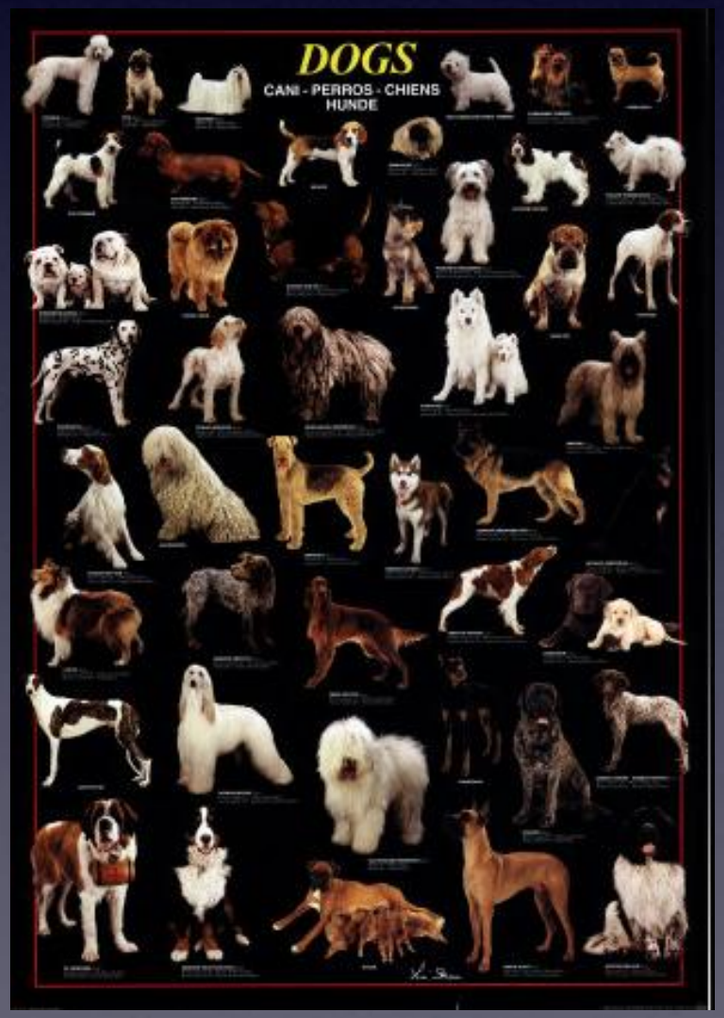
Humans

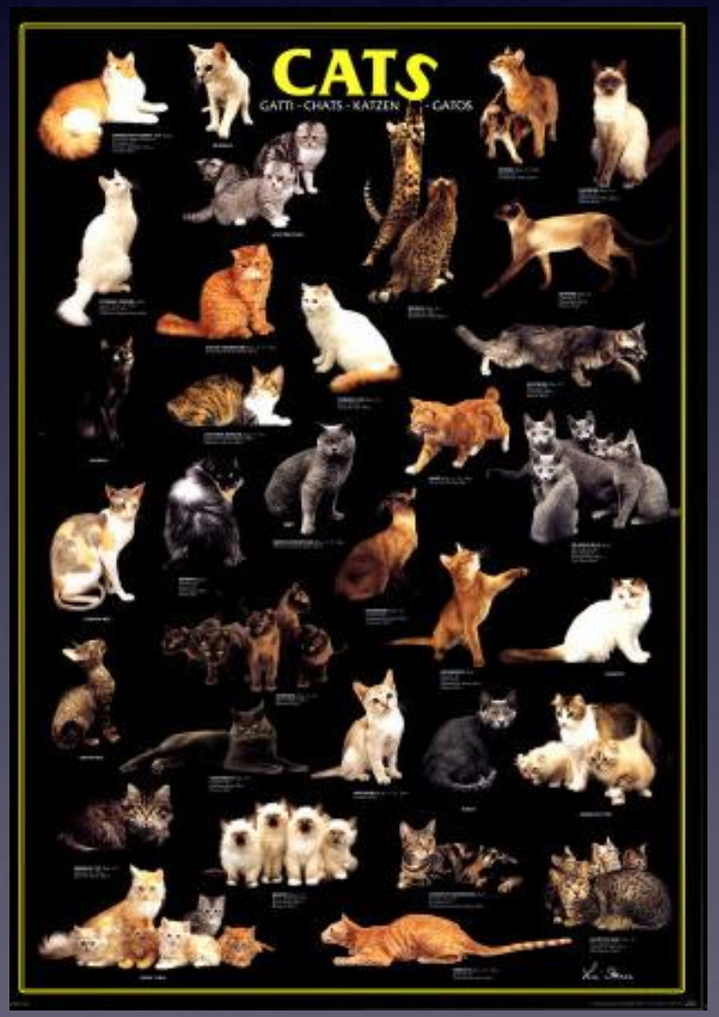
Pigeons



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

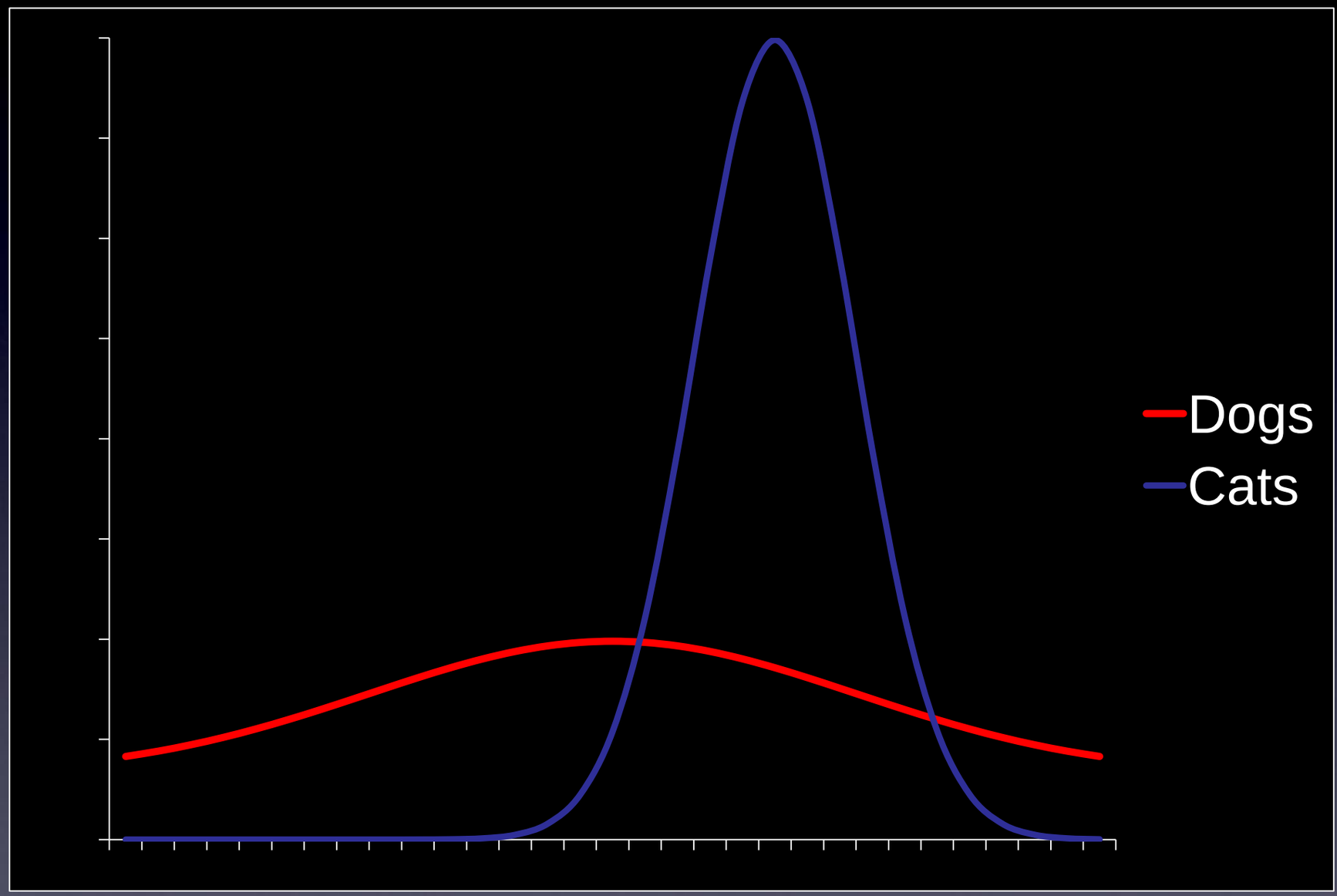
…

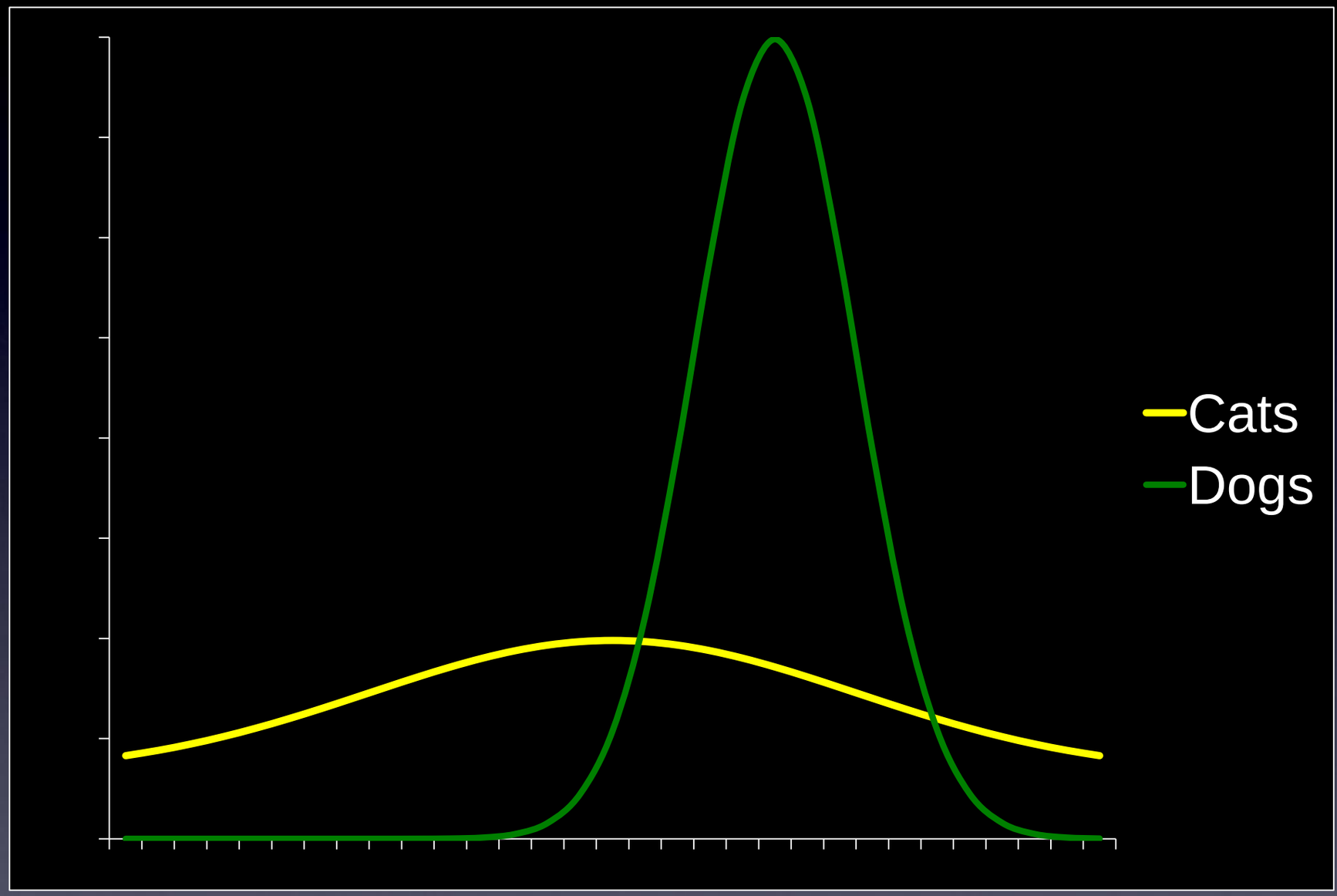
Dog 11 vs. Dog 12

TEST

Dog 14

Cat 14


Dogs
Cats


Cats
Dogs

- 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

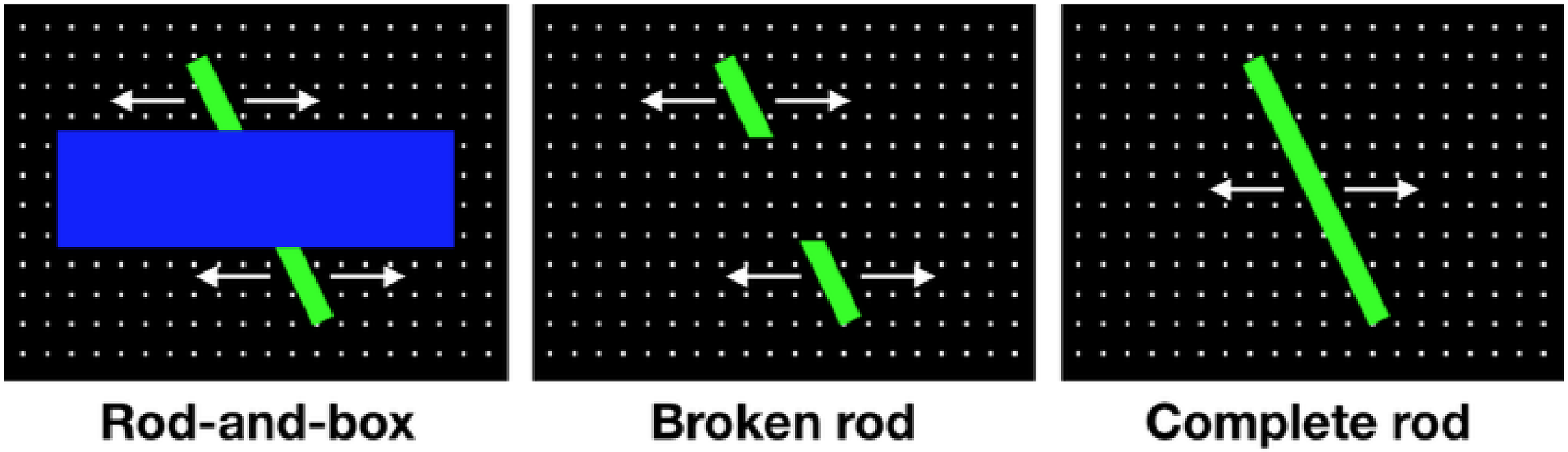
Is there a problem with the “precocious infant” argument?

- 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

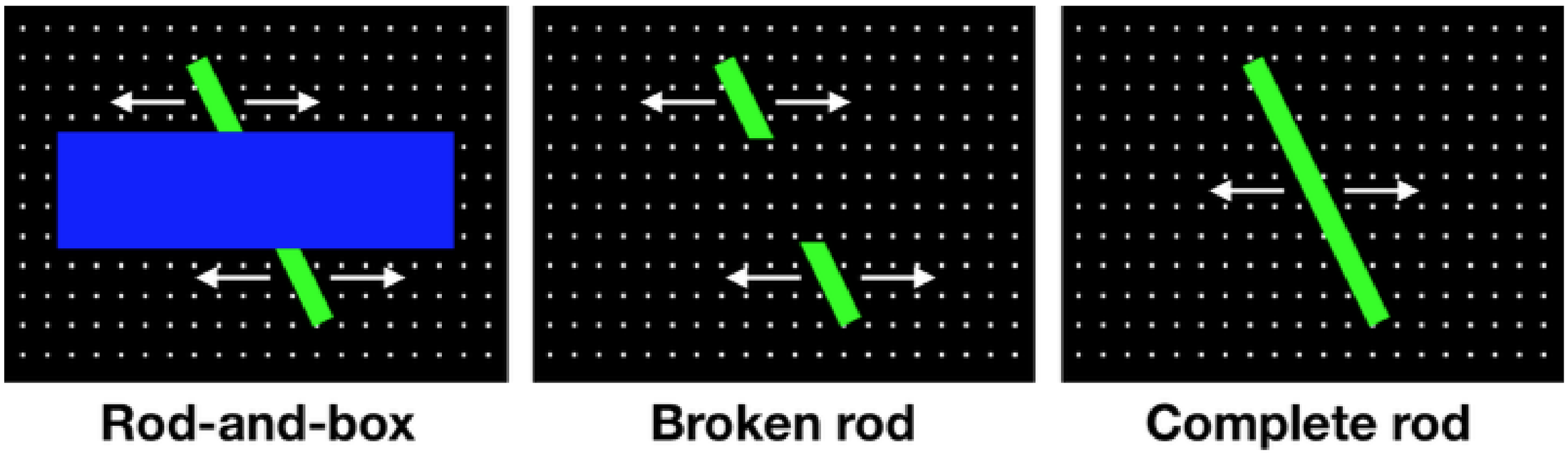
- Object
- Number
- Space

Case 1: Objects



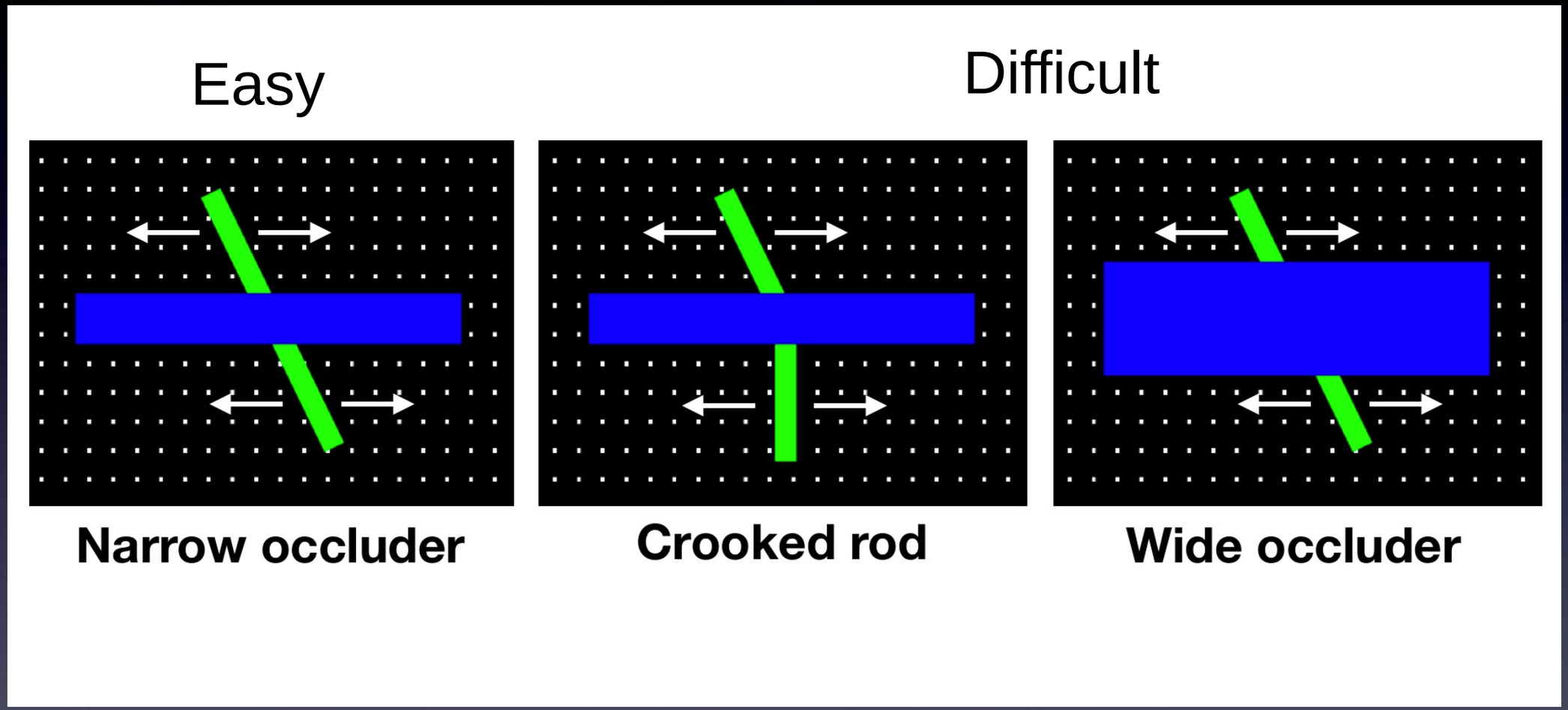
Kellman & Spelke (1983): 4-month-olds look longer at the broken rod

What about neonates?



Slater et al (1996): Neonates look longer at the complete rod

And 2-month-olds?



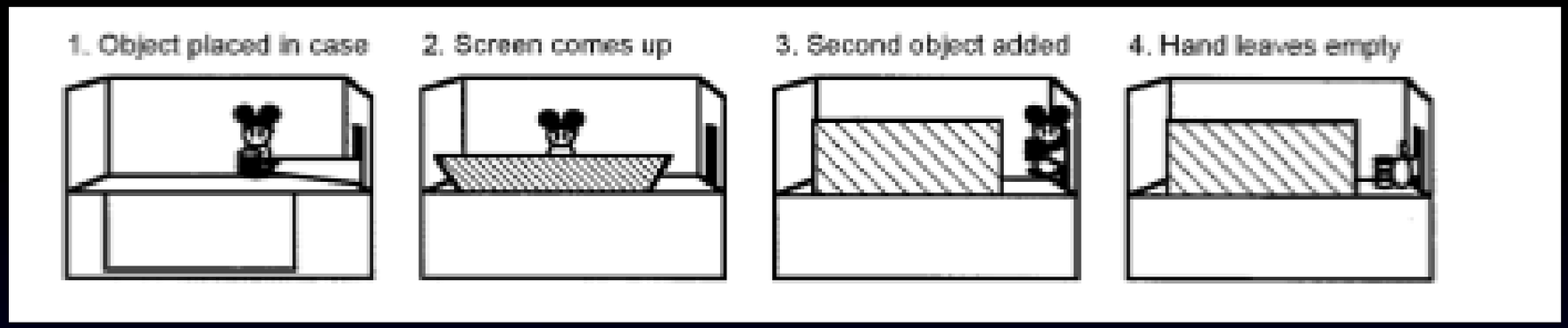
Johnson & Aslin, 1996; Johnson, 2004: 2-month-olds succeeded only in the easy condition, but not in the difficult condition

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

Training



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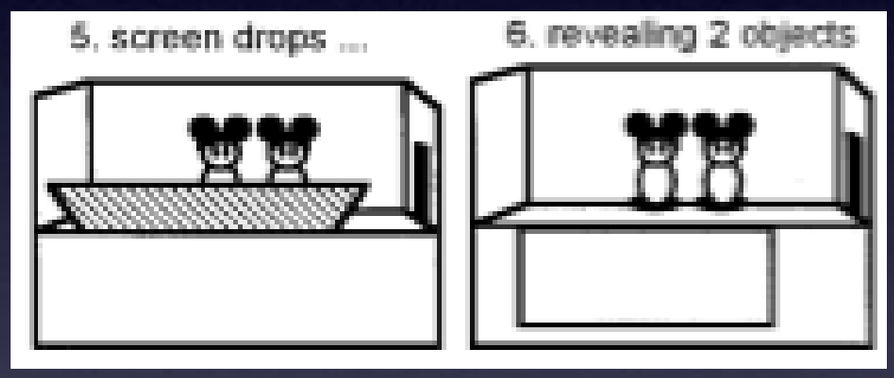
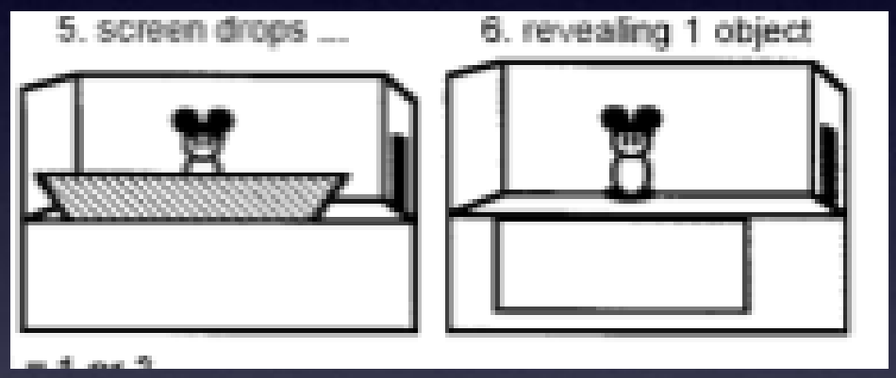


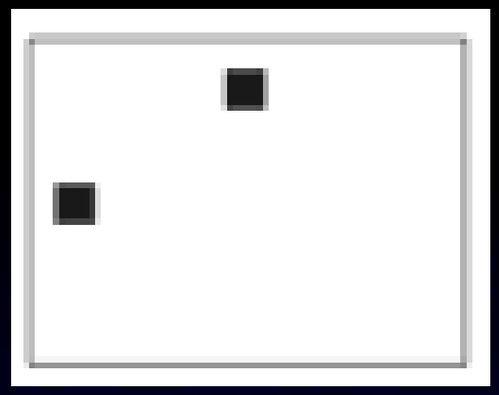


Possible Outcome Impossible Outcome

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

Case 2: Number

Training



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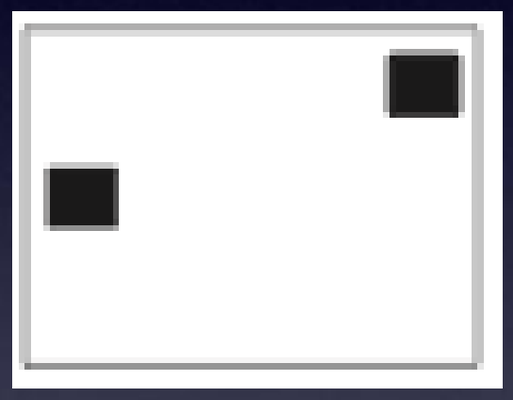
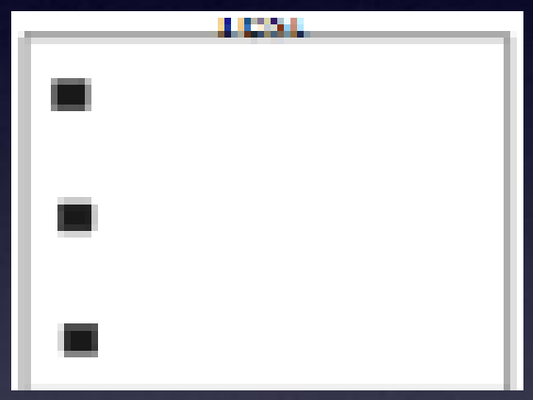




Same Number

Same Contour Length

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

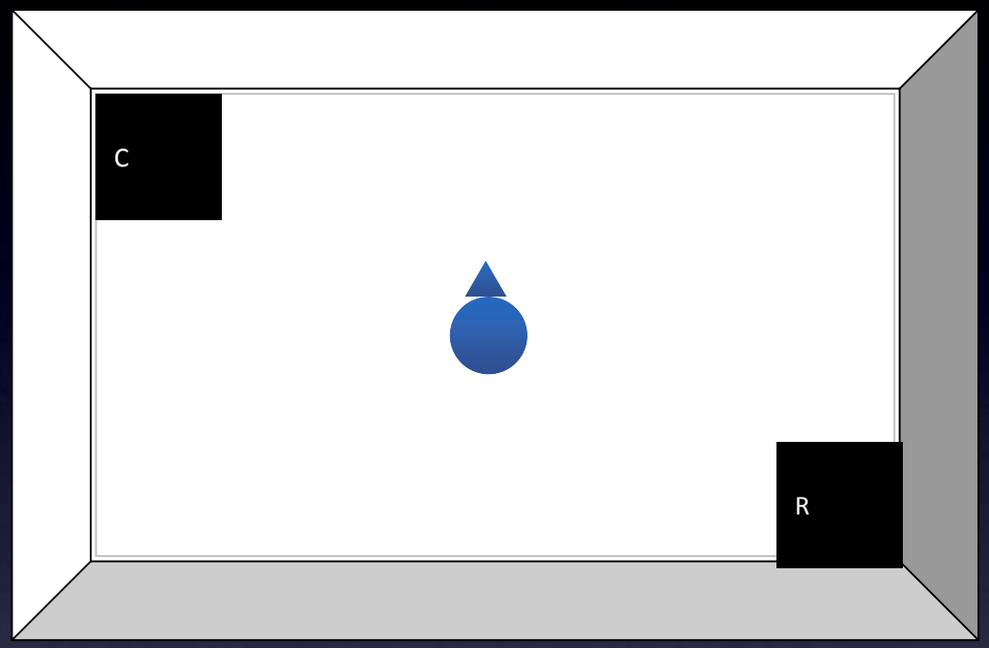
In fact, Mix et al (2002) did not find a single study that controlled all these cues!

Moral

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

Case 3: Space

40%

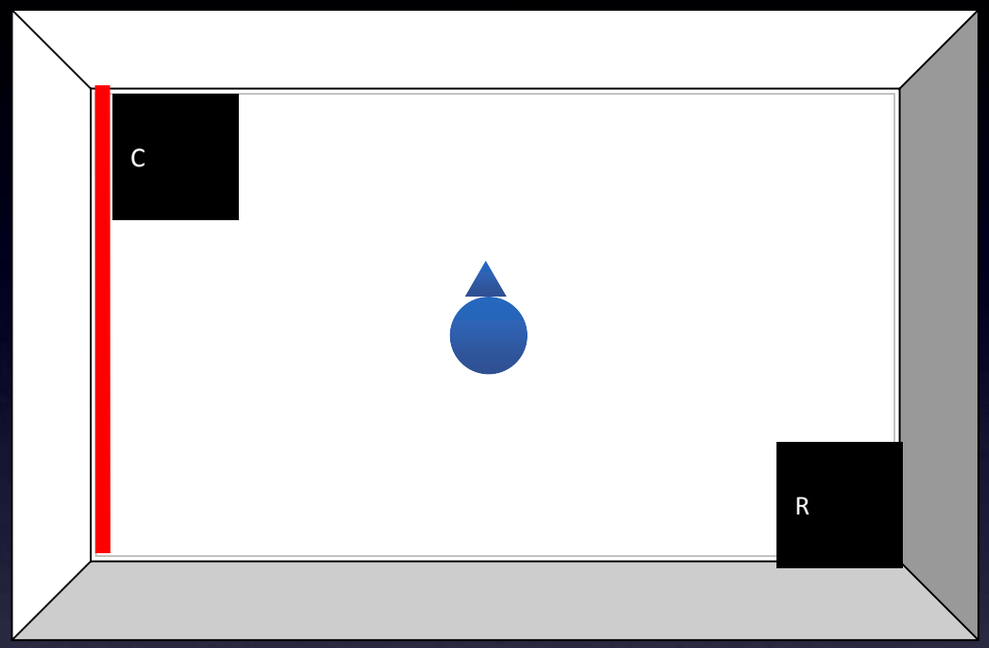


40%

Hermer & Spelke, 1996: Geometric Module?

Adding a distinct landmark did not help

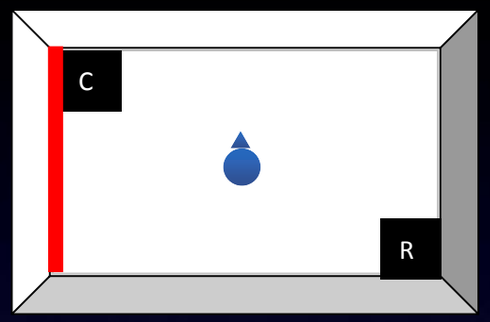
40%



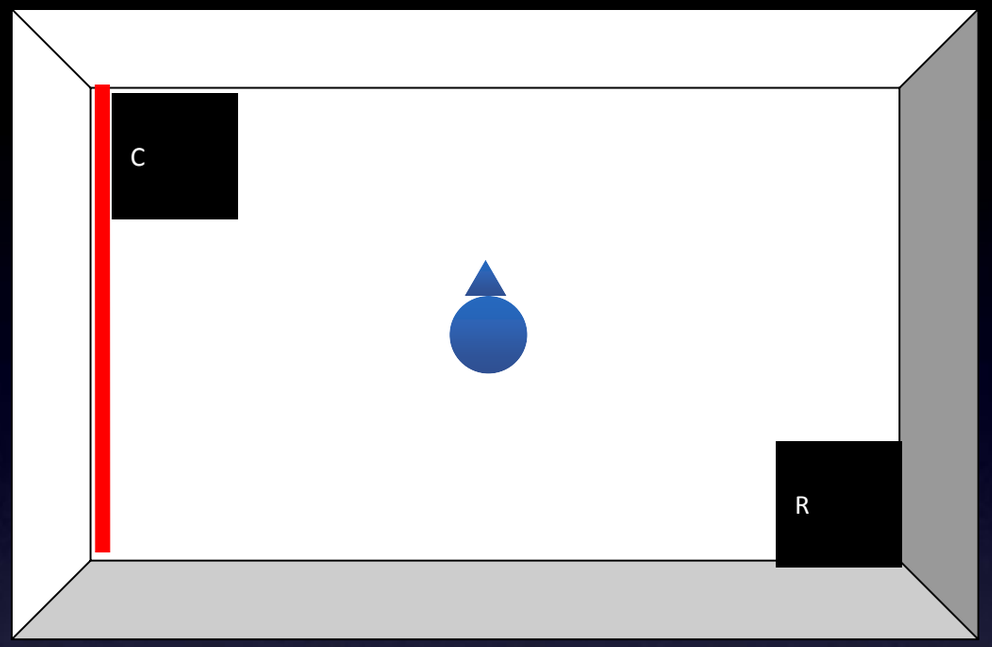
40%

Spelke: Encapsulated geometric module

Questioning the modularity



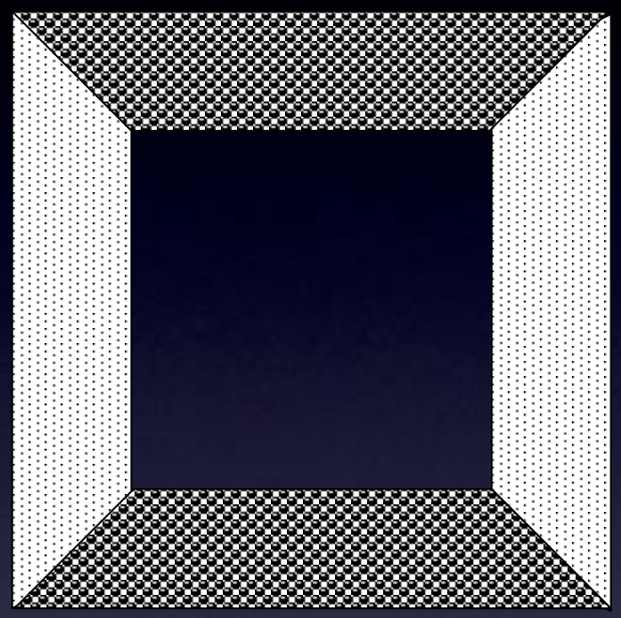
No use of landmarks



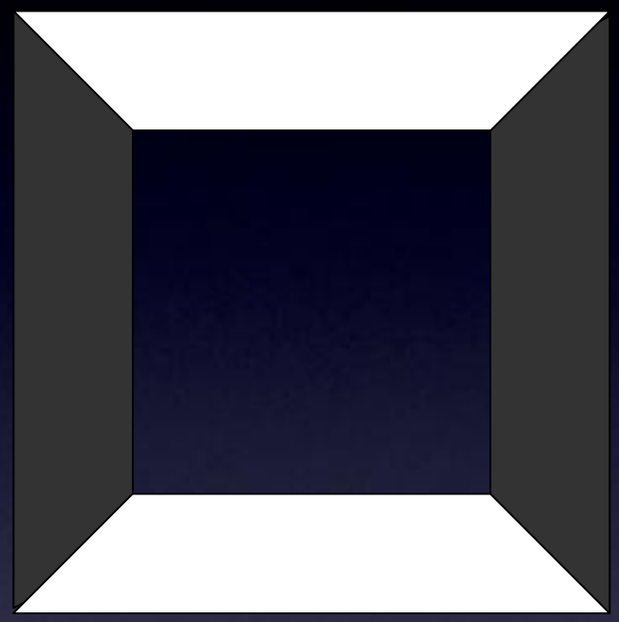
Use of landmarks

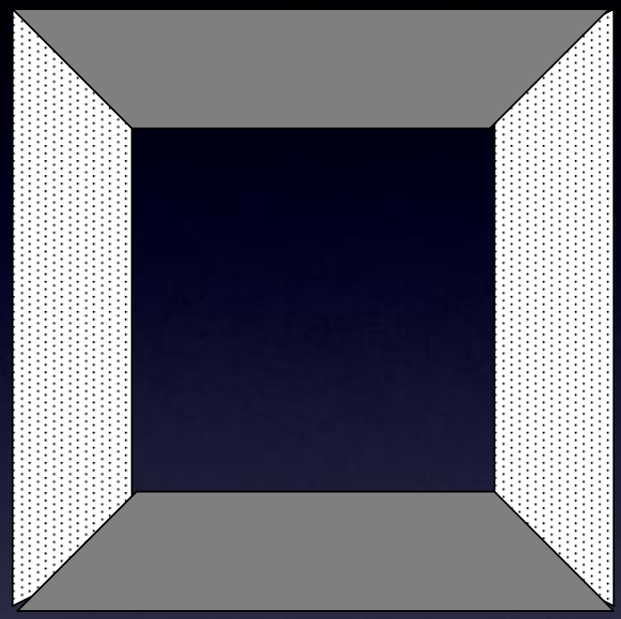
Cheng & Newcombe (2005)

Orientation without geometry?



Toddlers Succeed





Toddlers fail

Huttenlocher and Lourenco (2007)

Lessons from the 3 case studies

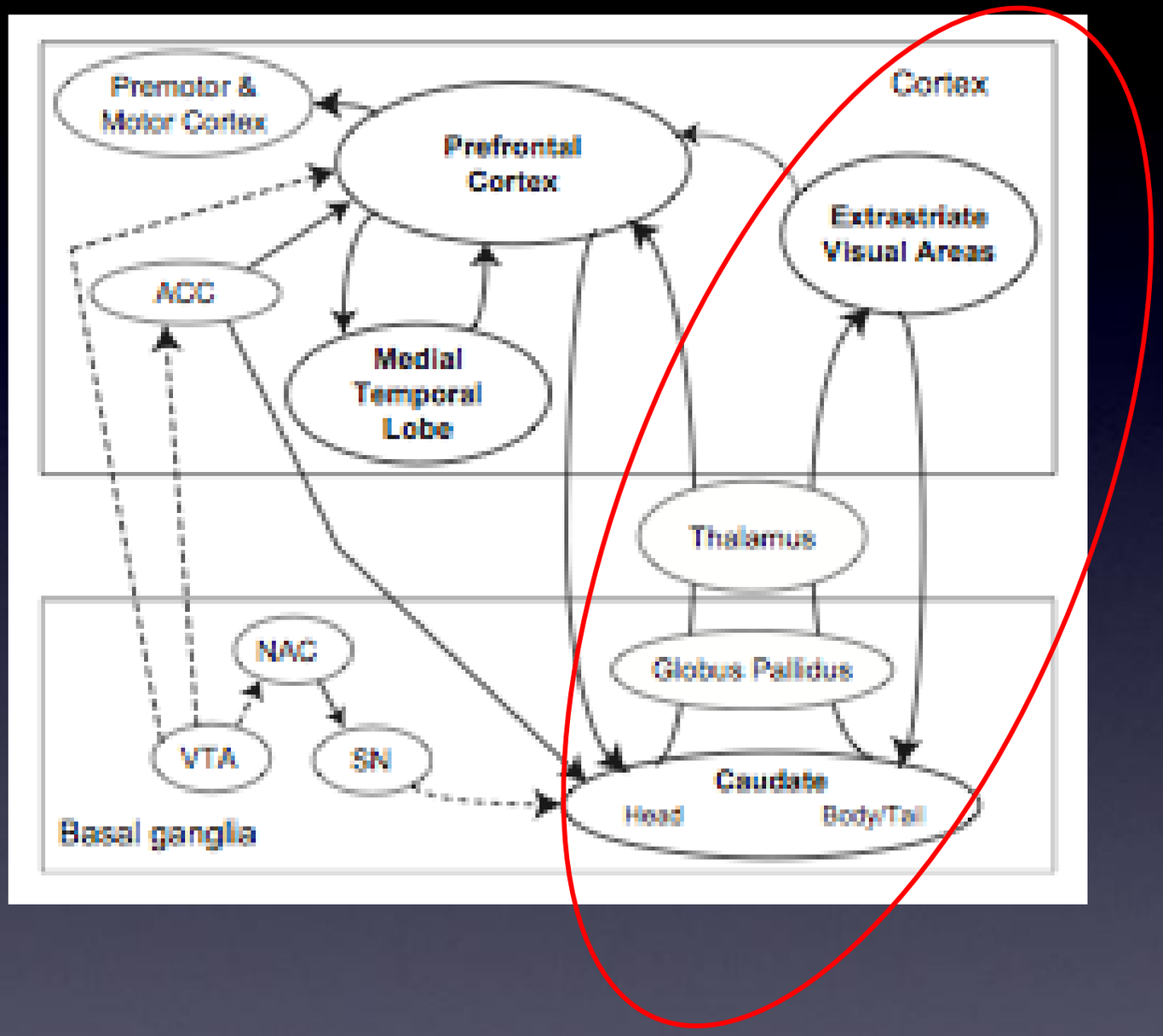
- There was little support for nativism
- What is more important, in all these cases, participants were successful when “deep” features were supported by surface features.

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.

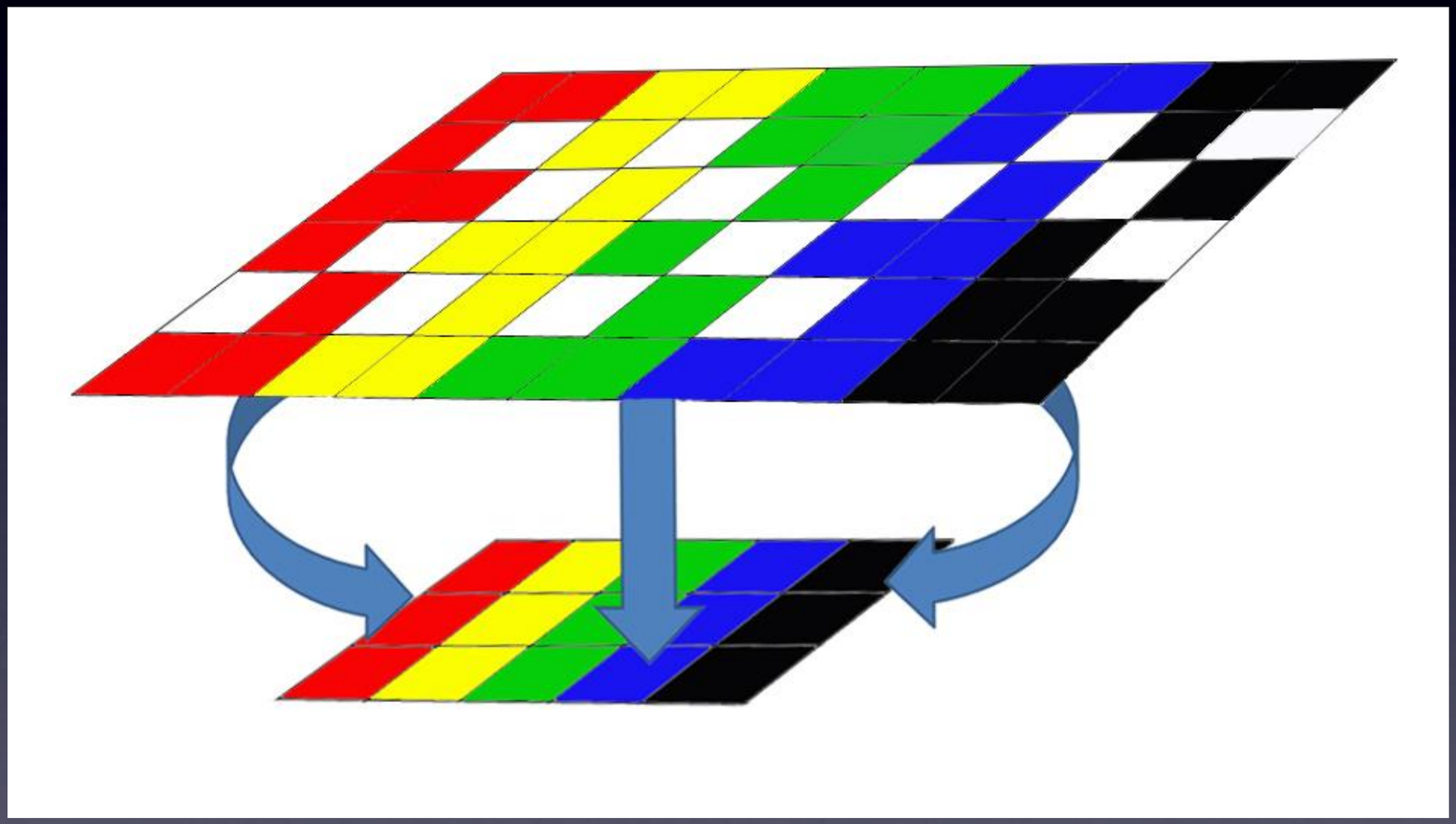
Distinct Asynchronously Developing Learning Systems?

- The cortico-striatal system (early onset) exploits coherent co-variation and it based on “compression”
- The Frontal-MTL (late onset) system is based on “selection” and does not need coherent co-variation

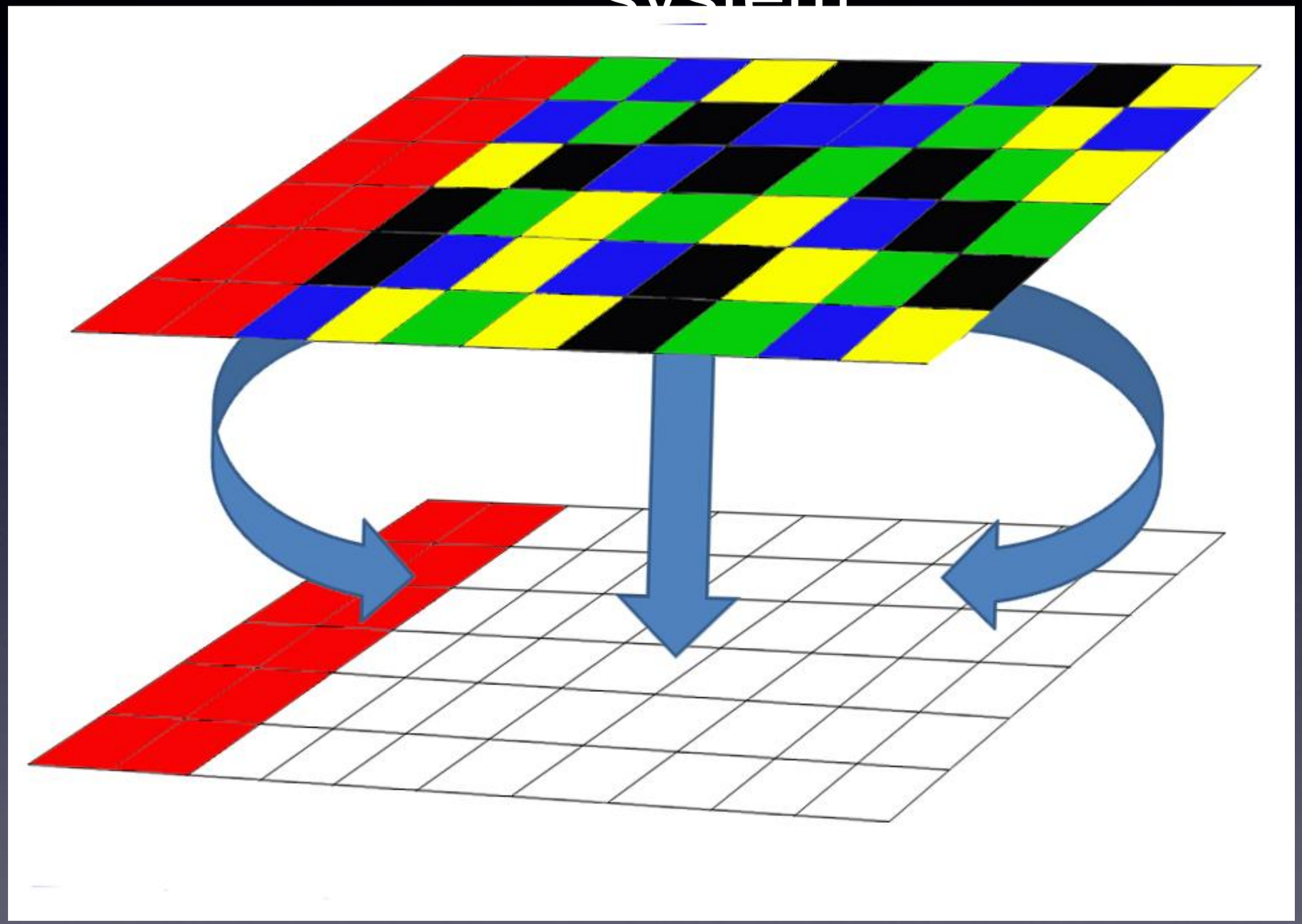


Adapted from Ashby, et al, 1998

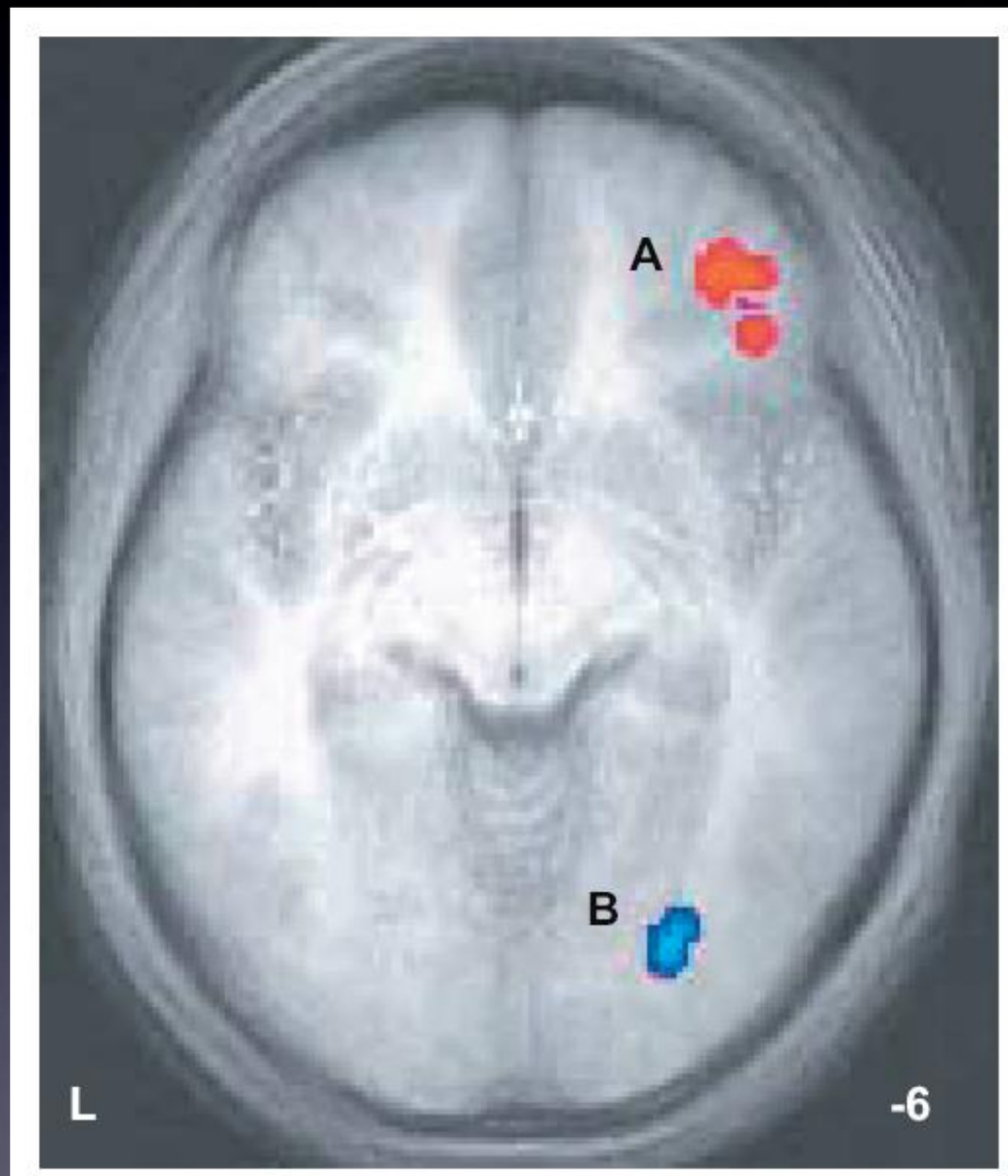
Coherently co-varying structures can be learned spontaneously by a compression-based system

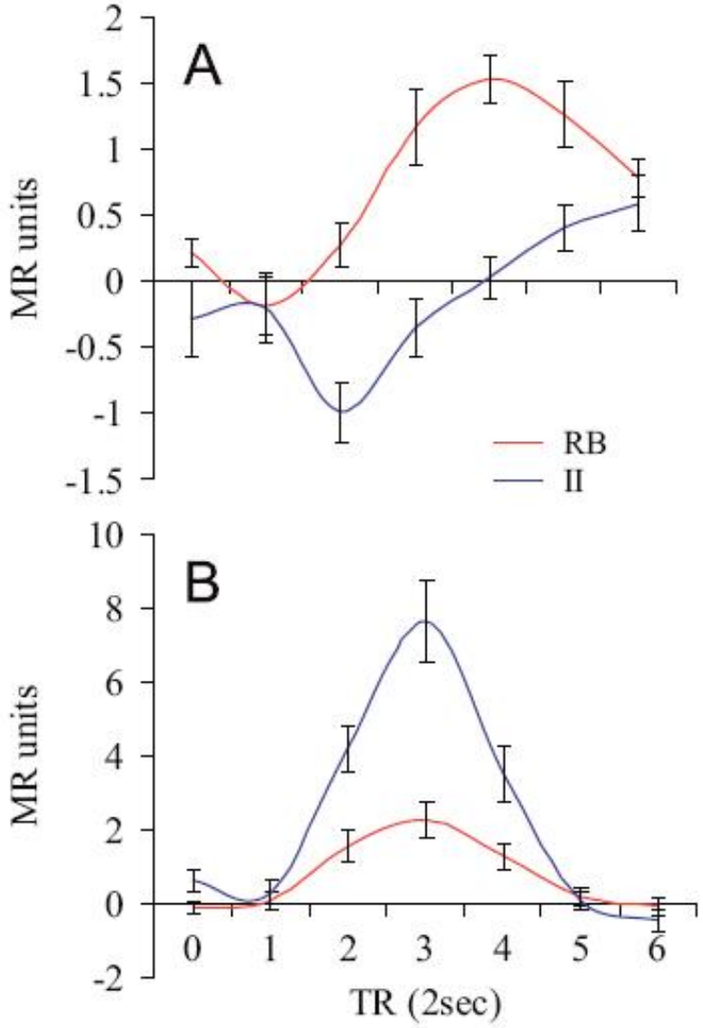


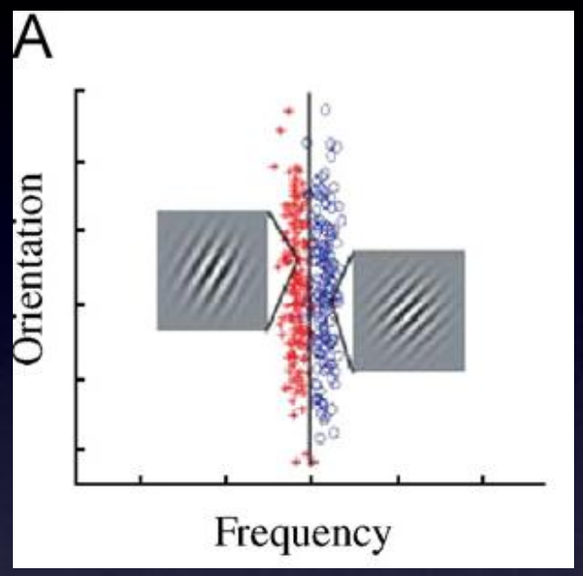
Structures lacking coherent co-variation require the involvement of a selection-based system

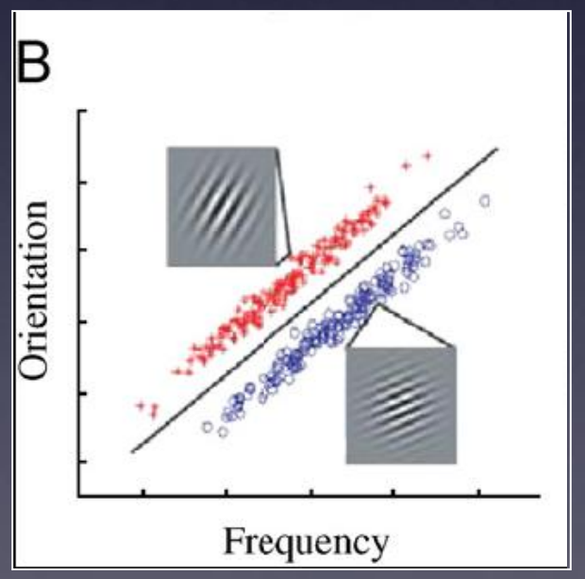


Distinct Systems of Learning?









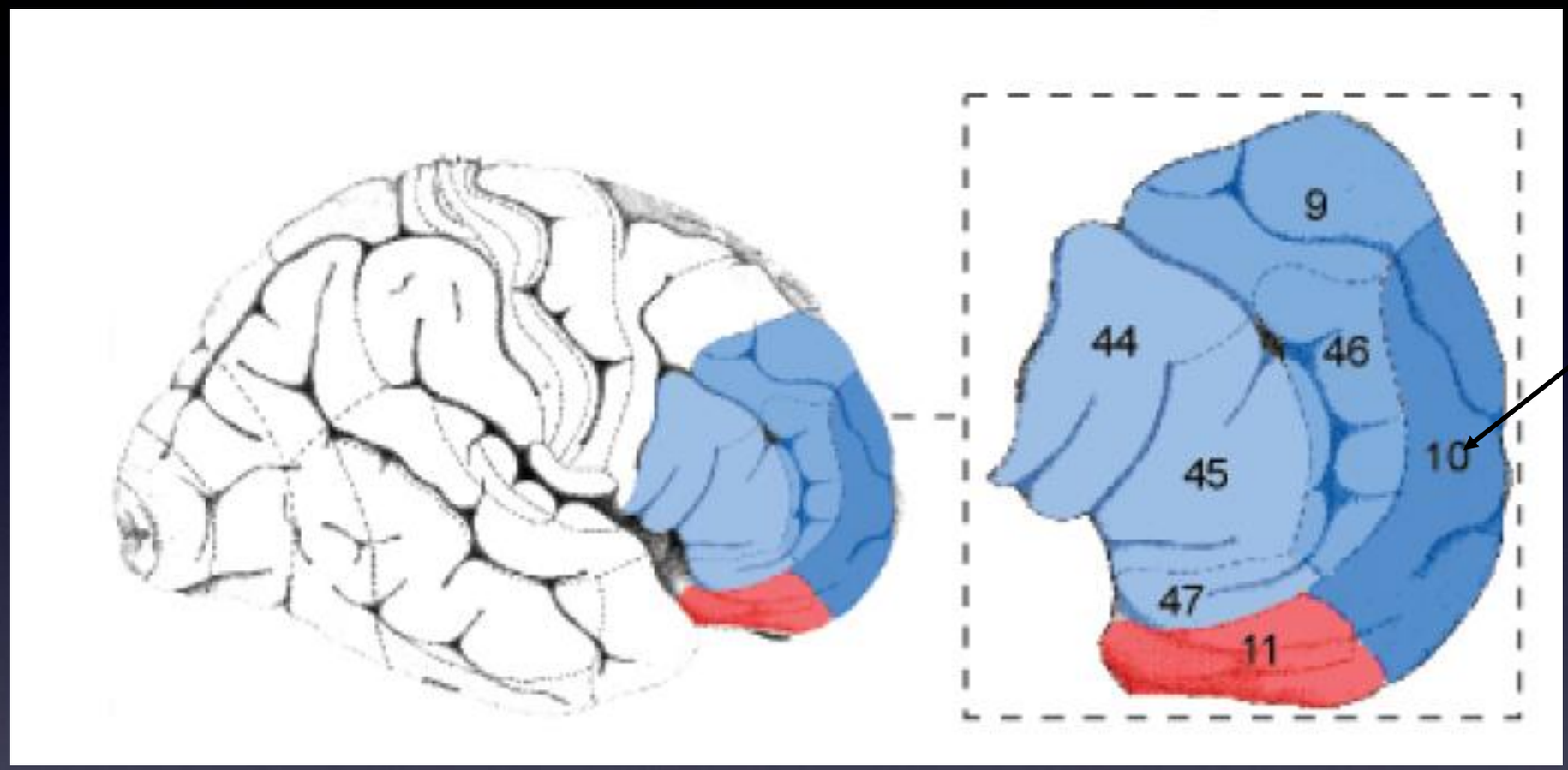
E.M. Nomura, P.J. Reber / Neuroscience and Biobehavioral Reviews 32 (2008)

Properties of the Systems

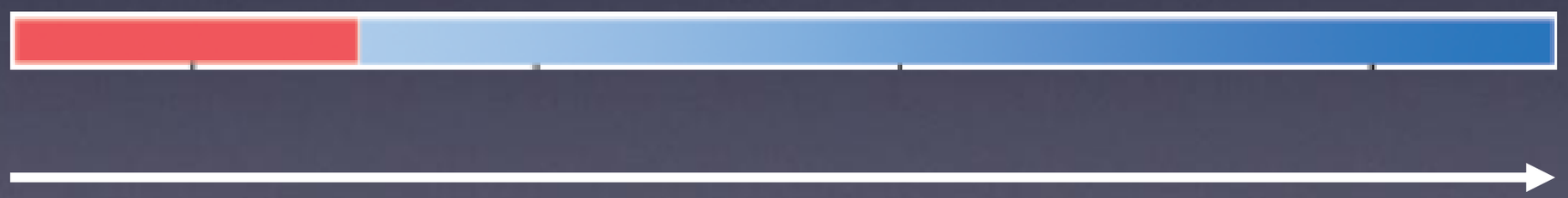
Compression-based System	Selection-based System
Is based on many to one cortico-striatal projections	Depends critically on the prefrontal cortex
Exploits massive statistical redundancy in the input	Enables focusing on few highly predictive and regular dimensions
Supports non-deliberate, implicit learning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

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



Maturation

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

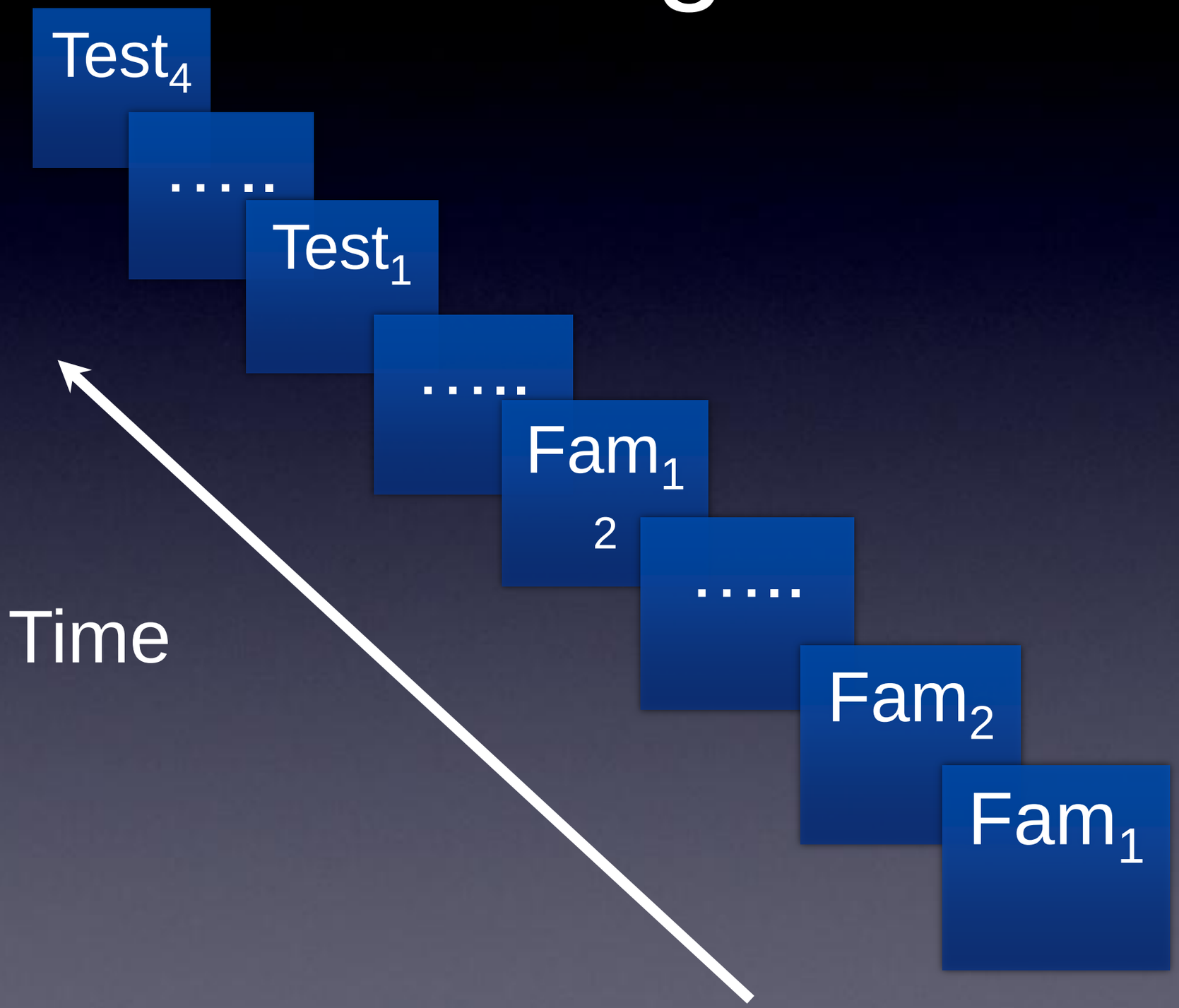
Early learning by compression

Evidence from successes and failures of infant learning

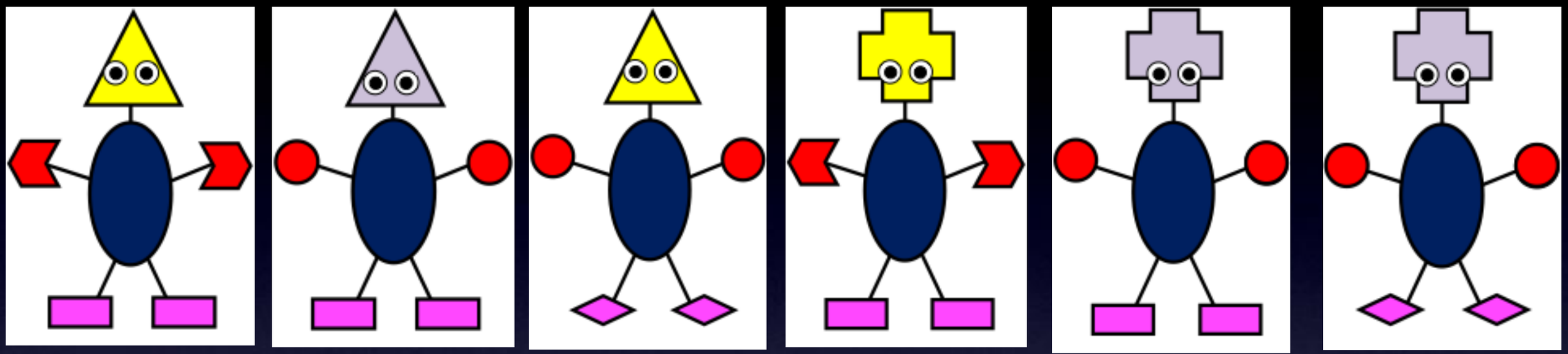
Successes and failures of infant category learning

- Participants: 8- and 12-month-olds
- Category learning task

Overview of the Paradigm

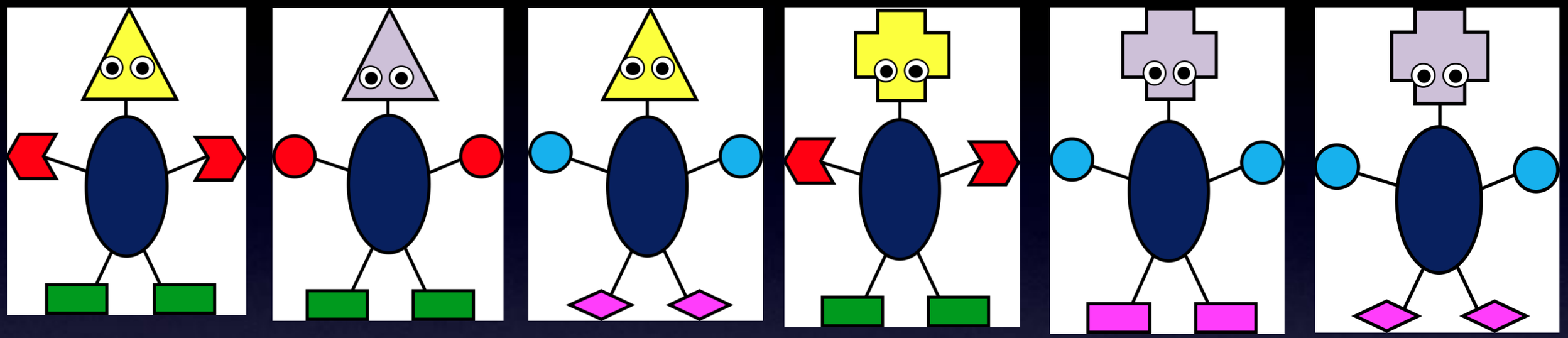


Dense Category

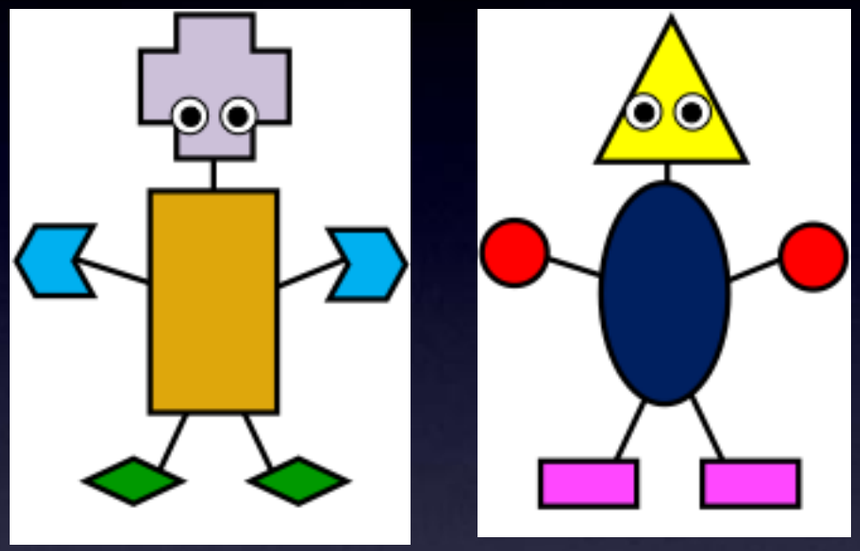


Training Items

Sparse Category



Training Items



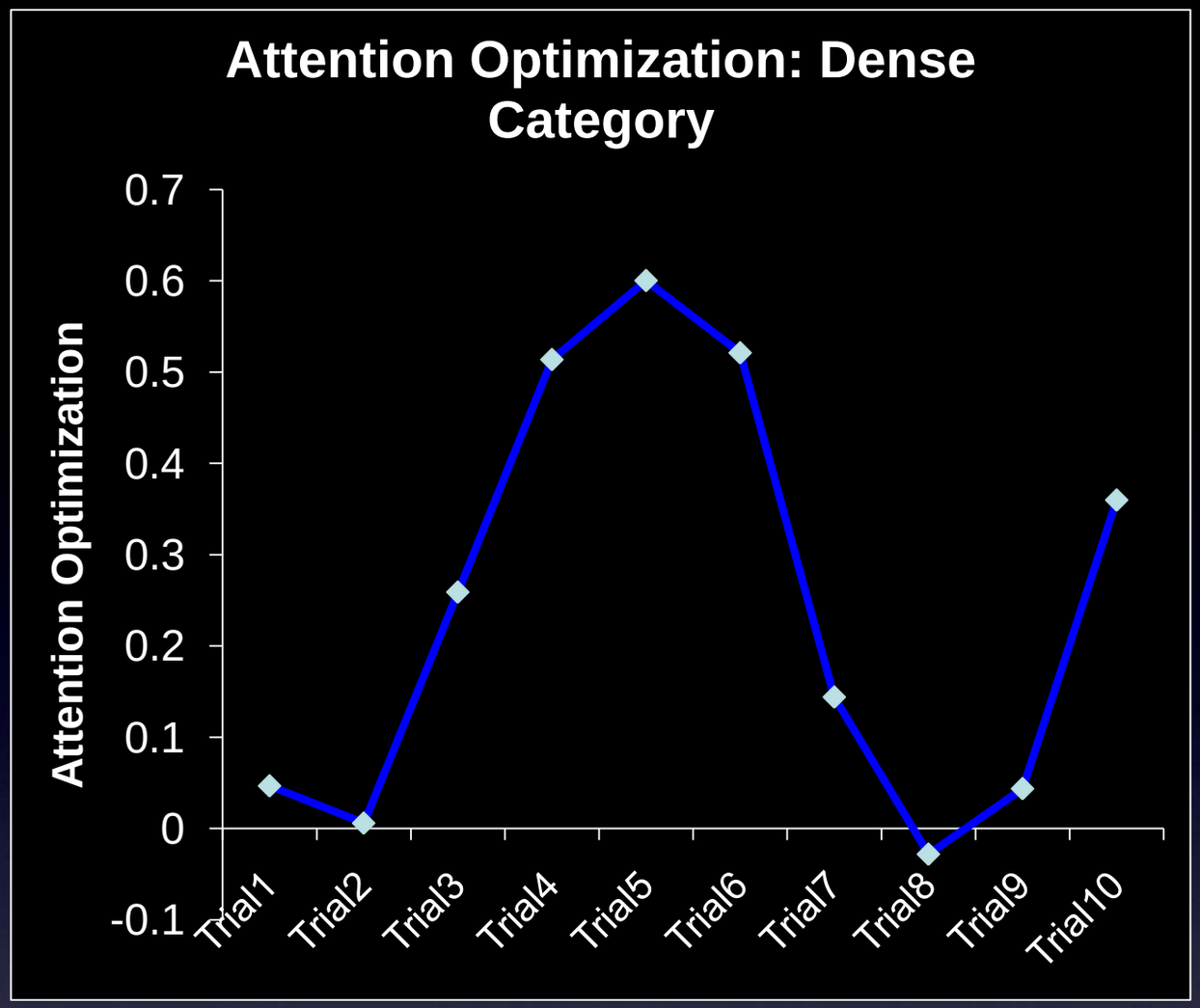
Testing Pair

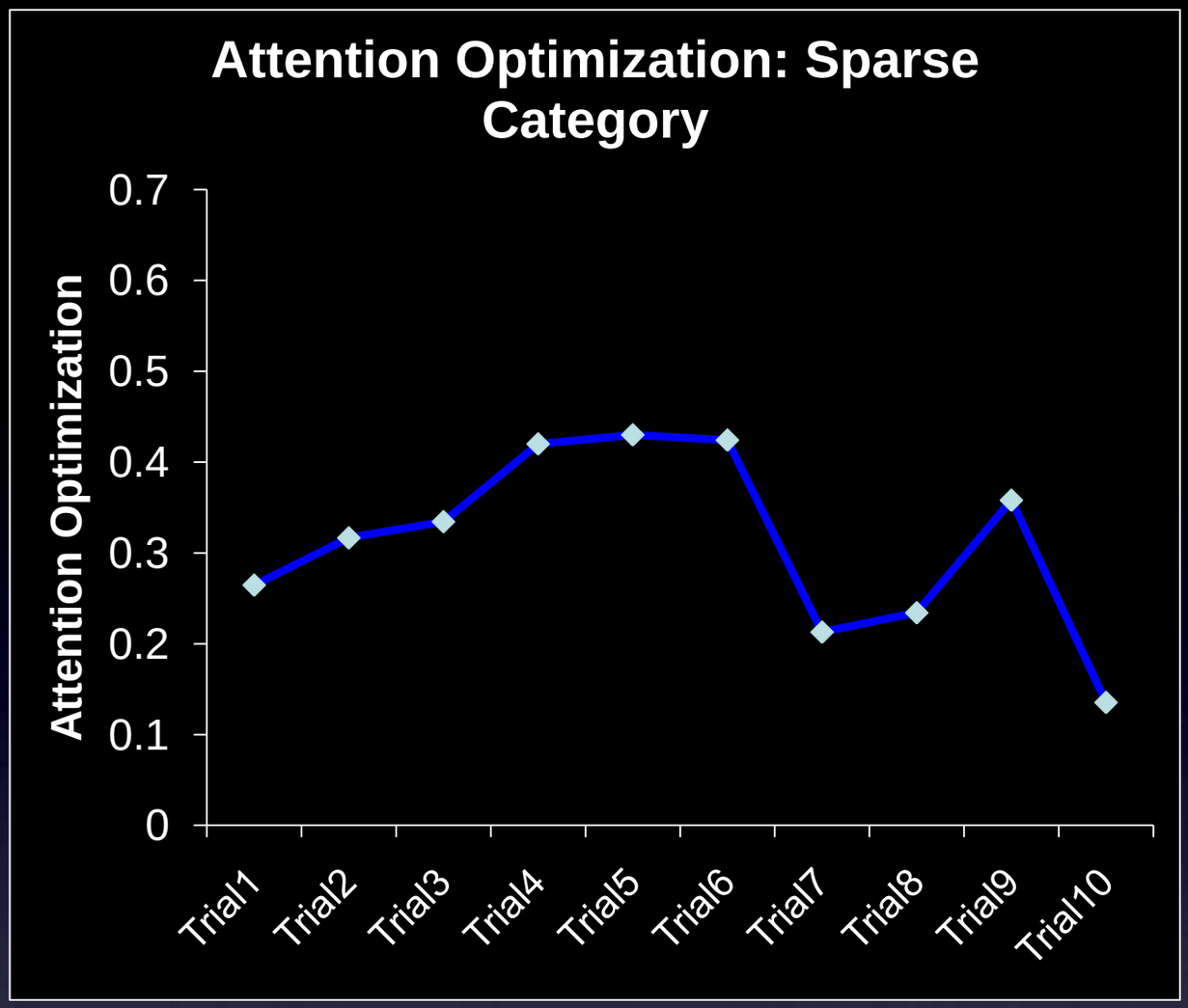
Results

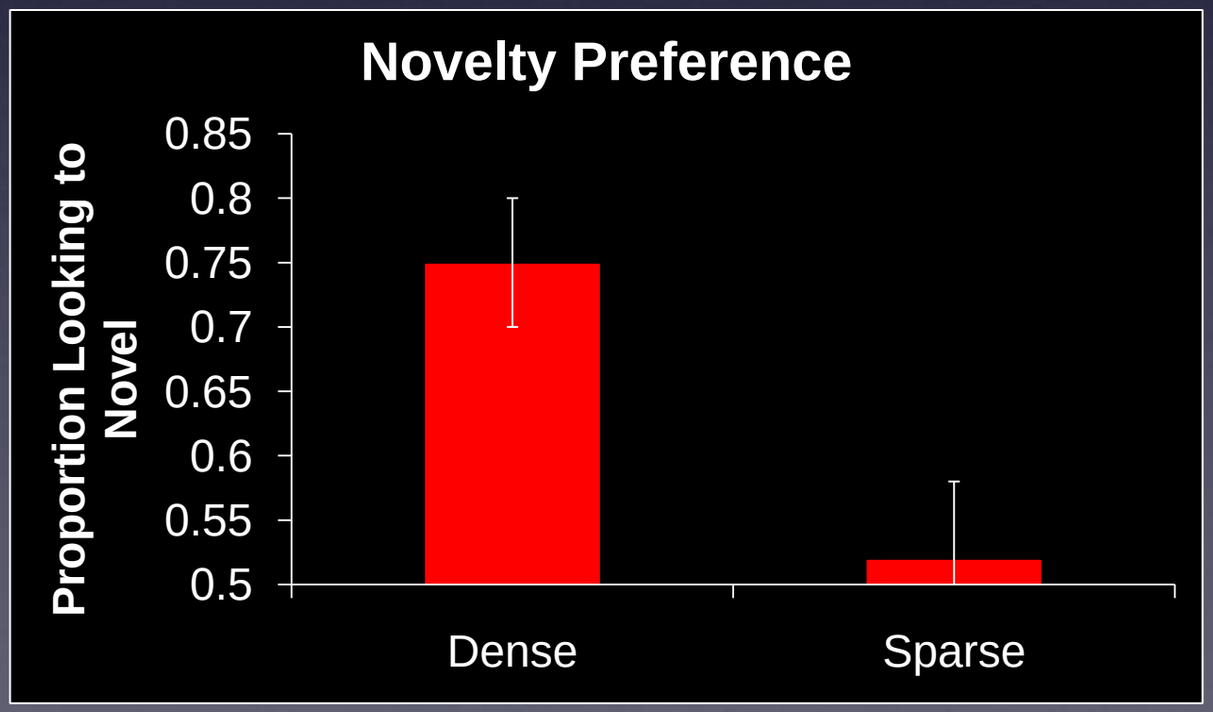
- Attention optimization scores were calculated for each trial

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

- Values > 0 indicate more looking to relevant and values < 0 indicate more looking to irrelevant.


Attention Optimization: Dense Category
Attention Optimization
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
Trial1
Trial2
Trial3
Trial4
Trial5
Trial6
Trial7
Trial8
Trial9
Trial10

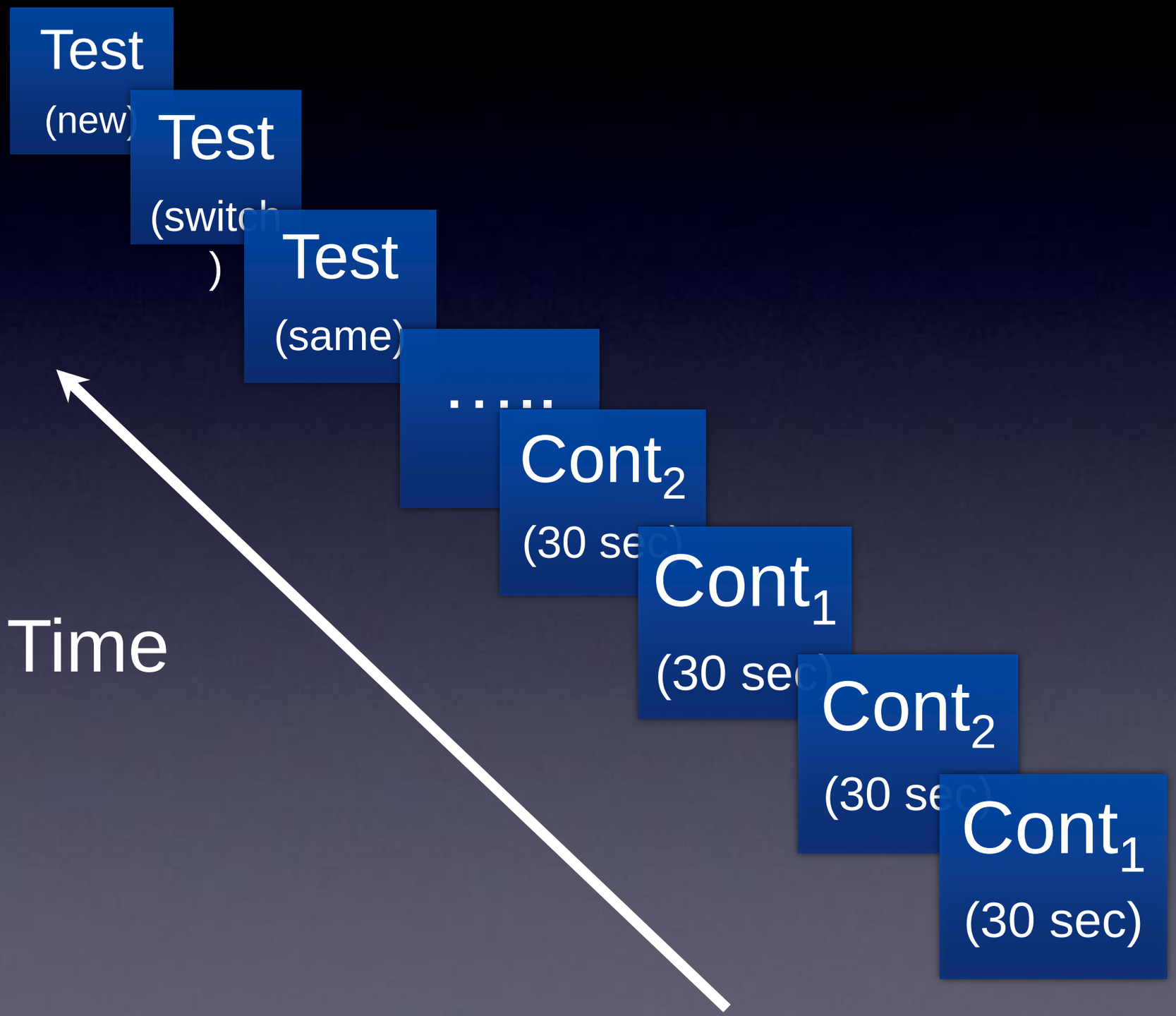

Attention Optimization: Sparse Category
Attention Optimization
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Trial1
Trial2
Trial3
Trial4
Trial5
Trial6
Trial7
Trial8
Trial9
Trial10


Novelty Preference
Proportion Looking to Novel
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
Dense
Sparse

Learning succeeded only when there was coherent co-variation, but failed otherwise

Success and failures of infant learning of complex contingencies

Overview of the Paradigm

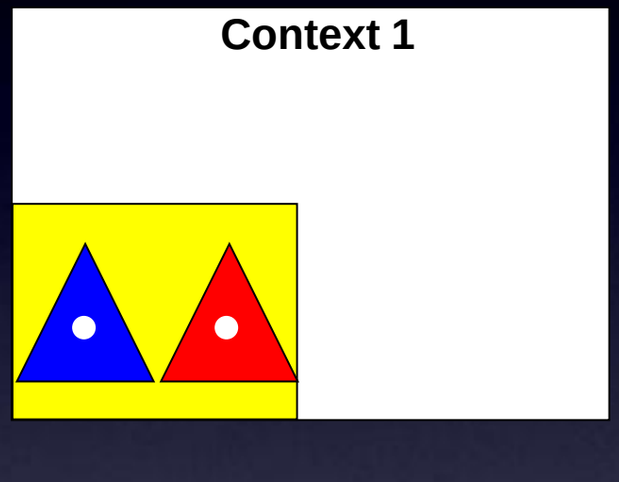


Multiple Correlations Condition

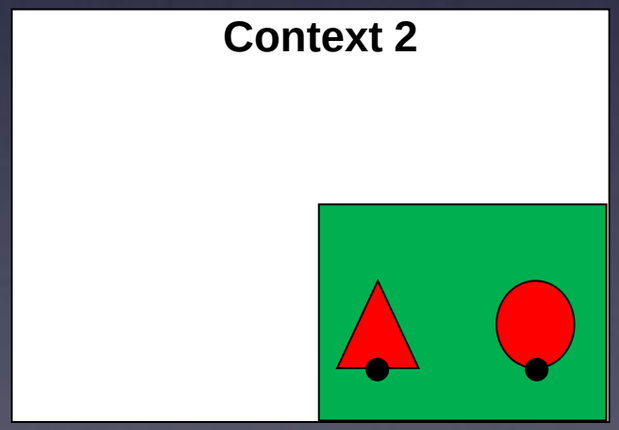
Familiarization Phase

Participants:

12- and 14-month old infants



60 sec of accumulated looking



60 sec of accumulated looking

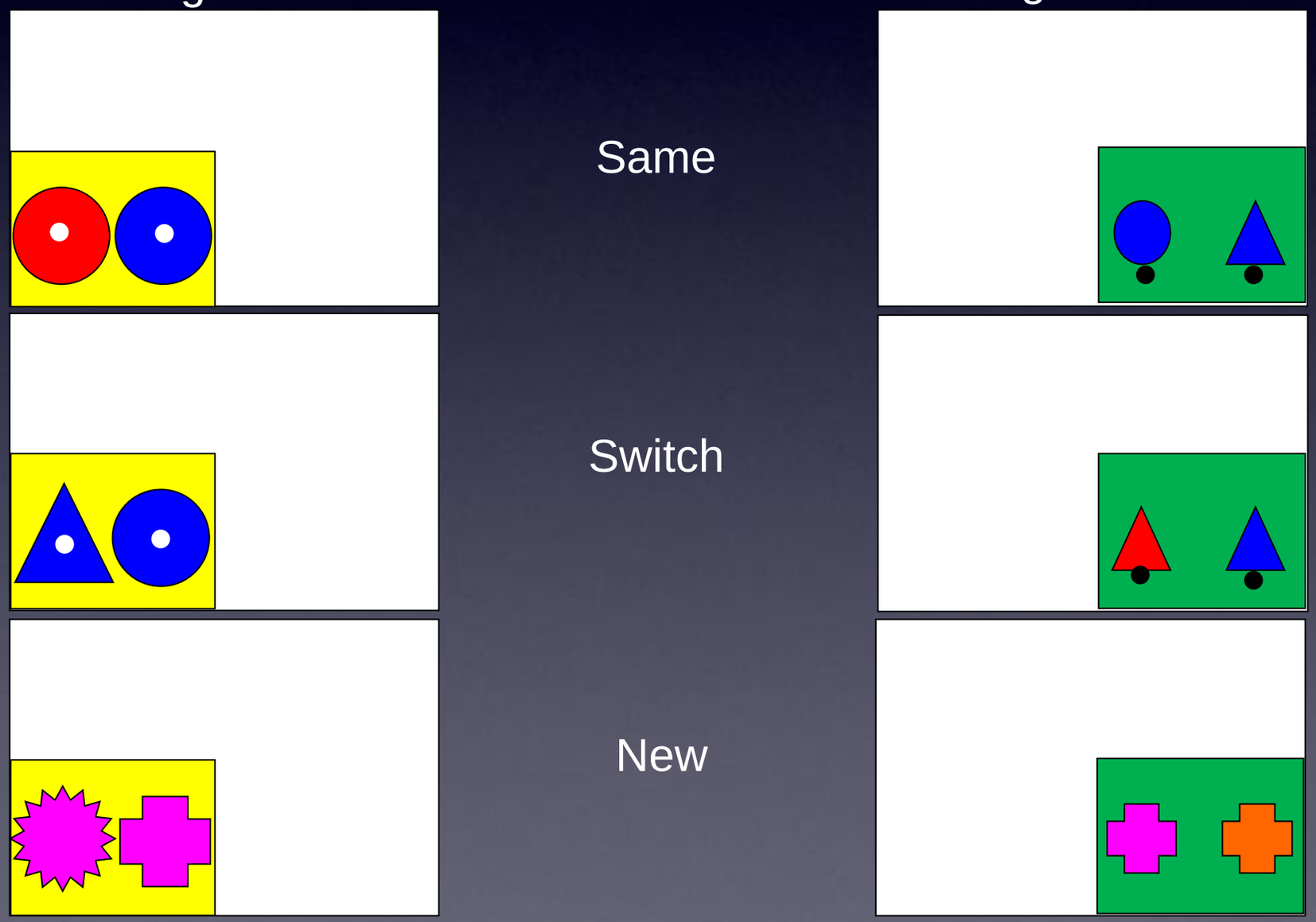
Test Phase

30 sec of accumulated looking

per test item

Testing: Context 1

Testing: Context 2

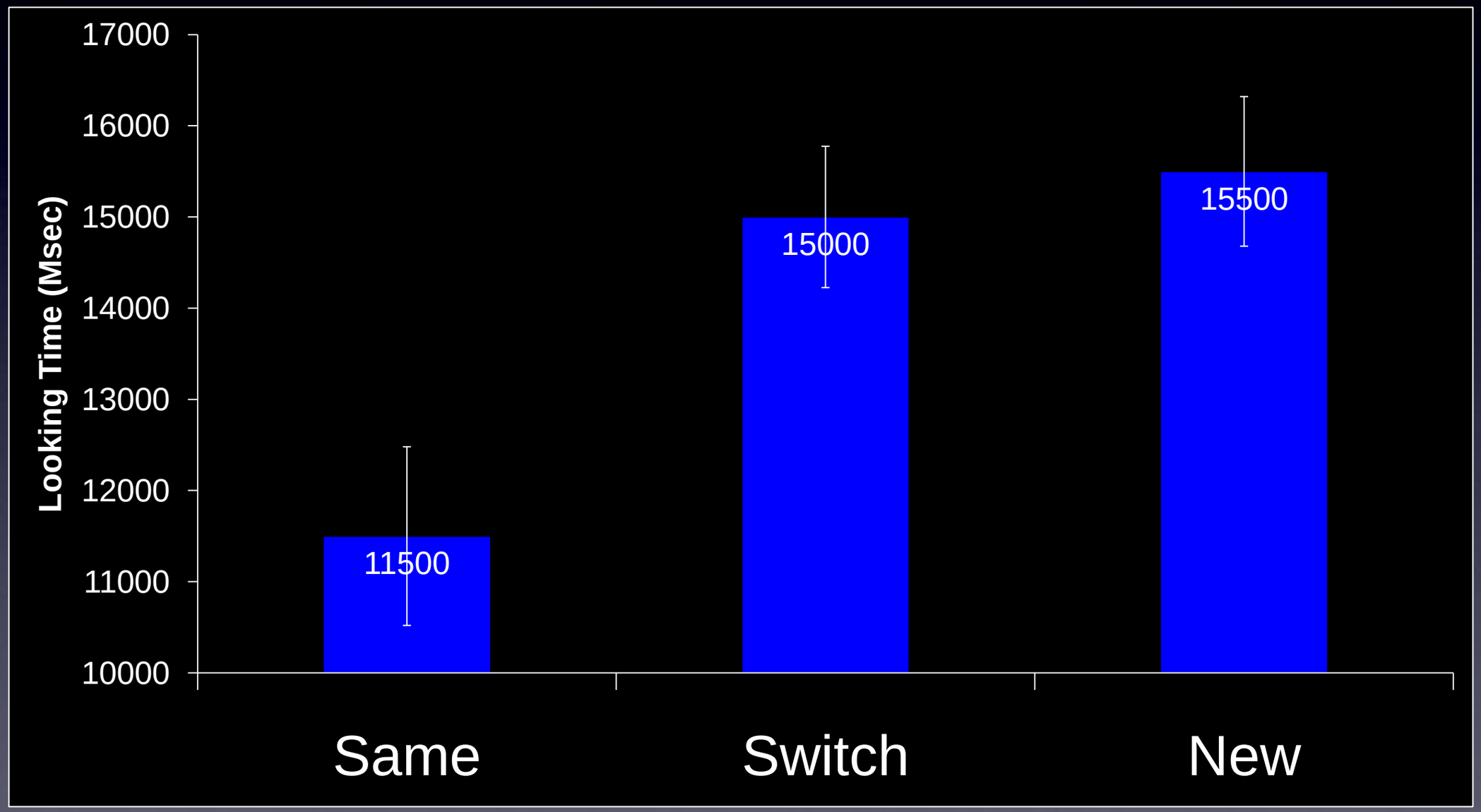


Same

Switch

New

Infants Succeed

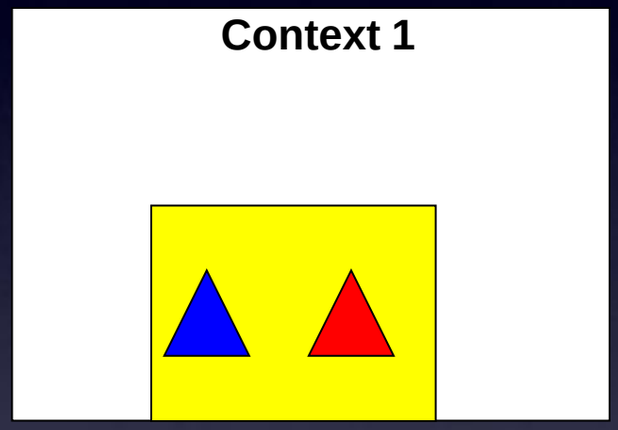


Reduced Number of Correlations

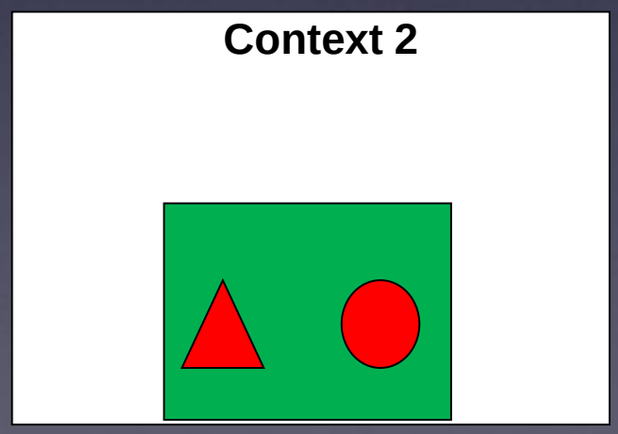
Familiarization

Participants:

12- and 14-month old infants

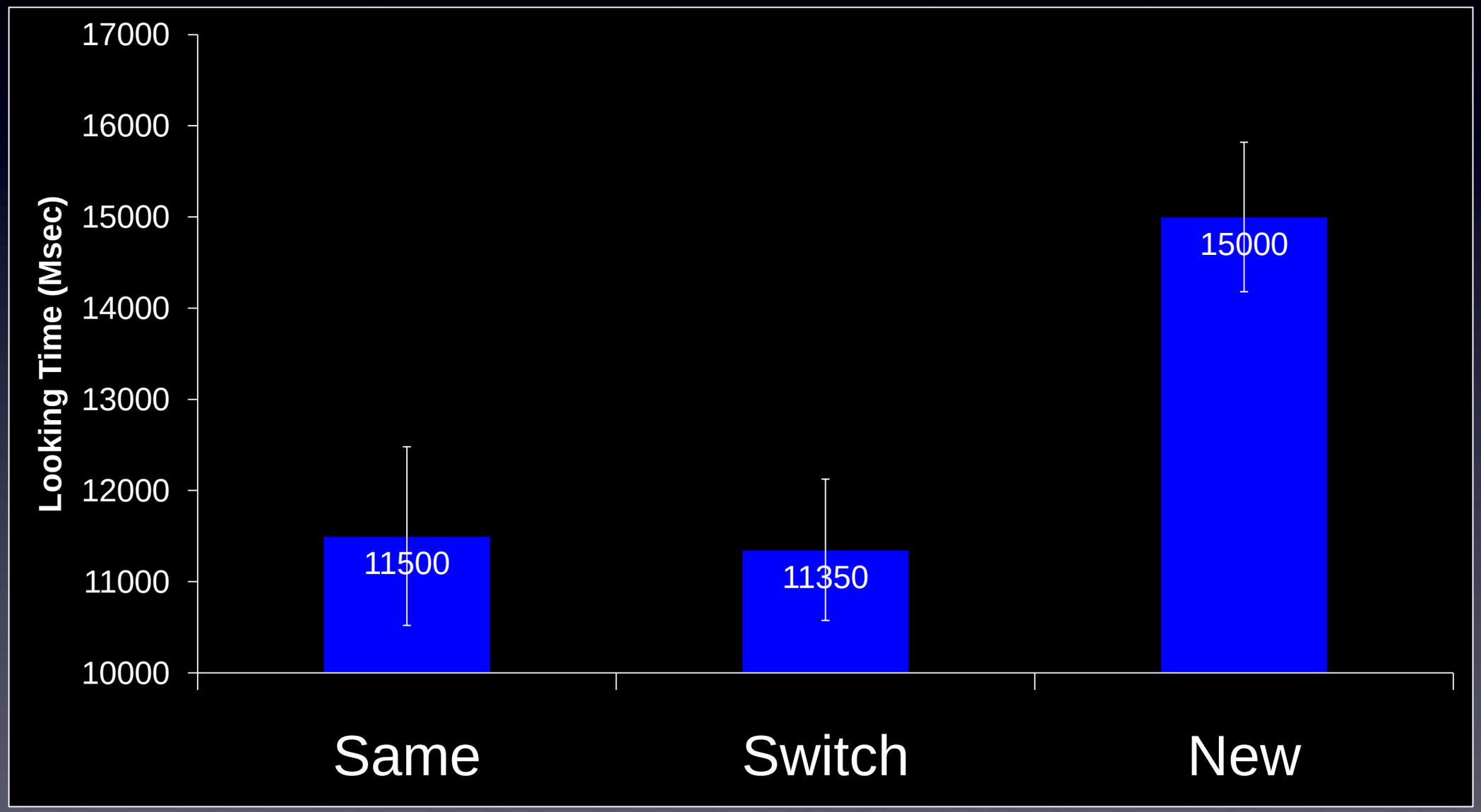


60 sec of accumulated looking



60 sec of accumulated looking

Infants Fail



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!