Infant Cognition 3: Multi-sensory integration to construct knowledge

Micah B. Goldwater, PhD
University of Sydney

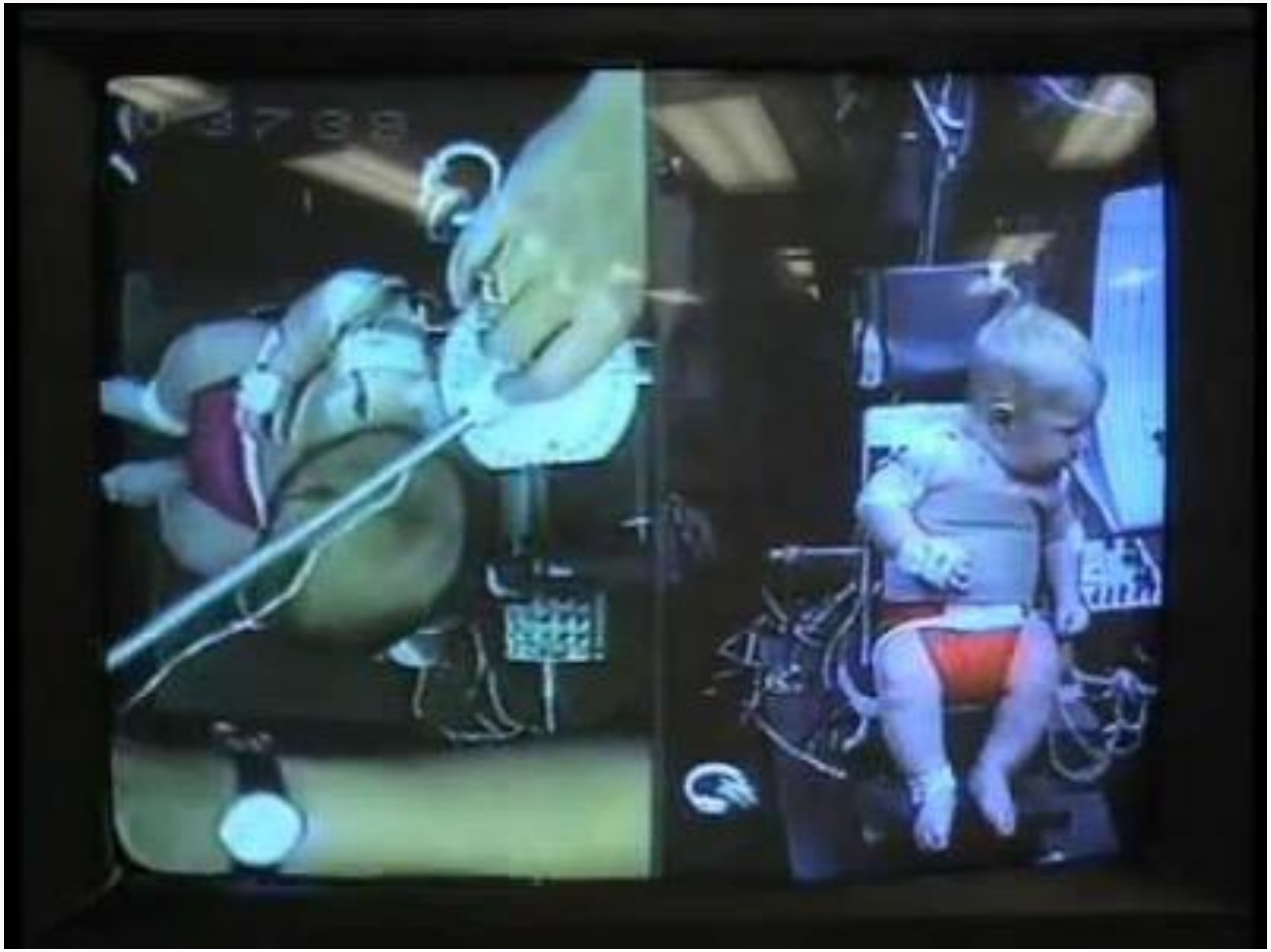
Reading

- Cohen & Cashon (2006)- still relevant
- Smith (2013) From “American Psychologist” which has a bit more of a general-audience kind of style

Building knowledge from multi-sensory integration

- 1st point- development is piecemeal

Dynamic Systems & Motor Development



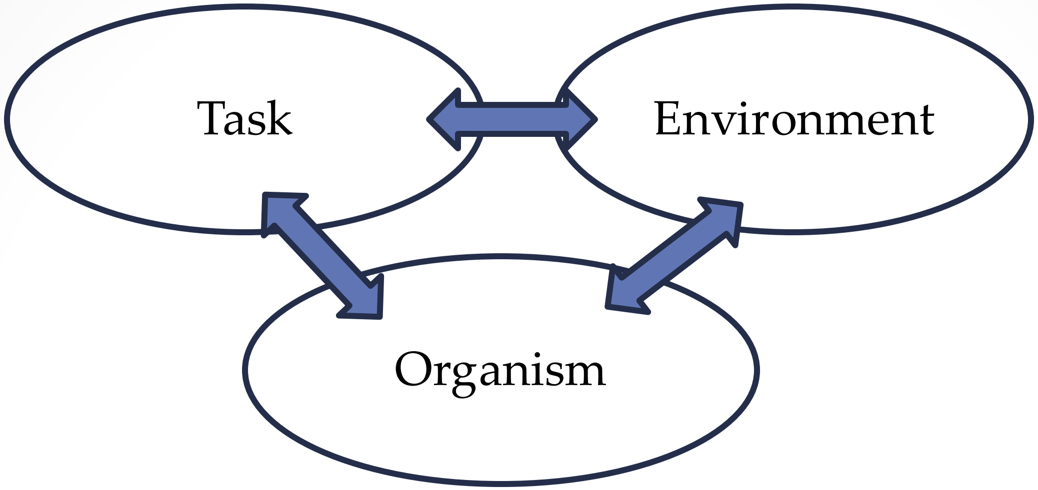
Just watching the first few minutes here, but watch the rest on your own

A key insight: motor learning/training is specific to those actions

Dynamic Systems & Motor Development

Risk perception does not generalize from sitting to crawling

Dynamic Systems & Motor Development



- Development is driven by the dynamics of these three interacting

Task-Environment- Organism

What changes in the organism?

Brain & Body

- Have some put too much emphasis on brain changes to explain development?
- For example, motor control brain regions need to mature (and learn) to walk
- Thelen showed that fat/muscle growth is also critical
- Demonstrated babies could walk in water earlier

What about conceptual knowledge?

- Piaget explains error in terms of incomplete object schemas- object knowledge tied to actions
- Linda Smith (and colleagues, 1999) shows that simply resetting the infant's posture and body (but standing and sitting) can eliminate A not B error

What are concepts, really?

- Dynamic systems says there is no such thing as a concept in this traditional sense.
- “Concepts” emerge from a complex system of brain, the body, and the world all interacting

- Remember how Piaget failed to explain how discrete symbolic representations are created by sensorimotor exploration?
- Smith “solves” the problem by denying it: There are no discrete representations, even in adults!

So how does intelligence emerge?

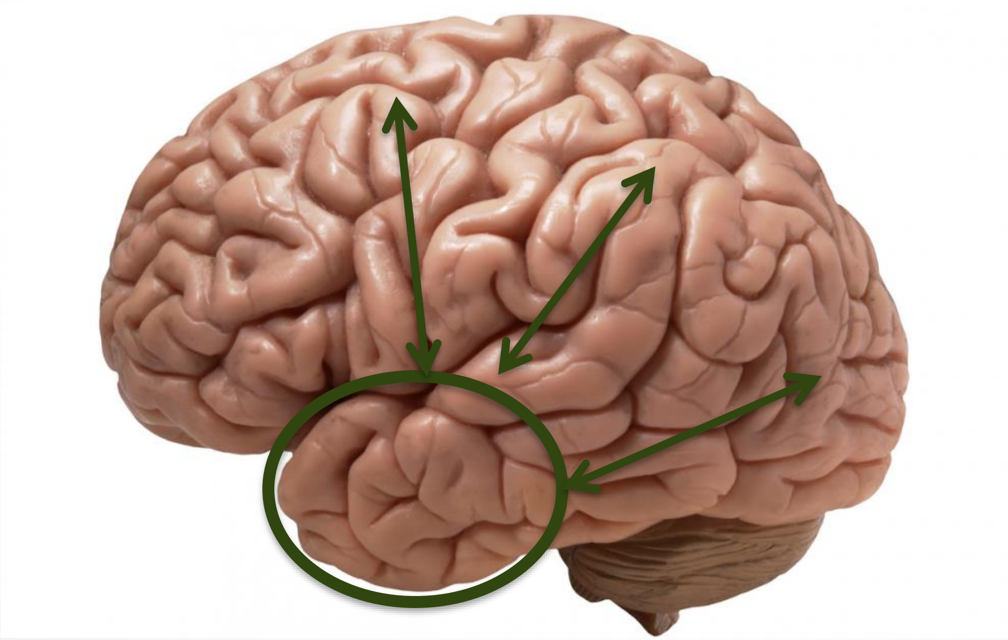
- Children are sensitive to statistical contingencies in action and perception
  - Knowledge grows from sensorimotor exploration of world: Piagetian

- Other networks exist to integrate multi-sensory information, feedback to them.
  - Development of action affects the development of vision and vice-versa

- Operating at this higher-level of multi-sensory integration, new higher-order correlations can be formed.
-
- This hierarchical construction is key to human intelligence

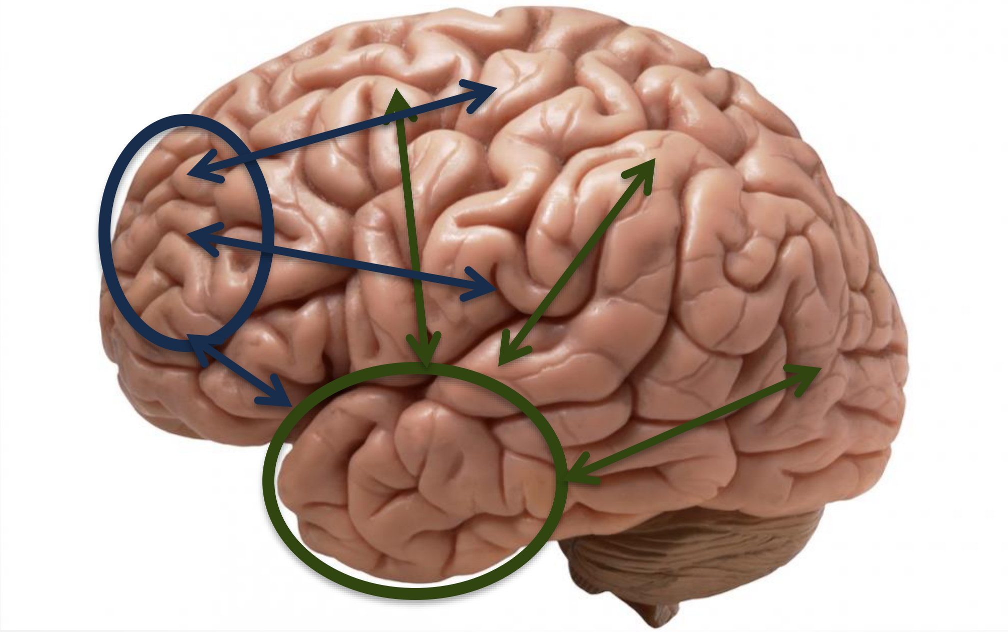
Multi-sensory integration in the brain

- Word meanings activate associated sensory systems all over the brain
  - “kick” activates the leg control part of motor cortex, “punch” activated hand part
  - “canary” activates yellow in visual cortex
- Also a “multi-modal hub” in anterior temporal lobe



Multi-sensory integration in the brain

- Highest-order integrative network: pre-frontal cortex integrates disparate information
  - Frontal pole/ Broadman’s 10/aPFC/
  - Area most associated with fluent intelligence, abstract problem solving, analogical reasoning, e.g., aspirin: pain:: muffler:noise
  - Our aPFC is way bigger/more connecty than other primates’.
  - Preview of abstract thought and executive function.

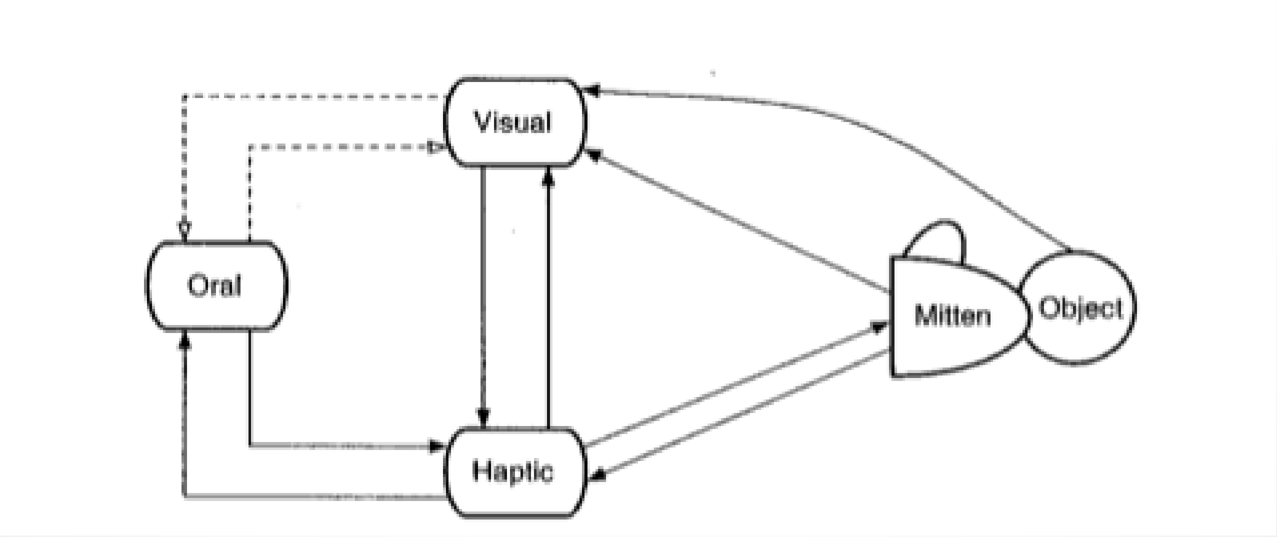


“Intelligence is multi-sensory integration”

- First 6 months infants develop systematic visual inspection, and oral & manual exploration of objects behaviors

"Intelligence is multi-sensory integration"

- First 6 months infants develop systematic visual inspection, and oral & manual exploration of objects behaviors
- Sticky mittens given to 2 month-olds allowing for better grasping of objects leads to more mature visual inspection and oral exploration of objects
  - Remember oral representation of outside world in Piaget?



Multi-sensory integration: the visual cliff

- Learning to crawl first induces the fear of the cliff, and then handling objects accelerates getting over the fear.

Generalizing actions across objects in 2020

- https://x.com/alvinfoo/status/1350729710599196674
- Unfortunately you need to log in because of "sensitive content" (it is not sensitive content)

Building knowledge through statistics: visual object categories

- Objects are typically categorized based on their common features
  - birds have wings, beak, feathers, and fly
- Features are correlated across objects
  - Across all objects, things that have beaks tend to also have wings and feathers.
- Can infants keep track of feature-correlations?
- Younger & Cohen pioneered this research

Principles of Constructivist Infant Cognition

- Innate domain general information processing system that detects low-level featural information, such as color, motion
- Higher-level units formed from relationships among these.
- Higher-level units formed from these units. Learning is hierarchical & constructive
- Infants tend to use highest level units to interpret their environment
- If system gets overloaded, revert to lower-level of processing while incorporating new information

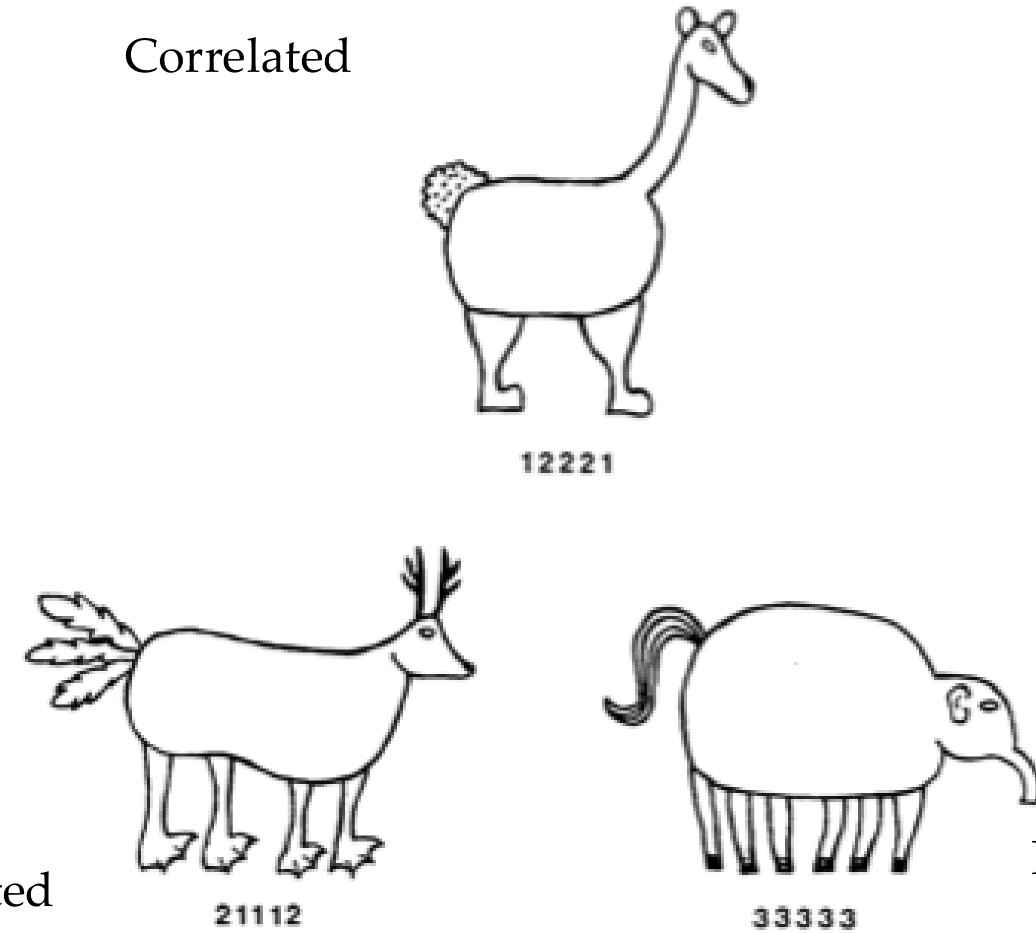
Detecting feature-correlations

- Younger & Cohen 1983
- 4, 7, & 10 month-olds habituate to novel animals
- Vary on feet, legs, ears, tail, body.
  - e.g., hoof feet, 4 legs, pointy ears, fluffy tail, giraffe body
- Some features correlated across animals
  - e.g., hoof feet always co-occur with giraffe body, but with any tail and ears.
- At test, infants see 3 novel animals:
  1. Familiar features and preserves correlations from habituation,
  2. Familiar features but violates correlations
  3. Novel features (a totally novel stimulus)
- Novel features should elicit dishabituation
- If infants learned the feature correlations, then the uncorrelated exemplar should also elicit dishabituation

Detecting feature-correlations

Younger & Cohen 1983
Example test stimuli

Correlated



Uncorrelated

Novel

Detecting feature-correlations

Younger & Cohen 1983

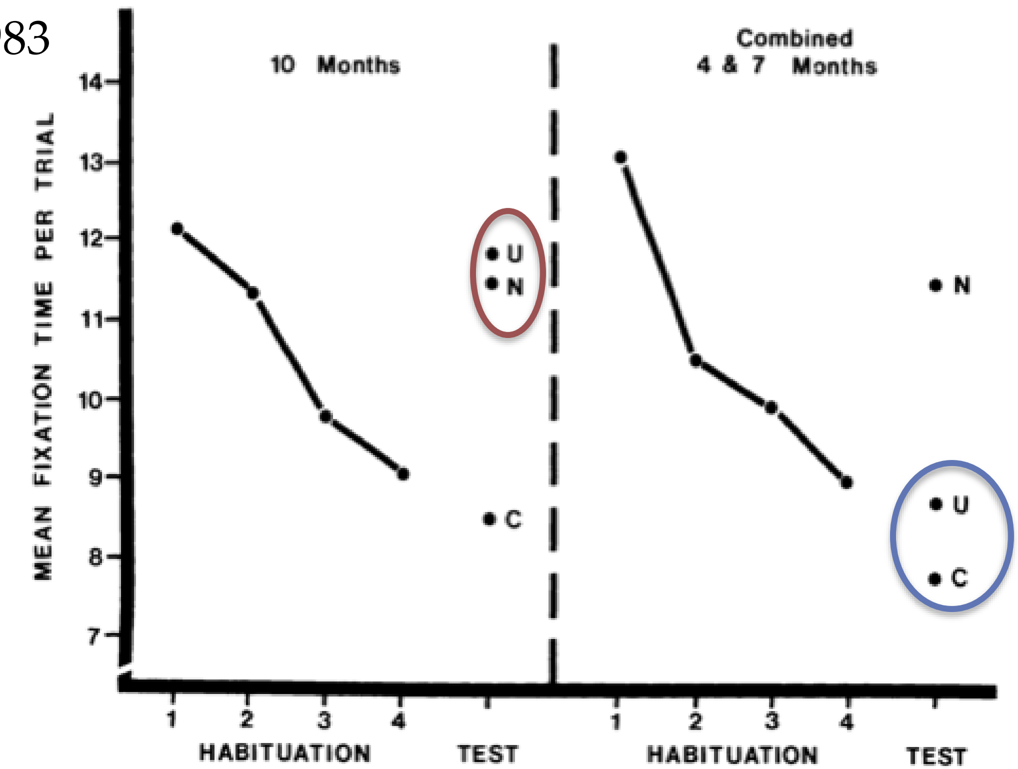


FIG. 2.—Mean fixation times in seconds for the habituation and test data from Experiments 1 and 3. The 10-month data (Experiment 1) are shown on the left, the combined 4- and 7-month data (Experiment 3) on the right. For each experiment, the eight habituation trials are shown as four blocks of two consecutive trials. *C*, *U*, and *N* refer to the Correlated, Uncorrelated, and Novel test stimuli, respectively.

10 month-olds dishabituate to both uncorrelated familiar features and novel features. They learned the correlations.

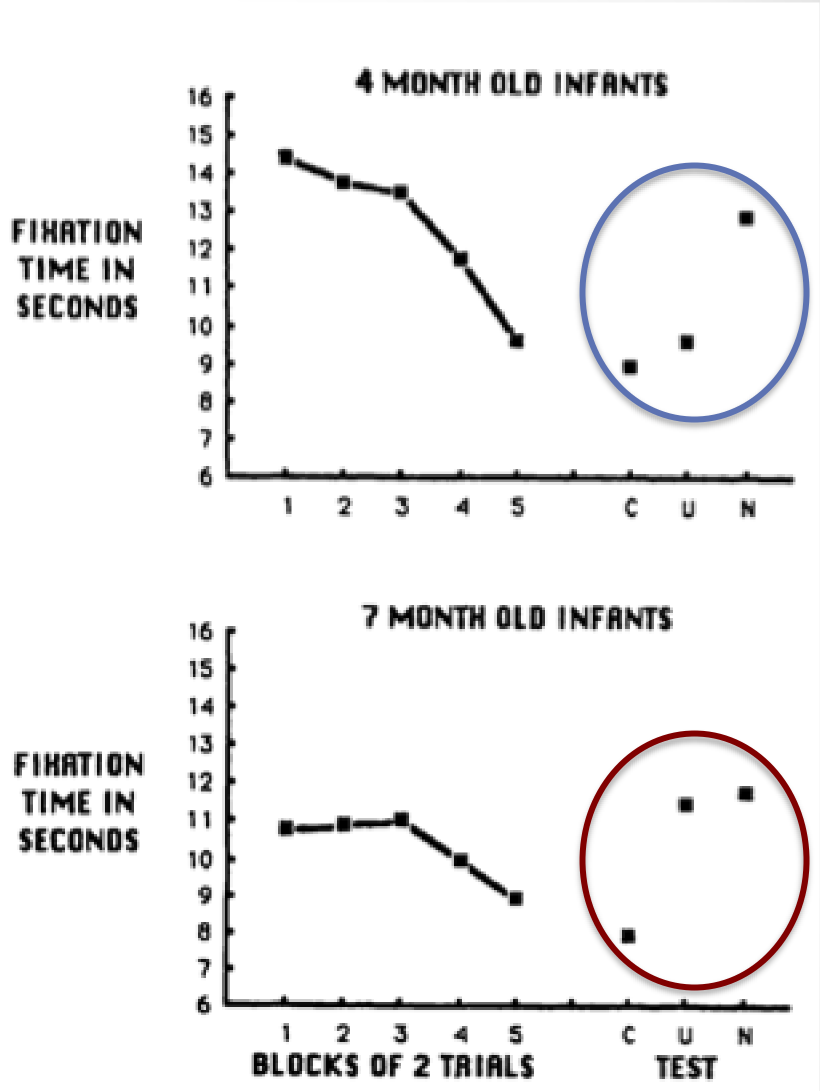
4 & 7 month-olds stay habituated to familiar features regardless of preserving the correlation. They show no signs of learning the correlation.

Detecting feature-correlations

- Younger & Cohen 1986
- 4, 7, & 10 month-olds habituate to novel animals
- Now they vary on just 3 features
  - e.g., hoof feet, fluffy tail, giraffe body
- Experiment 1: All 3 features perfectly correlated across animals
  - Just 4 and 7 month-olds in E1
- At test, infants see 3 novel animals:
  1. Familiar features and preserves correlations from habituation,
  2. Familiar features but violates correlations
  3. Novel features (a totally novel stimulus)
- Novel features should elicit dishabituation
- If infants learned the feature correlations, then the uncorrelated exemplar should also elicit dishabituation

Detecting feature-correlations

- Younger & Cohen 1986
- Exp 1. 4 & 7 month-olds
- 4 month-olds only dishabituate to novel features.
- 4 month-olds do not learn the correlations.
- 7 month-olds dishabituate to uncorrelated and novel test examples.
- 7 month-olds do learn the correlations.



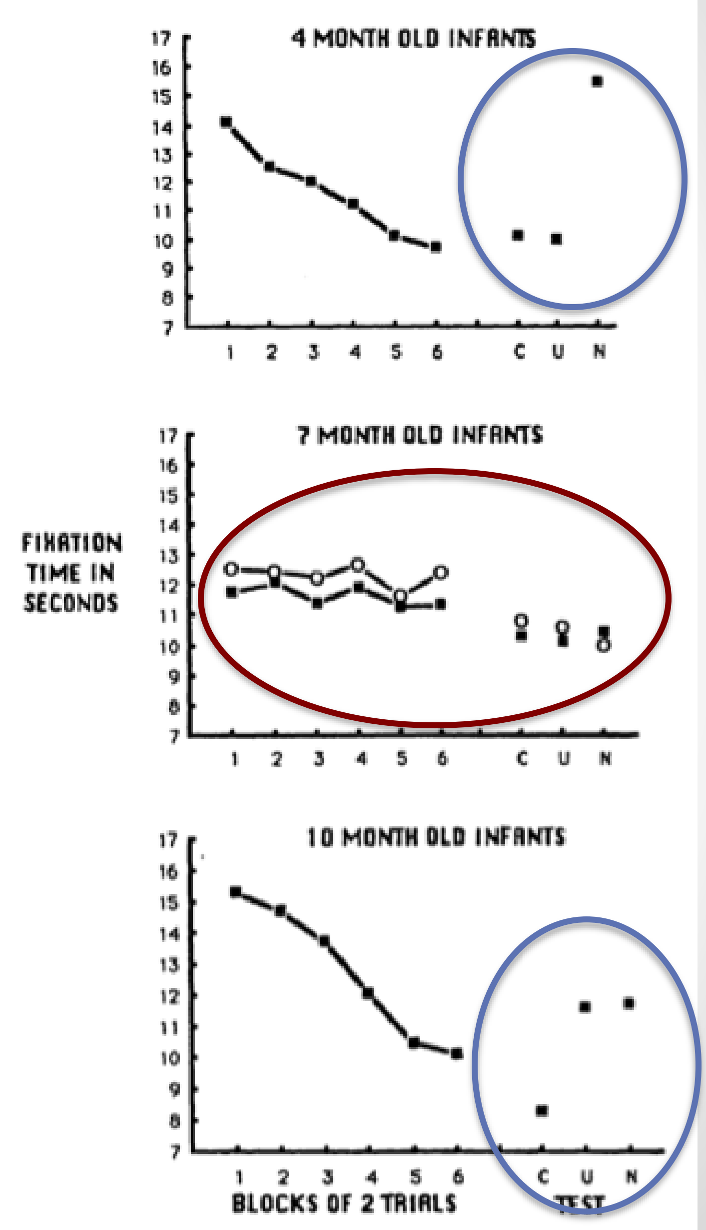
Detecting feature-correlations

- Younger & Cohen 1986
- 4, 7, & 10 month-olds habituate to novel animals
- Experiment 2: 2 out of 3 features are correlated across animals
    - e.g., hoof feet always co-occur with giraffe body, but with any tail
- Same test trials as before

Detecting feature-correlations

- Younger & Cohen 1986
- Exp 2. 4, 7, & 10 month-olds
- 4 month-olds do not learn the correlations
- 10 month-olds do learn the correlations.

- 7 month-olds do not even habituate! Show no preferences.
- After 12 habituation trials, they aren't done processing the stimuli yet.



Detecting feature-correlations

- Younger & Cohen 1986
- Experiment 2: 2 out of 3 features are correlated across animals
  - e.g., hoof feet always co-occur with giraffe body, but with any tail
- 4 month-olds habituate to the feature sets but not the correlations.
- 10 month-olds habituate to the correlations in the features.
- 7 month-olds attempt to learn the correlations, but need more time than the 10 month-olds.

Detecting feature-correlations

- Younger & Cohen 1986
- Experiment 4: 2 out of 3 features are correlated across animals
  - we're skipping E3
- 7 month-olds given more habituation trials
- They look like 4 month-olds generalizing their habituation to both correlated and uncorrelated test trials

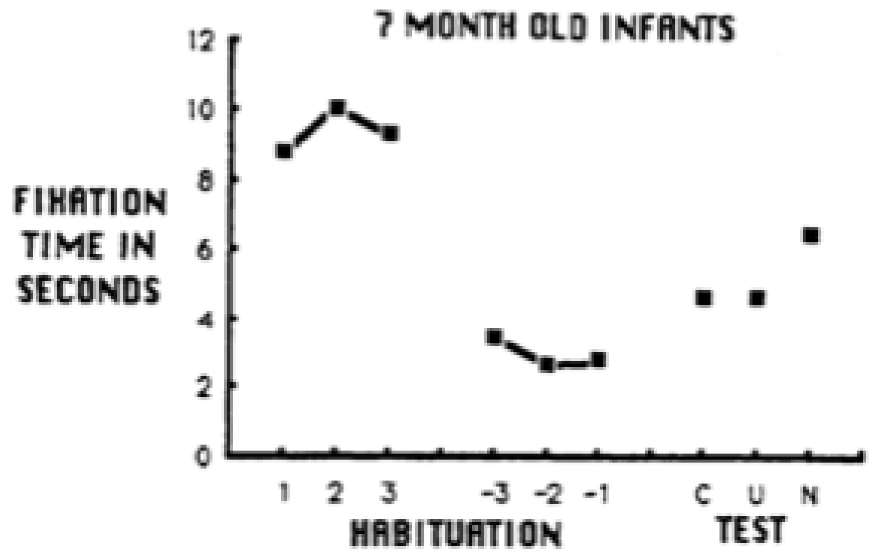


FIG. 3.—Mean fixation time in seconds for the initial and criterion blocks of three habituation trials and the test trials for Experiment 4. *C*, *U*, and *N* refer to the correlated, uncorrelated, and novel test stimuli, respectively.

Principles of Constructivist Infant Cognition

- Infants construct units from lower-level units.
- Infants tend to use highest level units to interpret their environment
- If system gets overloaded, revert to lower-level of processing while incorporating new information
- In Younger & Cohen (1983;1986)
- 4 month-olds don’t learn the correlations
- 10 month-olds do
- 7 month-olds can learn the correlations in simple tasks. They attempt to learn the correlations when tasks are more complex, but ultimately fail and revert to processing like 4 month-olds.

Words and higher-order correlations

- Back to object ‘concepts’ specifically
- Systematic multi-modal interaction with objects help to form object categories.
- Word learning systematically builds on this ability
- A large proportion of the child’s first 100 words refer to categories where common shape is most critical feature
- Children develop a *shape bias* in word learning

Developing the shape bias

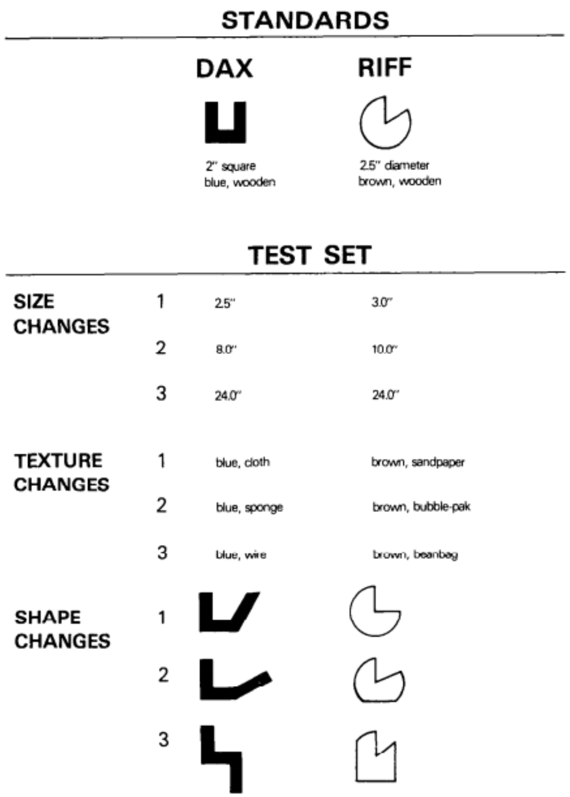


Figure 1. Stimulus sets for all experiments. Stimuli are specified in terms of how they differ from the standard. A duplicate of the standard was always included in the test set, whereas subsets of size, texture, and shape changes were used for different experiments. See text for details.

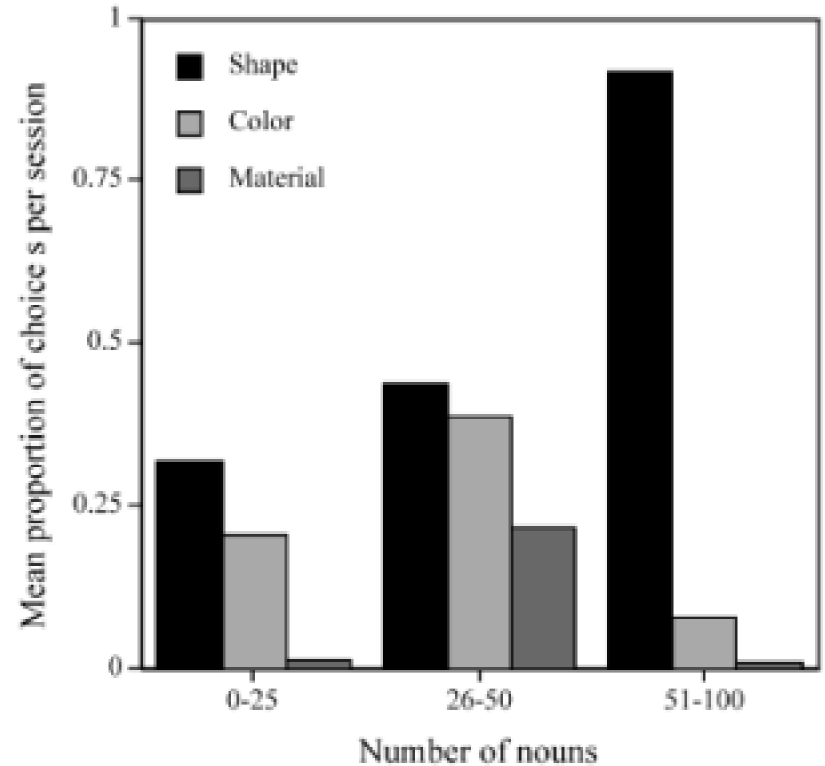


Figure 2. Mean number of shape choices in noun generalization task as a function of the number of nouns in the children's productive vocabulary.

~18 month olds

Landau, Smith, & Jones 1988

Gershkoff-Stowe, & Smith 2004

Developing the shape bias

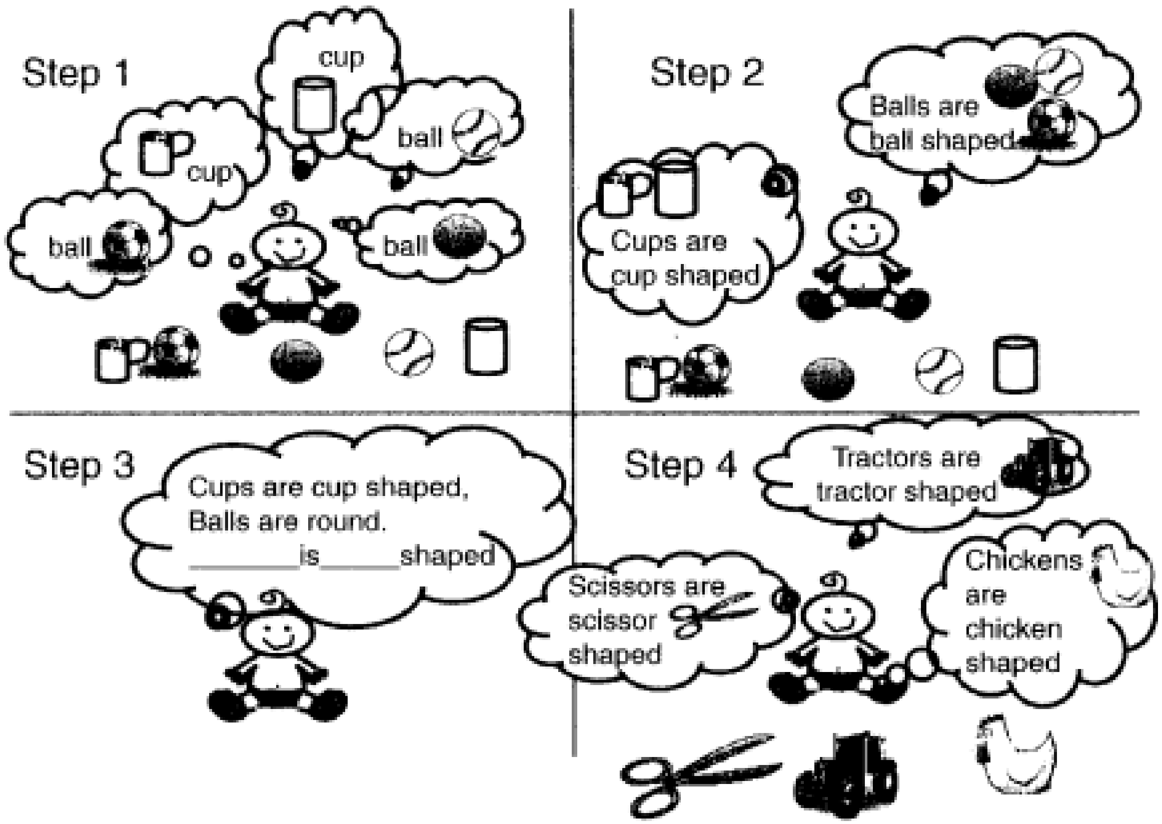


Fig. 16.6 Steps in forming a higher-order generalizations: (1) learn specific word object associations; (2) make first-order generalizations for each of the specific categories; (3) make higher-order generalizations across the regularities discovered in those first-order generalizations; and (4) use these higher-order generalizations to rapidly learn new categories.

Beyond shape

- Shape becomes particularly important for classifying new category members
- Children learn about all sorts of features, and their correlations within and across categories
  - e.g., wings, beaks, & flying co-occur
- Other systematic connections between domains and feature types
  - e.g., natural kinds vs. artefacts: texture

Dynamic systems & abstract thinking: language statistics

- According to dynamic systems:
- Language system itself becomes its own dynamic system- it does feedback to perception it does not need to
- Look at ChatGPT: entirely based on language statistics, no access to perception and action

Multi-sensory integration summary

- Infants build object “concepts” through learning correlations of features within a sensory modality and across modalities through connected action-perception systems
- There is a construction of hierarchical networks with feedback across levels of hierarchy
  - Inspired by brain structure
- These action-perception links support early word-learning, but then systematic language use feedback and accelerate action-perception category learning.
-