9.85 Cognition in Infancy and Early Childhood

Lecture 7: Number

What else might you know about objects?

Spelke Objects

i. Continuity. Objects exist continuously and move on paths that are connected over space and time.

ii. Cohesion. Objects are cohesive: they are internally connected and externally bounded entities that maintain both their connectedness and their boundaries over time and space.

iii. Contact. Objects influence each others' motions if and only if they touch.

What else might you know about objects?

- Object permanence in 3.5 month-olds?
- http://web.uvic.ca/~lalonde/Psyc435A/object/

Spelke, et al., Origins of Knowledge

- **What's the peripheral origins thesis and the central origins thesis?**
- Peripheral origins thesis
  - Perception and action as the basis of knowledge
- Central origins thesis
  - Initial concepts become the basis of later concepts

Spelke, et al., Origins of Knowledge

- **What do Spelke et al., claim is true about infant reasoning in general?**
- Active representations
  - Infants can represent states of the world they no longer perceive
- Core knowledge
  - Infant reasoning in “core” areas is the same as mature adult reasoning.

Spelke, et al., Origins of Knowledge

- **What are the 4 constraints on object motion that they look at?**
- Core
  - Continuity -- objects only move on connected paths; they do not jump in place of time
  - Solidity -- objects only move on unobstructed paths; no two objects occupy the same place at the same time.

Spelke, et al., Origins of Knowledge

- Not core
  - – Gravity -- objects move downward without support
  - – Inertia -- objects do not change their motion spontaneously.

Spelke, et al., Origins of Knowledge

- **What's the argument for why we should think continuity and solidity are "core" and gravity and inertia aren't?**
- Argument from adult patterns of error.
- Never judge that objects will move discontinuously or pass through other objects
- Frequently misjudge object trajectories

Spelke E. S., K. Breinlinger, J. Macomber, and K. Jacobson. "Origins of knowledge." *Psychol Rev* 99, no. 4 (October 1992): 605-32.

Spelke, et al., Origins of Knowledge

Consistent = superficially novel but respects solidity & continuity.
Inconsistent = superficially familiar but violates solidity and continuity.

Figures removed due to copyright restrictions. Please see: Spelke E. S., K. Breinlinger, J. Macomber, and K. Jacobson. "Origins of knowledge." *Psychol Rev* 99, no. 4 (October 1992): 605-32.

Spelke, et al., Origins of Knowledge

- **Are you convinced? What are alternative accounts? (They mention two).**
- Greater the distance between initial and final position of the ball = longer looking
- They are looking longer at the expected position -- where the ball landed in the past.
- (Note -- this might not reflect knowledge about solidity; just expectations based on the habituation).

Spelke, et al., Origins of Knowledge

- Does this solve

the problems?

How?

Figures removed due to copyright restrictions. Please see:
Spelke E. S., K. Breinlinger, J. Macomber, and K. Jacobson. "Origins of knowledge." *Psychol Rev* 99, no. 4 (October 1992): 605-32.

Spelke, et al., Origins of Knowledge

- Other problems?
- Actually saw final position of ball in the control experiments before looking time started.
- Control positions were “more familiar” than test ones.

Spelke, et al., Origins of Knowledge

Please see:
Spelke E. S., K. Breinlinger, J. Macomber, and K. Jacobson. "Origins of knowledge." *Psychol Rev.* 99, no. 4 (October 1992): 605-32.

Core principles or not?

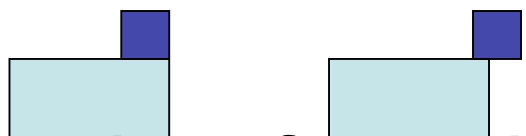
- Maybe infants learned to expect continuity over the course of the habituation trials.
- And what about gravity?

Developing object knowledge

- Any contact v. contact from below

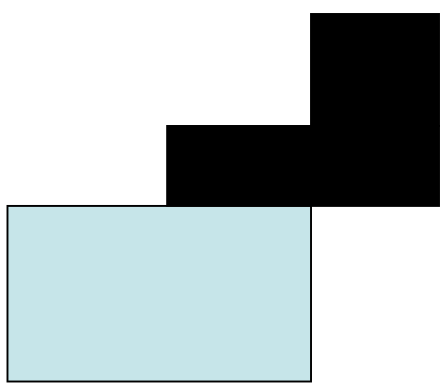
- By 4.5 to 5.5 months of age, however, infants come to distinguish between the two types of contact.

- Initially, infants believe that the box will be stable even if only a small portion of its bottom surface rests on the platform.



- By 6.5 months of age, however, infants expect the box to fall unless half or more of its bottom surface lies on the the platform.

- Eventually infants come to recognize that the overall shape of the box affects its support.



What’s the relationship between number and objects?

- In order to know “how many” things there are you have to individuate objects.
- But you might be able to individuate objects but
  - Only represent one a time
  - Only represent a few at a time
  - Only represent approximations (a lot; a little)
  - Represent all of these but not represent relations between them (adding,subtracting)

Two intuitions about number

- “The knowledge of mathematical things is almost innate in us … This is the easiest of sciences, a fact which is obvious in that no one’s brain rejects it;for layman and people who are utterly illiterate know how to count and reckon.” (Roger Bacon;1219-1294)

Two intuitions about number

- "It must have required many ages to discover that a brace of pheasants and a couple of days were both instances of the number two."(Russell, 1872-1970)

Core system 1

Approximate number

- Tested on arrays of 8 dots
- Varied continuous extent on habituation
- Shown two displays, both novel with respect to continuous extent
- Do babies look longer at the array with the same number of dots or different number of dots?

Core system 1: **Approximate** representations of large numbers

- Why do we think this is “approximate”?
- Because it’s dependent on ratio
- 6-month-old infants can discriminate numerosities with a 1:2 ratio (8 dots v. 16; 16 v. 32) but not a 2:3 ratio (8 v. 12; 16 v. 24).
- 10-month-olds can do 2:3
- Adults can do 7:9

Core system 1: **Approximate** representations of large numbers

- Why do we think this applies to large numbers?
- Because it fails for small ones …
  - Infants can't discriminate arrays of 1 v. 2; 2 v. 4 and 2 v. 3 dots when continuous extent is varied across habituation trials.

Core system 1: **Approximate** representations of large numbers

- Why do we think these are abstract representations? (Rather than something specific to visual stimulation)
- Because they are cross-modal.
  - Infants can track the number of sounds (controlling for rate and duration).
  - Sounds are subject to the same ratio limits: 1:2 at 6 months; 2:3 at 9 months
- Because they support computations.

Core system 1: **Approximate** representations of large numbers

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Core system 1: **Approximate** representations of large numbers

- Baseline looking times to 5 v. 10 were not significantly different.
- But infants who had seen an addition operation looked longer at 5.
- Infants who had seen a subtraction operation looked longer at 10.

Core system 1: **Approximate** representations of large numbers

- Analog magnitude system
  - True for loudness, brightness, size, temporal discrimination.
- Conforms to Weber's law: the discriminability of two stimuli depends on their ratio.
  - Easy to tell one candle from two; hard to tell 18 candles from 19.
  - Try it -- say "the" while trying to tap 4 times; now 28.
  - For 4, variance is very small (3-5). For 28 variance is very large, (14-40)

Core system 2: Exact small number

- Tracks both the precise quantity of a small number of objects (3-4)
- And their continuous extent.

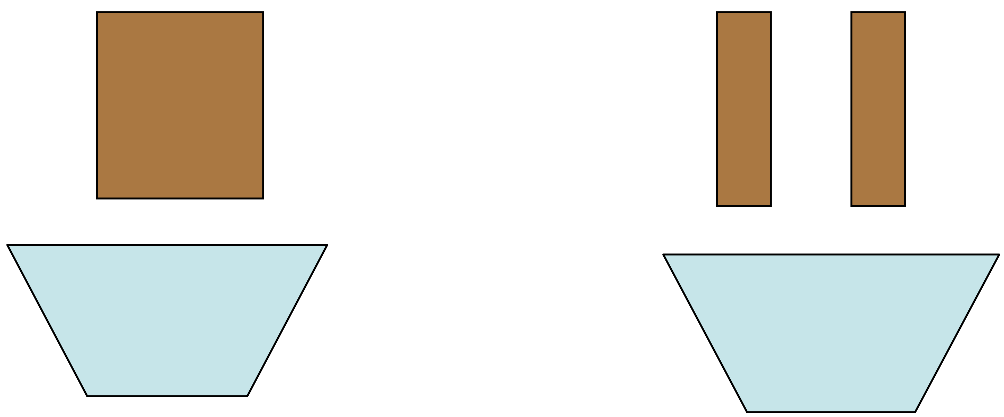
Figure removed due to copyright restrictions.
Please see:
Fig 1c in Feigenson, L., S. Dehaene, and E. Spelke. "Core systems of number." *Trends Cogn Sci* 8, no. 7 (Jul 2004): 307-14.
Comment in: *Trends Cogn Sci* 8, no. 10 (Oct 2004): 447-8; author reply 448-9.

Core system 2: Exact small number

- Given crackers (all the same size), 10-month-olds spontaneously go for the larger number on 1 v. 2 and 2 v. 3
- But they fail on 3 v. 4, 2 v. 4, 3 v. 6 and even on 1 v. 4.
- Note that this is not due to the ratio -- there's an upper limit on the number of objects they can track.

Core system 2: Exact small number

- However, infants can also compute continuous extent.



- In this scenario, they go for the one large cracker over the two small ones.

Core system 2: Exact small number

- Converging evidence:
- Shown 1 object hiding; they didn't search long after retrieving 1.
- Shown 2 objects, searched after retrieving only 1.
- Shown 3 objects, searched after retrieving only 2.
- But shown 4 objects -- looked just like 1 object.

Core system 2: Exact small number

- Is core number related to work with adults on object-based attention?

Core number and object-based attention

- http://ruccs.rutgers.edu/faculty/pylyshyn/DemoPage.html

Core number and object-based attention in babies

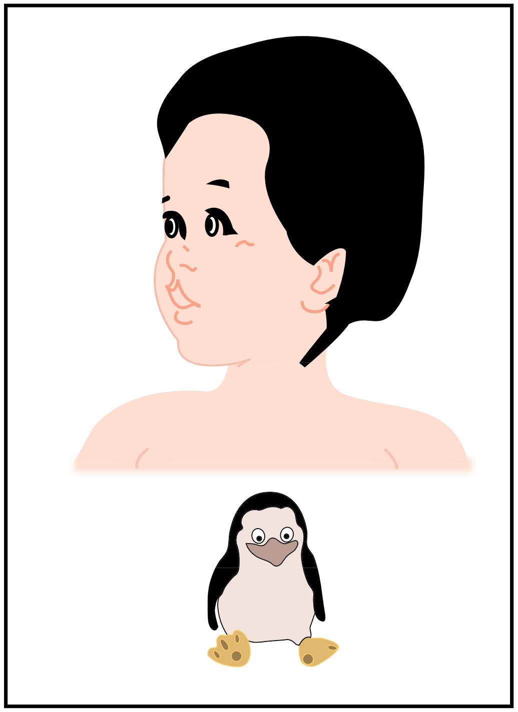


Illustration courtesy of MIT OCW.

Dissociations between systems 1 and 2.

- Large approximate number discrimination is sensitive to ratio; small exact number discrimination is sensitive to absolute number of individuals.
- Large number discrimination is robust over changes in continuous extent; small exact number discrimination is sensitive to changes in continuous extent.

Summary of core systems

What about symbolic understanding of number?

- Two distinct representations of number in infants.
- But neither represents the information we have in integers.
- The large number system doesn’t appreciate that the difference between 1 and 2 is the same as the difference between 14 and 15.
- The small number system doesn’t go past 3 or 4.

What about symbolic understanding of number?

What about symbolic understanding of number?

- The count list of integers tells you that each symbol is in one-to-one correspondence with each event.
- That each succeeding number is exactly one more than the one before.
- That the ordinal position of the last word is the cardinal number of things in the set.

What about symbolic understanding of number?

- When do children understand this?
- Children “learn to count” (as in learn the count list) at 2.
- But it takes another year and a half before they understand how counting represents number.

What about symbolic understanding of number?

- Children start as “one-knowers”
- If you ask for one goldfish, they’ll give you exactly one goldfish.
- But if you ask for 2, 3, or 7 they’ll give you a handful of fish -- never one but they won’t reliably give you more for 7 than for 2.

What about symbolic understanding of number?

- If you ask a one-knower “How many fish on this card?” (Cards contain 1-8 fish).
- They’ll tell you “one” for one fish and “two fish” for everything else.

What about symbolic understanding of number?

- It takes 6-9 months after children are “one-knowers” for them to become “two-knowers”
- It takes 6-months after that for them to become “three-knowers” (typically age 3).
- A few months later, they become able to count.

What about symbolic understanding of number?

- What's going on?
- Possibly related to language learning.
- Children learn one the way they learn "a" or "the" in language -- as a singular determiner.
- Children become "two-knowers" about when they begin to mark plurals in speech.
- Arguably, children then learn to map the arbitrary count list order onto their known quantifiers … and induce "counting".

Number

- So when is number easy?
- When it relies on core systems
- When is number hard?
- When it has to go beyond.