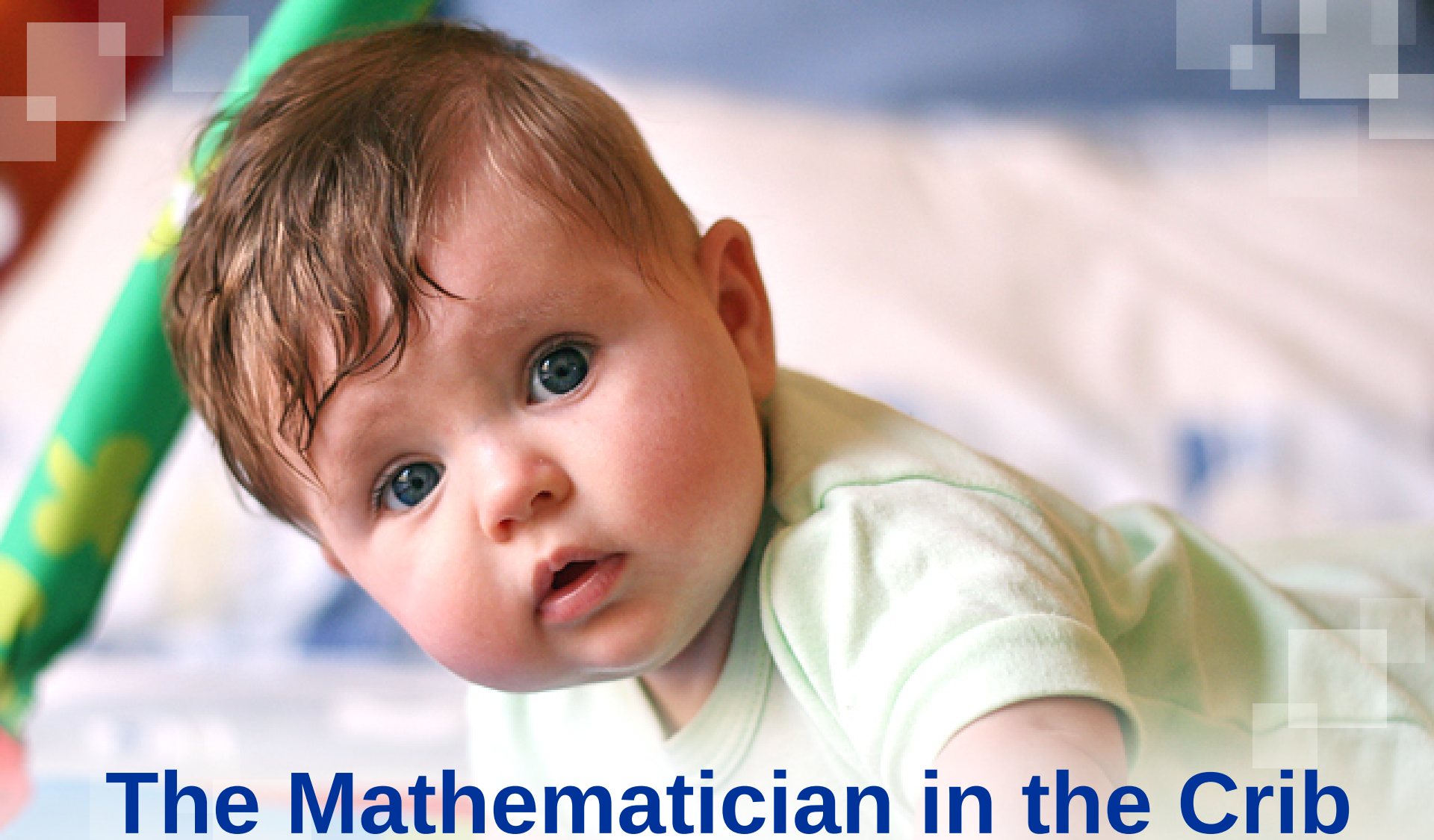


The Mathematician in the Crib

Early Math Understanding in Infants & Toddlers

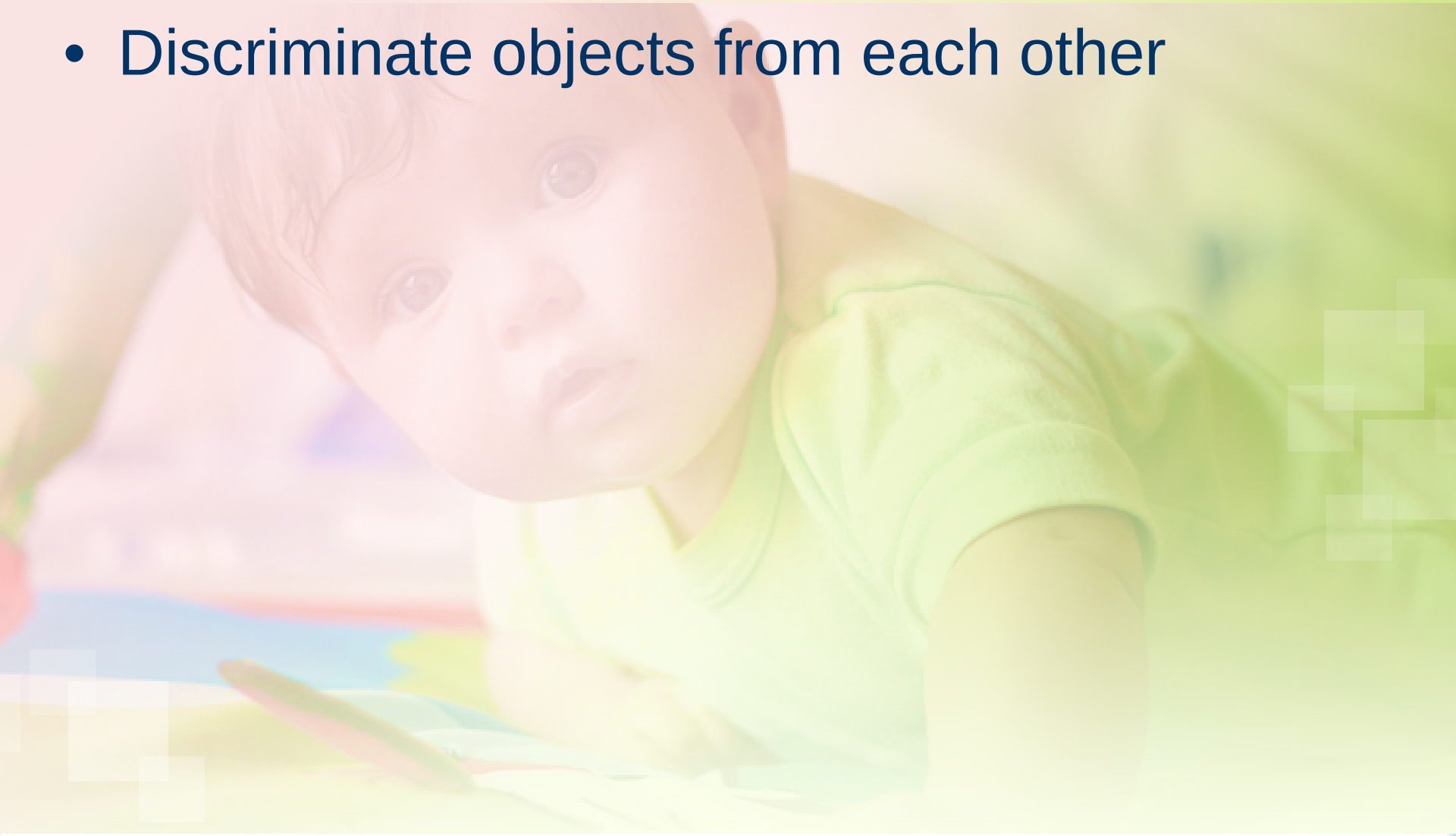
Carol A. S. Morris, Ph.D.

What do you think?

- At what age do you think children understand that 1 + 1 should = 2?
- How do you know?
  - What underlying skills would you look for?
- How would you find out?

Underlying skills

- Discriminate objects from each other



Discriminating numbers of objects

- Habituation/dishabituation paradigm
  - Bored with the familiar, become interested again when presented with something new
  - Babies look longer at novel events
- Can newborns (21-144 hours old) discriminate between arrays of small numbers of objects (dots)? (Antell & Keating, 1983)
  - Were able to discriminate 2 vs 3 dots but not 4 vs 6 dots

How about more dots?

- 6-month-olds:
  - Able to discriminate 8 from 16 dots (1:2), but not 8 from 12 dots (2:3) (Xu & Spelke, 2000)
  - Able to discriminate 16 from 32 dots (1:2), but not 16 from 24 dots (2:3) (Xu, Spelke & Goddard, 2005)
- Similar findings for discriminating:
  - Auditory stimuli (Lipton & Spelke, 2003)
    - Able to discriminate 8 vs 16 tones but not 8 vs 12 tones
  - Visual stimuli (Wood & Spelke, 2005)
    - Able to discriminate 8 vs 16 jumps by a puppet, but not 8 vs 12

Discrimination develops over time

- 6-month-olds are able to discriminate 8 vs 16 auditory tones, but not 8 vs 12 tones
- 9-month-olds are able to discriminate 8 vs 12 auditory tones but not 8 vs 10 tones

How about combinations of information?

- Does pairing visual with auditory information help infants make finer discriminations at an earlier age? (Jordan, Suanda & Brannon, 2008)
  - Paired a tone with a video of a bouncing ball
  - 6-month-old infants were able to discriminate 8 bounces from 12 bounces (2:3) when the video was accompanied by numerical auditory information
    - Could not discriminate without auditory information or with non-numerical auditory information
- What does that mean for you as a caregiver of infants?

Is it number? Or some other feature?

- Other perceptual features?
  - Changes in the size of the display?
  - Brightness or density of the display?
- Studies that control for these features still find similar results

Underlying skills

- Discriminate objects from each other
- Properties of objects
  - Object permanence
    - Objects continue to exist when out of sight
    - Piaget:
      - Develops at about 8 months
      - Tested with A-not-B search task

The A-not-B Task

- Infant is shown a toy being hidden in the same area (Site A) repeatedly; infant reaches toward Site A to get the toy
- Then, while the infant watches, the toy is hidden at Site B
- Toward which site (A or B) will the infant reach?
- A-not-B Error
  - The infant reaches toward Site A, even though he/she saw the toy be hidden at Site B

Explanations for the A-not-B Error

- Piaget:
  - Infant has not yet developed object permanence
- Thelen: (Thelen & Smith, 2006)
  - Memory for previous reaches becomes input for subsequent trials
  - Memory for previous reaches is stronger than memory of witnessing change in toy's position
  - Can change infant's response by varying the delay, the number of prior reaches to Site A, by changing the infant's position in between reaches

Other tests for object permanence

- Violation-of-expectation paradigm
  - Infants spend more time looking at events which are unexpected
  - Has been used to show that infants have greater understanding of certain properties of objects at earlier ages than previously thought
  - Video clip: https://www.youtube.com/watch?v=uwAGJDMIVsU&list=PL8XVPOU-7gtyUhWZ9A8T0eSrogadvX7CF&index=2

But can babies add? Or subtract?

- Wynn:
  - Used the violation-of-expectation paradigm
  - Showed 5-month-old infants scenarios in which
    - 1 + 1 = 2 and 1 + 1 = 1
    - 2 – 1 = 1 and 2 – 1 = 2
  - What do you think happened?
  - Video clip: https://www.youtube.com/watch?v=5BmxDpLqJWA&index=3&list=PL8XVPOU-7gtyUhWZ9A8T0eSrogadvX7CF
  - Infants looked longer at the incorrect event

Are they really adding and subtracting?

- Will infants look longer at events that are physically impossible? Or only at events that are arithmetically impossible?
  (Simon, Hespos & Rochat, 1995)
- Examined whether the identity of the objects made a difference
  - 1 Elmo + 1 Elmo = 2 Elmos
    = 1 Elmo (impossible arithmetic)
    = 1 Elmo + 1 Ernie (impossible identity)
    = 1 Ernie (impossible identity & arithmetic)
  - 2 Elmos – 1 Elmo = 1 Elmo
    = 2 Elmos (impossible arithmetic)
    = Ernie (impossible identity)
    = Elmo + Ernie (impossible identity & arithmetic)
- What do you think happened?

Are they really adding and subtracting?

- Found same results as Wynn: infants looked longer at impossible arithmetic events, regardless of the violation of identity
- “Numbers are labels for . . . collections of objects, and arithmetic is a language for the results of interactions between those objects.”
- “Any understanding of numerical or arithmetical concepts ought to be intimately bound up with an understanding of physical objects and the conditions of their existence.”

How many?

- Can they only do it with small numbers of objects?
- 9-month-olds were shown a video display (McCrink & Wynn, 2004)
  - 5 objects, add 5 = 5 or 10
  - 10 objects, take away 5 = 5 or 10
- Babies looked longer when
  - 5 + 5 = 5 rather than 10
  - 10 – 5 = 10 rather than 5

What does this mean?

- Wynn concluded that there is a “dedicated mental mechanism specific to number . . . which may have evolved through natural selection.”

How about other numerical tasks?

- Ordinal numerical competence
  - "Greater than" or "less than"
  - 2-year-olds able to were able to learn to "choose the winner" which was the one with the larger quantity (Brannon & Van de Walle, 2001)
    - Task did not use the words "more than" or "less than"
  - Their performance was not related to the relative size of the displays
  - Scores on verbal counting measures were significantly associated with performance on the ordinal comparison task
    - Only needed one correct answer on counting task to improve score on the ordinal task
    - Learning to count may make ordinal relationships more obvious

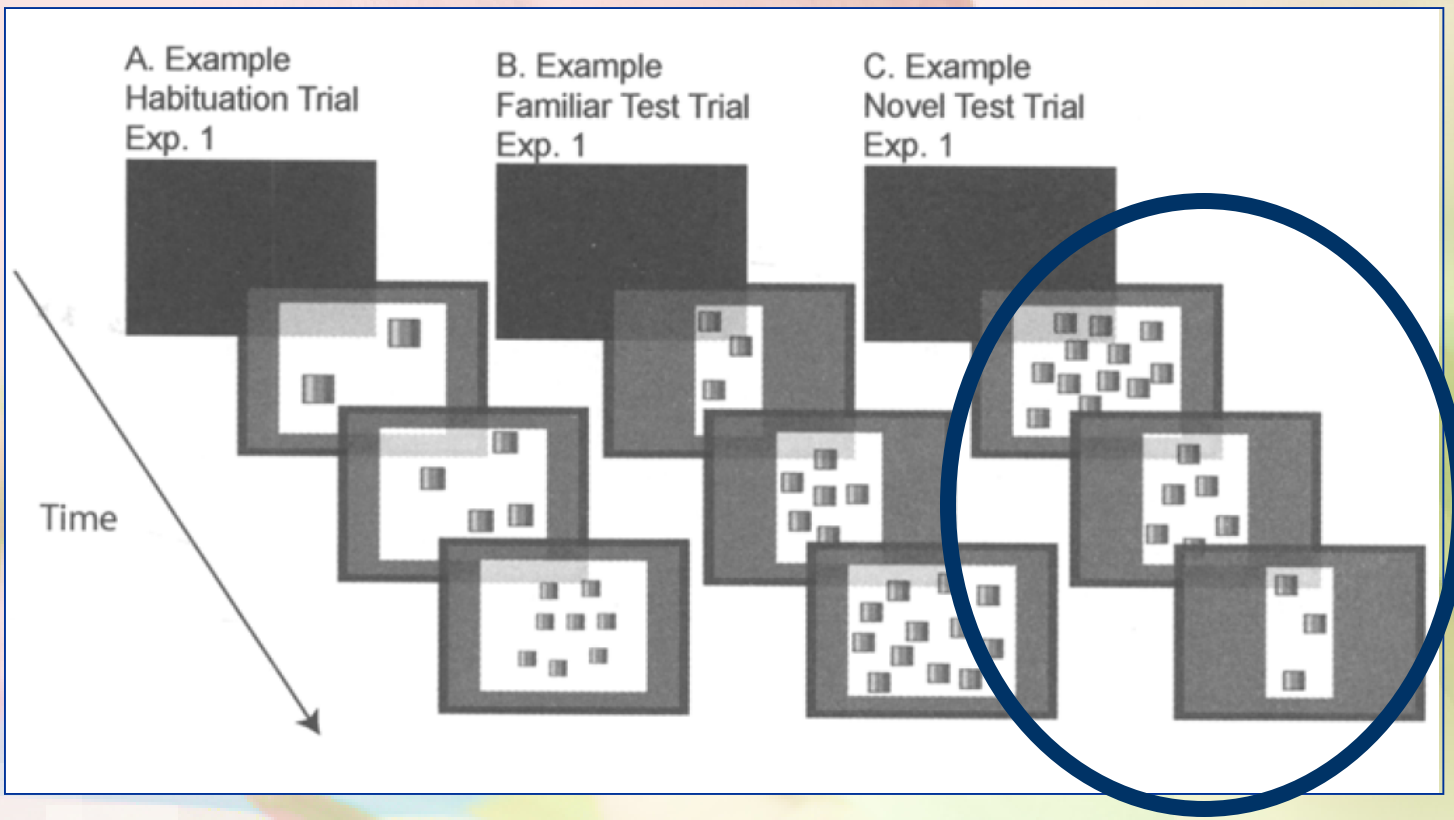
Can younger babies do that?

- 11-month-olds could discriminate a reversal in ordinal direction (Brannon, 2002)
  - Going from “more than” to “less than,” then reversing: from “less than” to “more than”
- 9-month-olds could also do it, but they needed other cues
  - Number, size, and surface area

What's the developmental sequence?

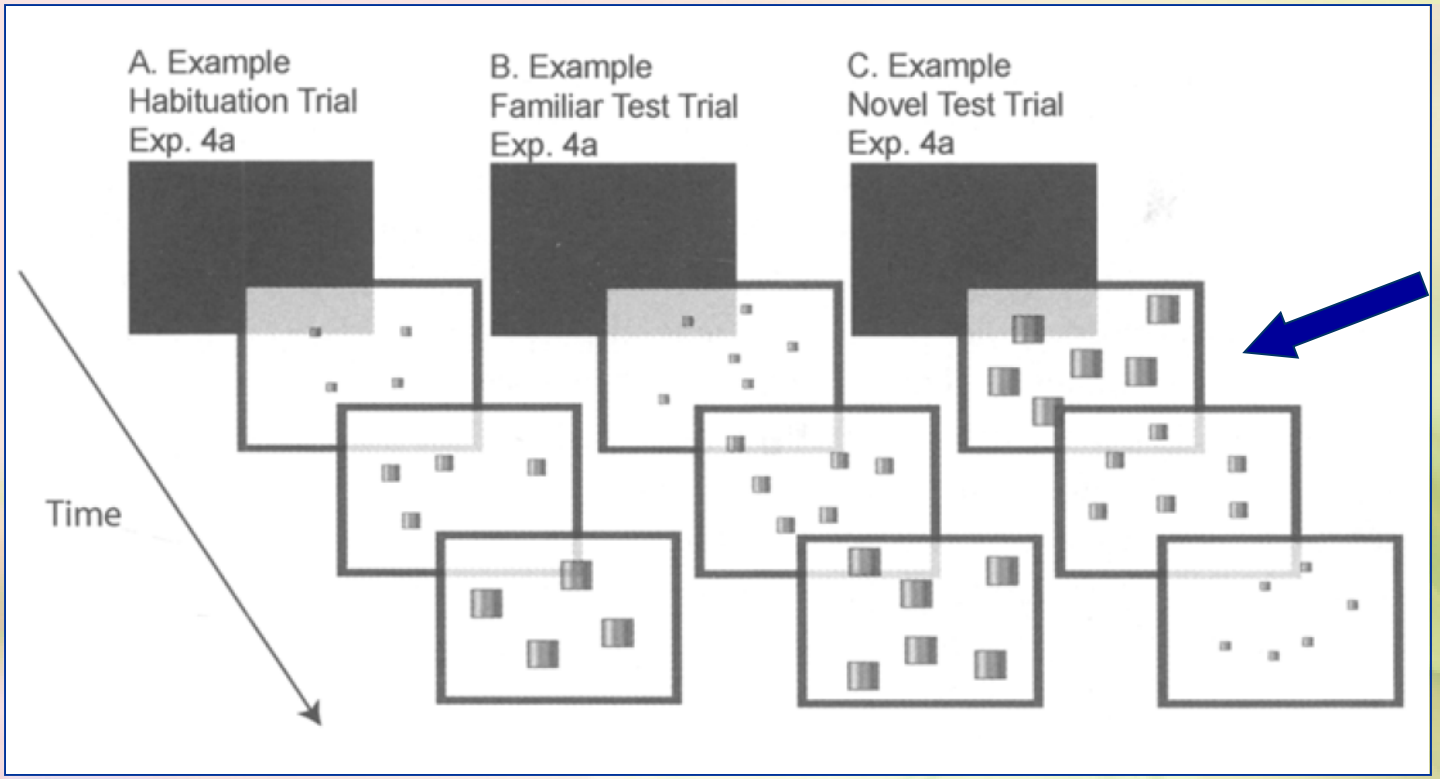
- Series of experiments by Suanda, Tompson, & Brannon (2008)
  - 11 mos olds could discriminate reversal
  - 9 mos olds could not
- Did the 9 mos olds need more time?
  - Longer looking time did not help
- Reversals in size or surface area instead of number did not help either
  - But the 11-month-olds could discriminate on any of the three criteria
- When 9-month-olds were given multiple cues (size, surface area, and number), they could discriminate the ordinal reversals

9-month-olds vs 11-month-olds



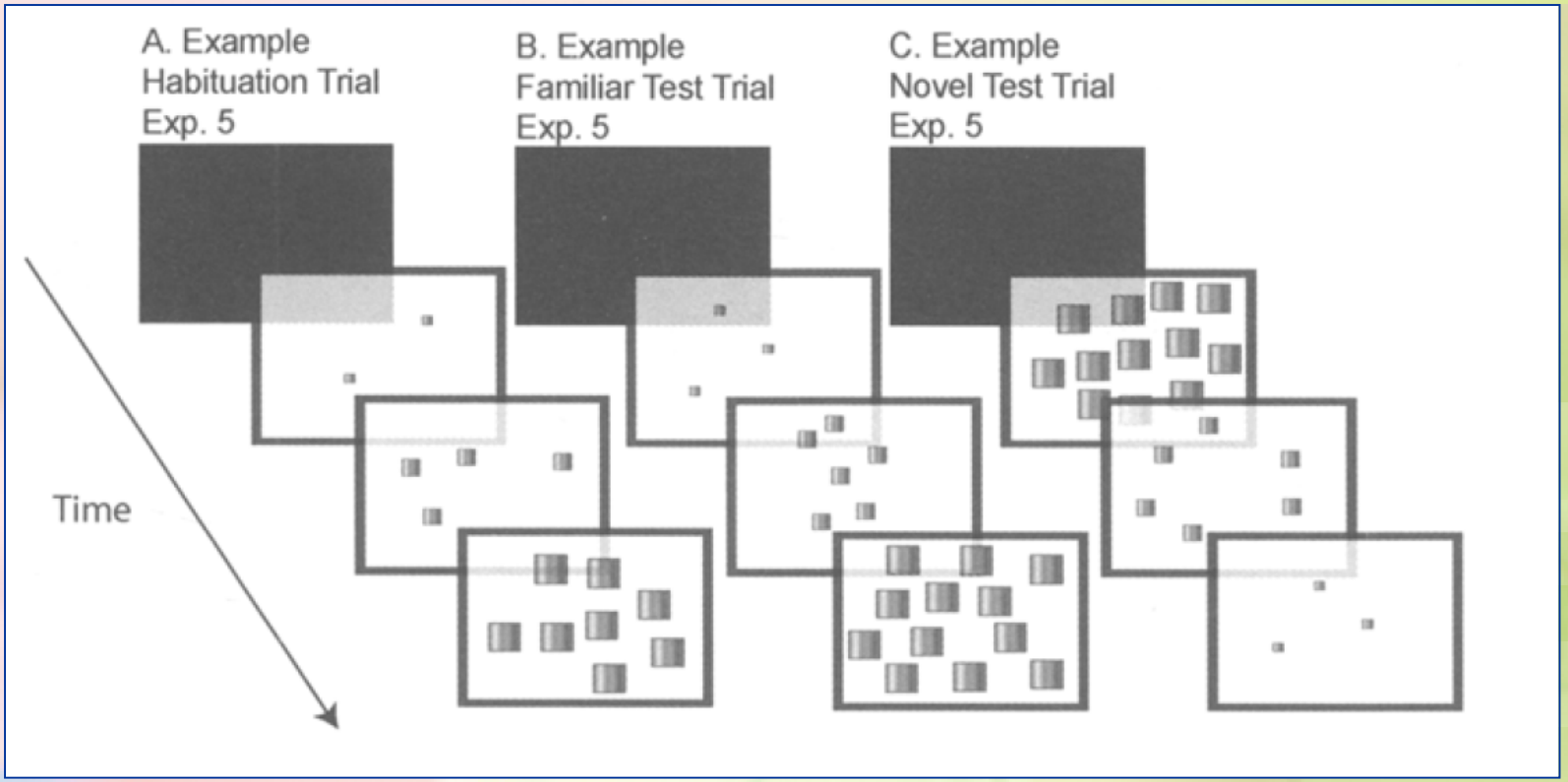
- 11-month-olds could discriminate this reversal
- 9-month-olds could not

Size-based sequence



- 9-month-olds could not discriminate this reversal

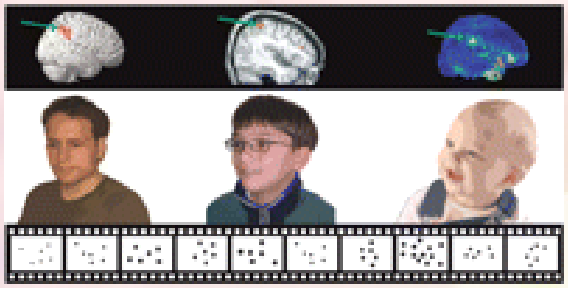
Size, area & number combined



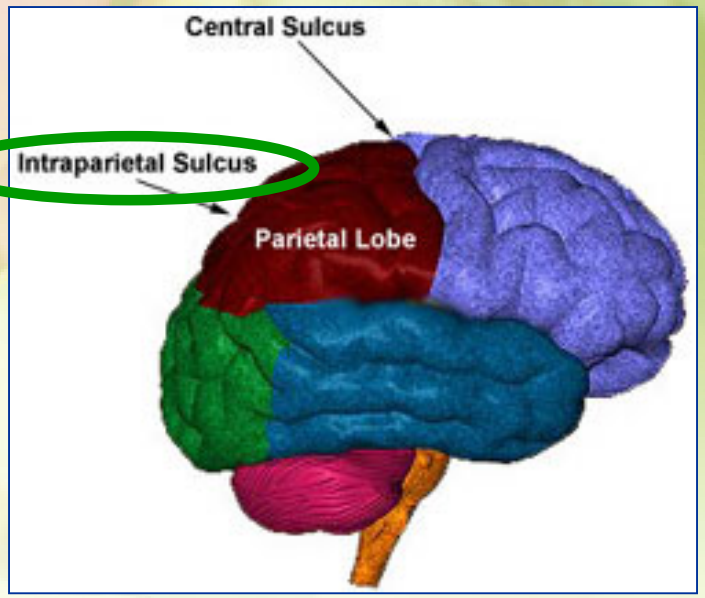
- 9-month-olds could do this one!

What's going on in the brain?

- Remember Wynn's proposal of an innate mental mechanism . . . ?
- Neuro-imaging studies show that the intraparietal sulcus "lights up" in numerical discrimination tasks



(A different area lights up for identity changes – Remember the Elmo study?)



What does all of this mean for you?

- What do you think you can do, as teachers of infants and toddlers, to enhance these skills?

What does all of this mean for you?

- With SES controlled, parents who talked more about number when their children were toddlers (14-30 months old) had children who knew more about the cardinal meaning of numbers at 46 months old
- “Number talk”
  - Cardinal values (“Five little monkeys . . .”)
  - Counting (“Let’s count the balloons . . .”)
  - Naming digits (“That’s a 3.”)
  - Units of measure (“We need 2 cups of flour.”)

Finding math everywhere

- Case study of one-to-one correspondence activities in the life of 12-38 month old
  - Aligned objects
    - Alignment of individual items from two sets of items
      - A cup on each napkin
  - Objects with slots
    - Alignment between free-moving objects and a corresponding set of holes or slots
      - Shape sorter
  - Distributed objects
    - One-to-one distribution of objects to people, animals, or dolls
      - Feeding one treat each to two dogs

Finding math everywhere

- Tagging objects and people
  - Acting on each object or person in a group once and only once (can be verbal or non-verbal)
    - Saying “step” on each stair step
- Tagging events
  - Performing an action for or verbally tagging each event in a series of events
    - Saying “Bless you. Bless you.” when someone sneezes twice.
- Turn-taking
  - Performing actions in alternation with another person’s actions
    - Taking turns with a toy

Group activity

- Think of three different types of everyday activities that teach one-to-one correspondence
  - **Aligned objects**: Alignment of individual items from two sets of items
  - **Objects with slots**: Alignment between free-moving objects and a corresponding set of holes or slots
  - **Distributed objects**: One-to-one distribution of objects to people, animals, or dolls
  - **Tagging objects and people**: Acting on each object or person in a group once and only once (can be verbal or non-verbal)
  - **Tagging events**: Performing an action for or verbally tagging each event in a series of events
  - **Turn-taking**: Performing actions in alternation with another person's actions

Vygotsky was right!

- “One striking aspect of these observations is the variety of ways children gain information about one-to-one correspondence in interactions with groups of people, rather than through object manipulations alone.” (Mix, 2002)

But wait a minute . . .

- If infants can do all this, why do 3-year-olds fail Piaget's conservation of number task?
- http://www.youtube.com/watch?v=GLj0IZFLKvg&feature=related

Why might preschoolers fail?

- Task demands
  - Required to interpret relational terms
    - “more” and “less” and “same as”
- Requirements of task rarely occur in day-to-day interactions
  - Aligned objects occurred infrequently compared to other activities
- Unable to ignore the perceptual differences
- Any other ideas?

Role of culture?

- What role do you think culture plays in the development of “number sense” in young children?

Role of culture?

- How numbers are represented creates different cognitive tools
  - Base-10 system in Japanese
    - 12 = “ten-two”
  - Children from cultures which use a base-10 system
    - performed better on a task involving place value
    - had less difficulty reciting the numbers and counting objects above 10

Role of culture?

- Attitude that success comes from hard work
- Classmates serve as resources rather than competition
- Teachers examine a few problems in depth instead of many problems superficially
- Children’s errors are used as learning tools for the group

On the other hand . . .

- In early childhood:
  - Japanese children spend 4x as much time in free play as U.S. children
  - The focus is on social development, such as the development of empathy
  - Japanese schools emphasize children supporting each other in learning together, not on test scores

A quick review

- Babies have a sense of number from very early on
- Babies can discriminate . . .
  - numbers of objects at 5 months old (1:2)
  - finer distinctions as they get older
    - having multi-sensory cues helps
  - ordinal reversals with multiple cues at 9 months old
  - ordinal reversals with single cues at 11 months old
- Babies know that 1 + 1 should not equal 1!

A quick review

- Talking to young children about numbers increases their “number knowledge”
- Cultural “tools” and values influence the development of math skills
- Math is everywhere!

Questions?

Thank you!

Enjoy the rest of the conference!

Further reading

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