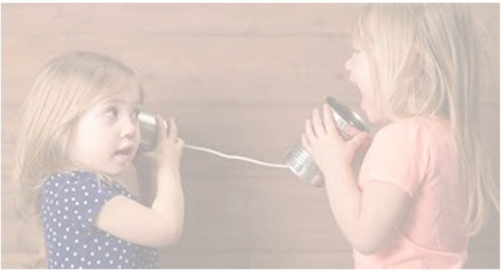
Numeracy development and disorders

Dr. Anna Samara

Lecture 10, 12/11/2020

School Room, 2012. Mark Wickline

Roadmap for Lectures 4 – 6 & 8

Oral language skills	Written language skills	Numeracy skills
		

Critical skills to access the school curriculum

Theory ⟷ Practice

Specific learning disabilities that affect LLN

Today's lecture

- The origins of numerical ability
  - Discrimination studies
  - Arithmetical transformation studies (extra study slides)
  - Theories
- Disorders of numeracy (Developmental Dyscalculia)
  - Key areas of difficulty
  - Theories

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Learning outcomes

- Define the term “numerosity”
- Provide evidence for and against the view that humans are born with a ‘number sense’
- Describe methods used to study infants’ numerical and arithmetic skills

Number are used to …

….to order things

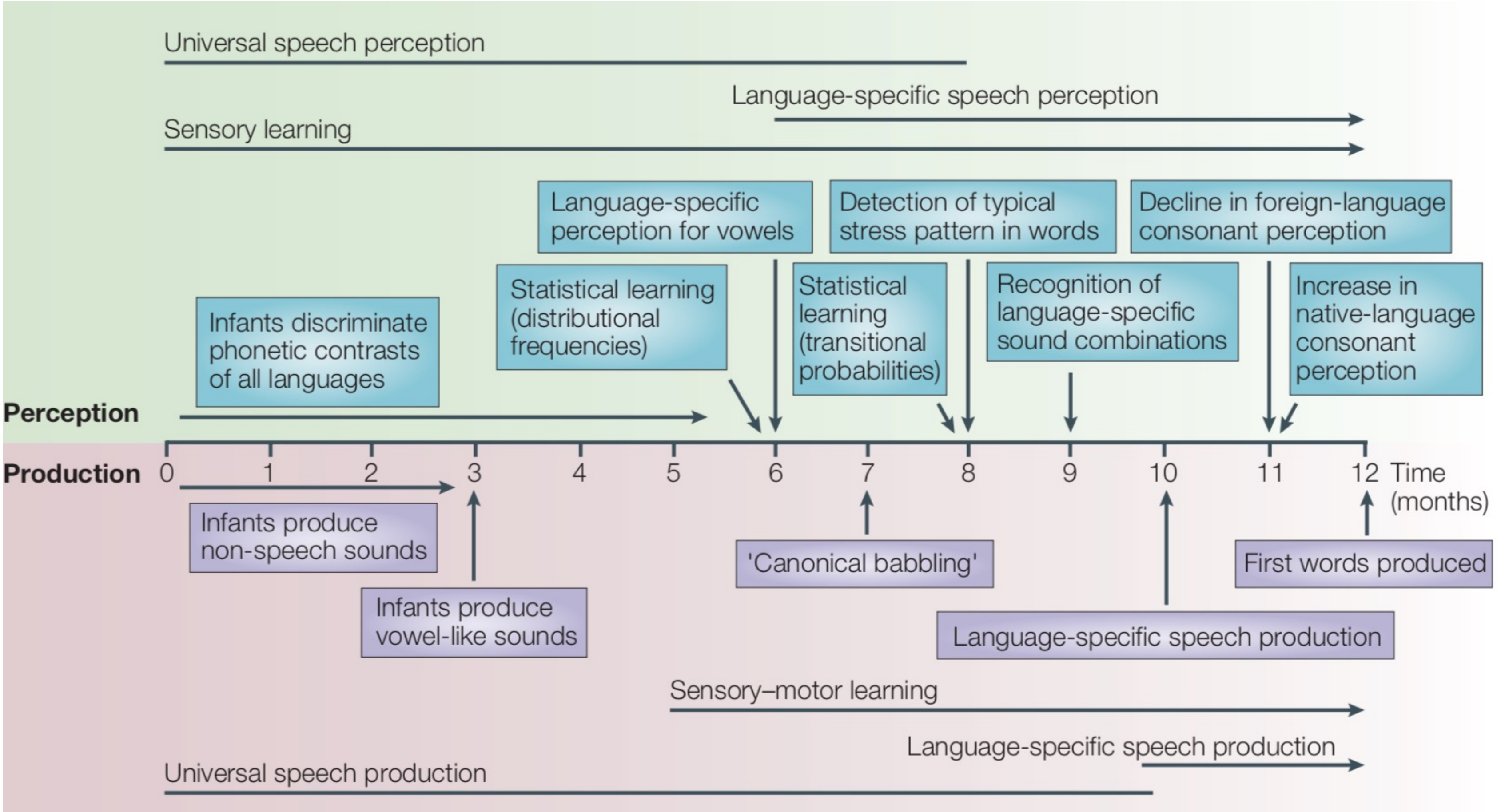
….to label things

….to denote magnitudes (*cardinality*)

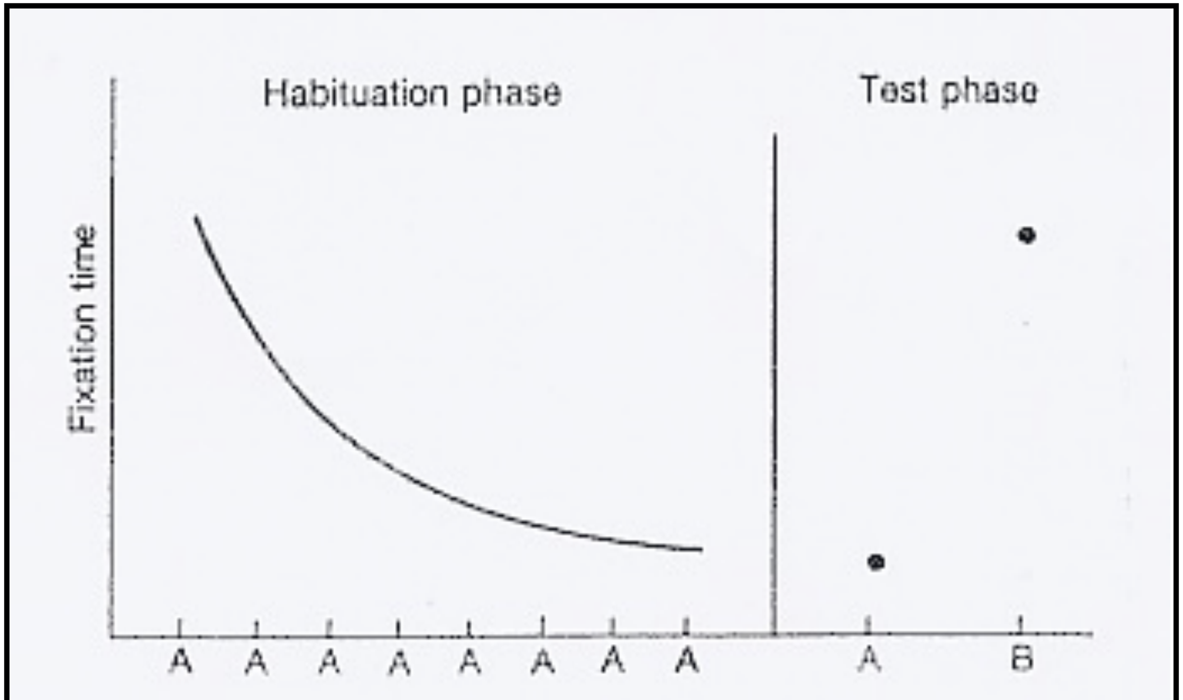
What is numerosity?

- **Cognitive counterpart to the term ‘cardinality’ (used by mathematicians): ‘How many things in a set’**
- Understanding this concept involves understanding:
  - Sets of things (not necessarily visible) have numerosities
  - Numerosities can be altered by combining/removing subsets etc
  - One-to-one principle: Two sets have the same numerosity if and only if members of each can be put in 1-to-1 correspondence with none left over
  - Difference between cardinality & ordinality

Early numerical abilities?

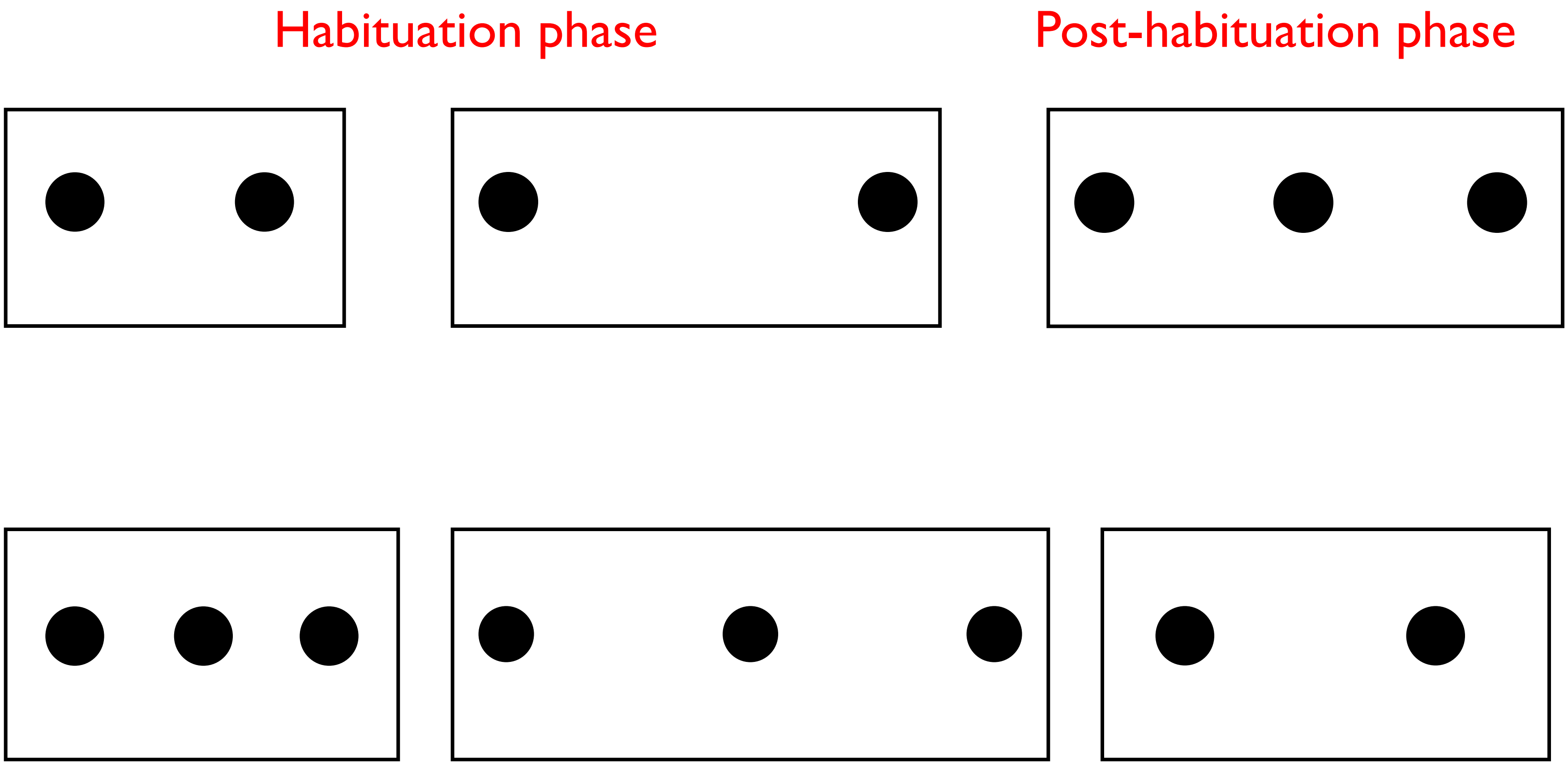


Methods: Habituation paradigms



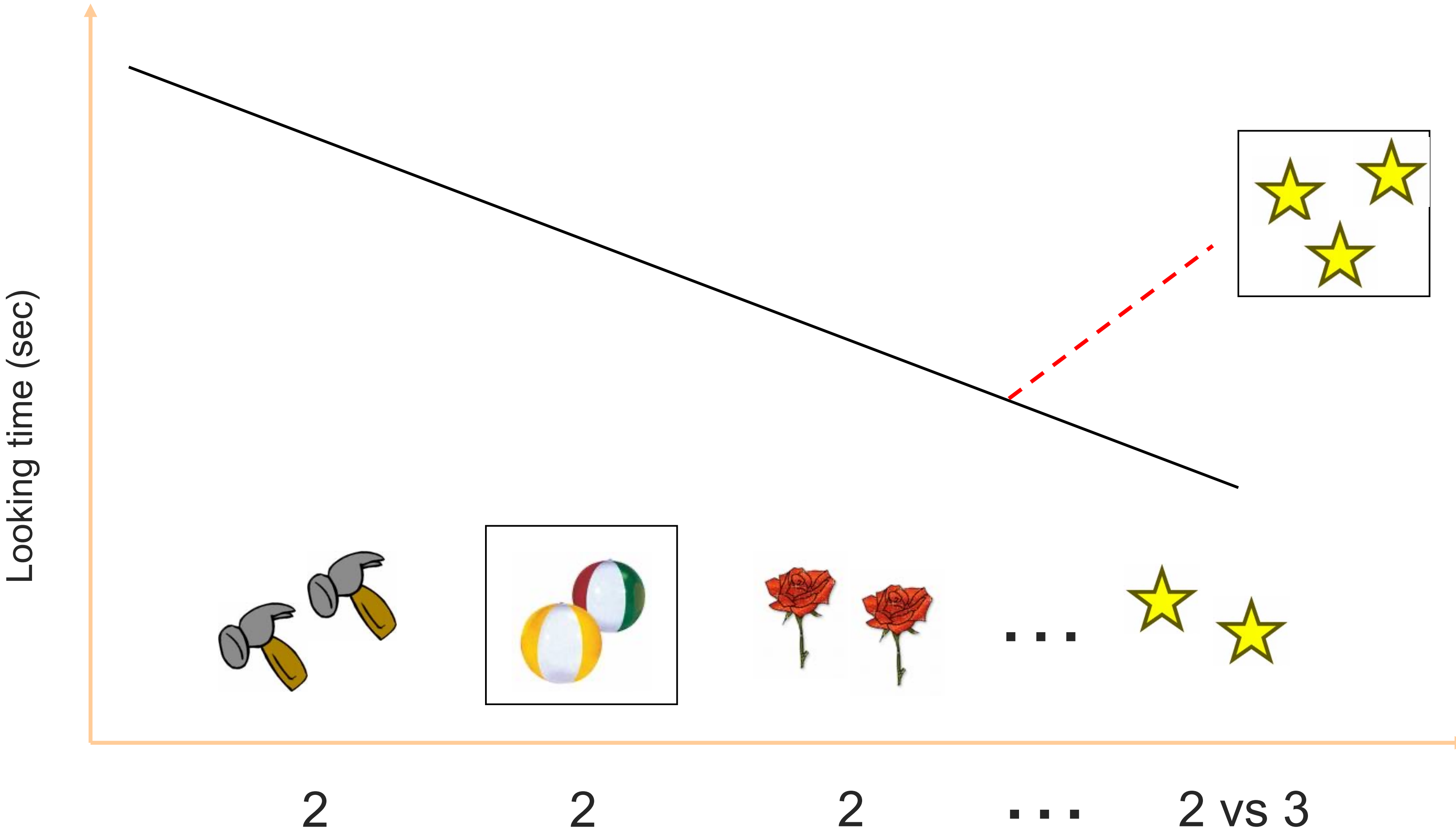
Do infants represent an abstract number concept?

Innate capacity to represent numerosities?



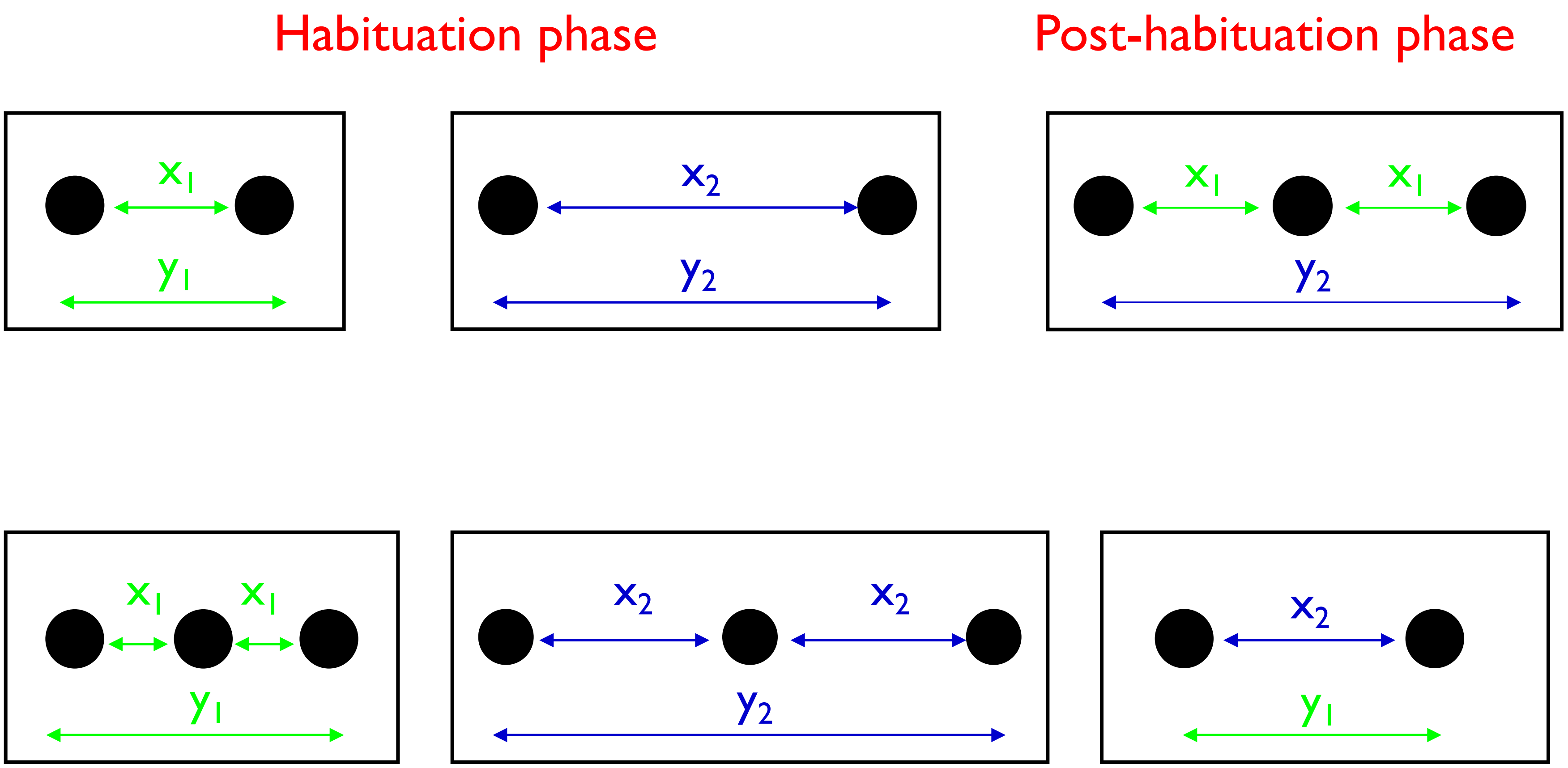
Antell & Keating, 1983

Homogeneity effects



Starkey, Spelke, and Gelman (1990)

A true numerical ability?



Starkey & Cooper (1980)

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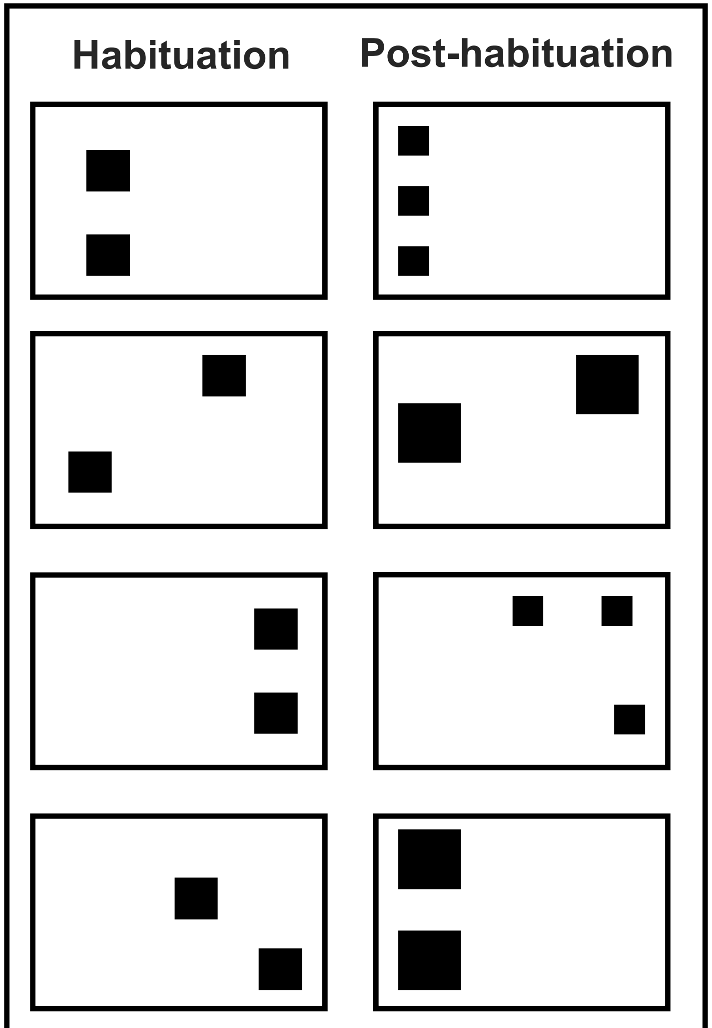
Nonnumerical model of infant abilities

- Many other continuous variables correlate with number (perceptual confounds)
  - Overall surface area (i.e., how much space they take over); brightness; total length of contour; density; size of individual elements etc.
- Reinterpretation of previous results regarding infants' discrimination of small visual sets
  - Numbers are represented only **implicitly**
  - The origins of this knowledge are rooted in such non-numerical, **domain-general** competencies

Numbers or contour?

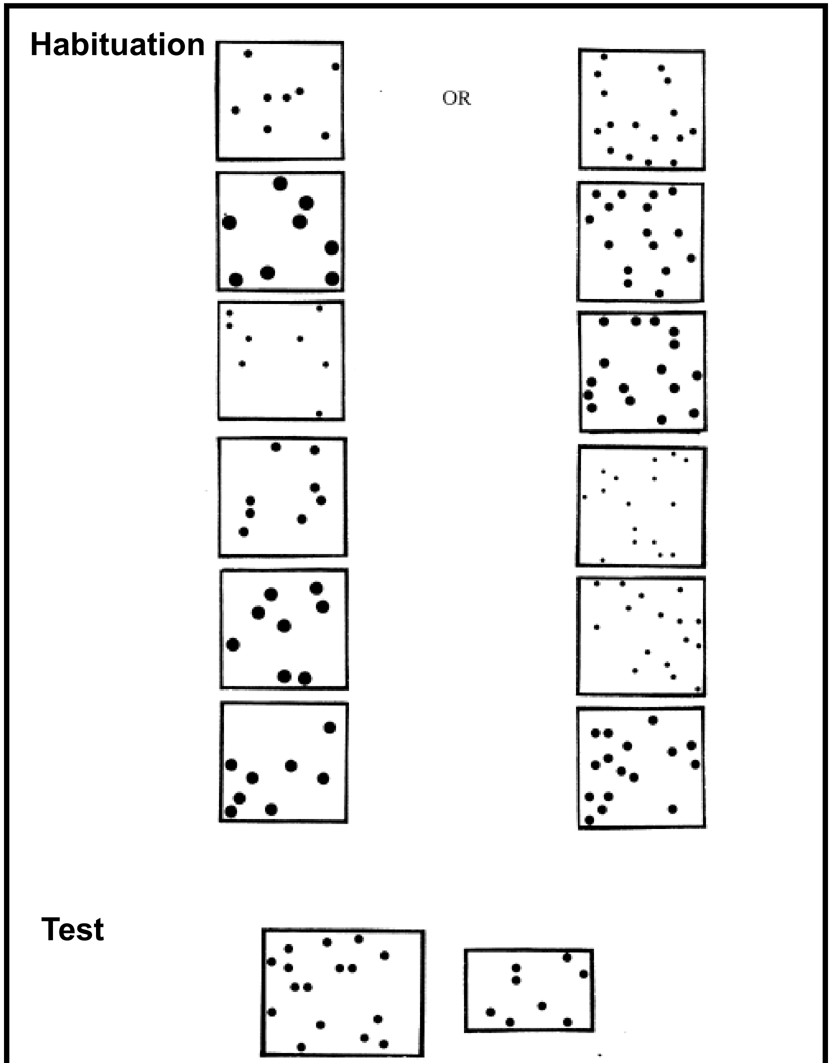


- Clearfield & Mix (1999)
- 6 to 8-month-olds
- Novel number, familiar contour length vs. familiar number with **novel contour length (total perimeter of items in the display)**

- When continuous and purely numerical quantity are put into conflict (rather than controlled or randomised), continuous quantity is a more powerful cue

Another shortcoming:

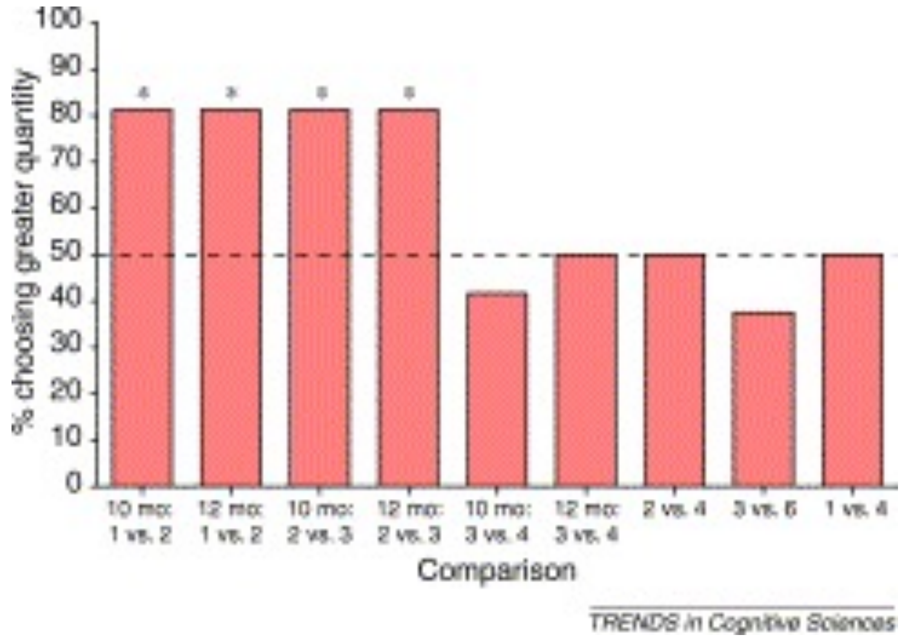
Infants were presented with **small numbers of entities**: 1,2, 3 objects



- Xu & Spelke (2000): Beyond subitizing range
- brightness, density, dot size, distribution controlled for
- 8 vs 16 dots (1:2 ratio) discriminated
- Replicated by Lipton & Spelke, (2003); Xu & Arriaga (2007); Xu, Spelke & Goddard (2005)
- Real numerical abilities underlying approximate number representations
- **Small number discrimination (e.g. 1 vs. 2) ? NO (Xu et al. 2005)**

Feigenson, Carey and Hauser (2002)

- 10-to-12-month-old infants
- Two amounts of crackers, placed one at a time in separate containers
- Dependent variable: which container the children preferred to crawl to
- Infants chose the container with more crackers when the number of crackers in each container was less than 4 (e.g., 1 vs. 2 or 2 vs. 3)
- When one container held 4 or more crackers (e.g., 3 vs. 6, or even 1 vs. 4), the infants chose randomly



Feigenson, Carey and Hauser (2002)

- Object-file system
  - For numerical computational abilities a size signature was found. Only when the number of crackers involved was within the size limits of an object-file system the children were able to reach a judgement of “greater than...”
  - Infants **were not relying on an analogue-magnitude** representation system. Instead, the set-size signature indicates that infants used a system dedicated to tracking small numbers of objects.

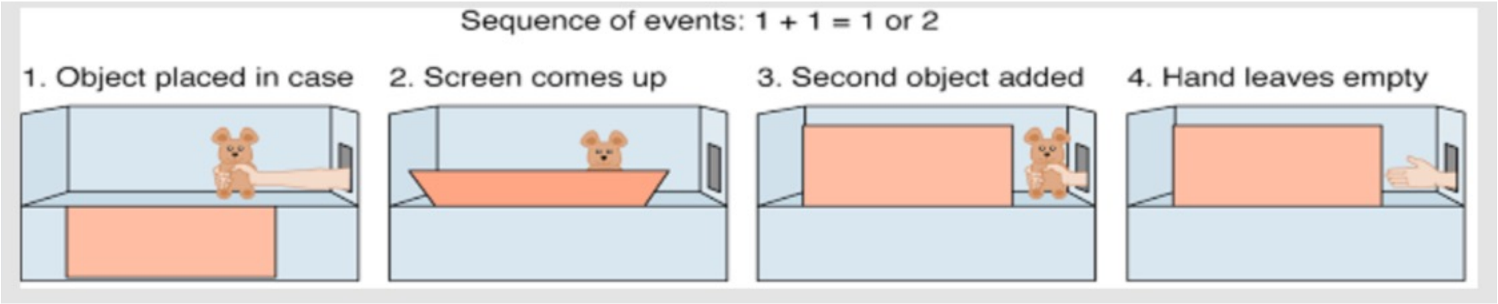
Take home (reconciling the data)

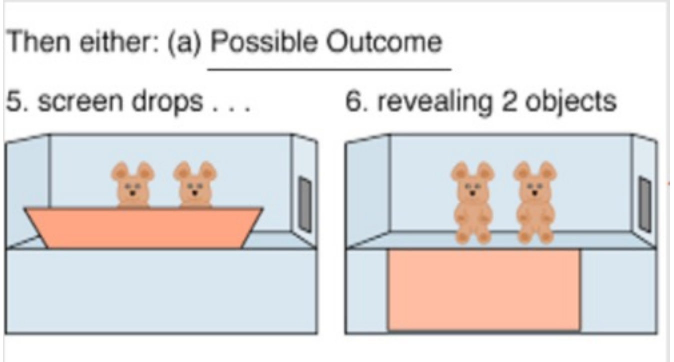
- Infants of 5-6 months (and probably earlier), do respond discriminatively to small numerosities
  - "Object-file" system responsible for precisely keeping track of small numbers of individual objects and for representing information about their continuous quantitative properties
- They can also discriminate larger numerosities when the proportional difference is sufficiently large
  - When numerosity is controlled, infants fail to extract information about continuous properties (Brannon et al., 2004), thus, large-number arrays appear spontaneously to trigger numerical representations only

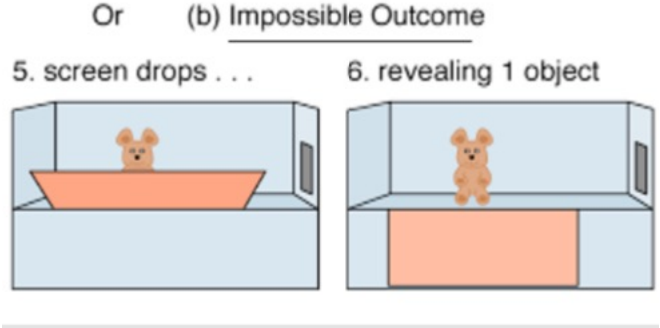
Extra study slide

Methods: Violation of expectancy paradigms

- Do infants perform **basic mathematical operations** on numbers ?







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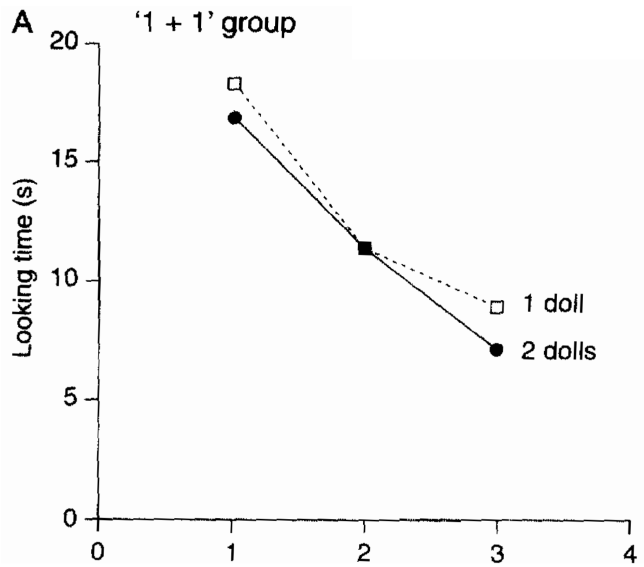
Extra study slide

Wynn (1992). Nature

- Do 5-month-old infants have some knowledge on the relationship between elements?
  - 1 + 1 = 2 or 1
  - 2 - 1 = 1 or 2
  - 1 + 1 = 2 or 3
- Infants looked longer at the impossible outcome, i.e., able to calculate the precise outcomes of simple addition and subtraction



Conclusions re: sensitivity to numerosity

- Do infants lack numerical competences?
  - NO! They can discriminate between quantities (and from 6 months can “add” and “subtract” 1 and 2)
  - Number sense for approximate large numbers
  - Controversy around the interpretation of infants’ success for small numbers: sometimes it is numerosity and sometimes perceptual correlates (and this may depend on stimuli presented and the behavior required (Feigenson, Dehaene, & Spelke 2004))
- Two core systems but they are both limited in their representational power. Neither system supports concepts of fractions, square roots, negative numbers, etc.

Core & recommended reading

- Butterworth, B. (1995). The development of arithmetical abilities. *The Journal of Child Psychology and Psychiatry, 46*, 3-18
- Clearfield, M. W. & Mix, K. S. (1999). Number versus contour length in infants' discrimination of small visual sets. *Psychological Science, 10*, 408-411.
- Feigenson, L., Carey, S., & Spelke, E. (2002). Infants' discrimination of number vs. continuous extent. *Cognitive Psychology, 44*, 33-66.
- **Feigenson, L., Dehaene, S., & Spelke, E. S. (2004). Core systems of number. *Trends in Cognitive Sciences, 8*, 307-314.**
- Lipton, J. S., & Spelke, E. S. (2003). Origins of number sense: Large number discrimination in human infants. *Psychological Science, 14*, 396 – 401.

Core & recommended reading

- Simon, T.J. (1997). Reconceptualizing the origins of number knowledge: A non-numerical account. *Cognitive Development, 12*, 349-372.
- Wynn, K. (1992). Addition and subtraction human infants. *Nature, 358*, 749-750.
- Wynn, K. (1998). Psychological foundations of number: numerical competence in human infants. *Trends in Cognitive Sciences, 2,* 296.
- Xu, F. & Spelke, E. S. (2000). Large number discrimination in 6-month-old infants. *Cognition, 74*, B1-B11

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- The digit code **13 81 98**