Set Representations in Infancy: A Numerical Necessity

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Johns Hopkins University

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Flexible Quantification

Outline

Outline

≈ 50

Core System 1:
Numerical Approximation

Outline

≈ 50

Core System 1:
Numerical Approximation

That Strawberry

Core System 2:
Individual object representations

Outline

≈ 50

Core System 1:
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That Strawberry

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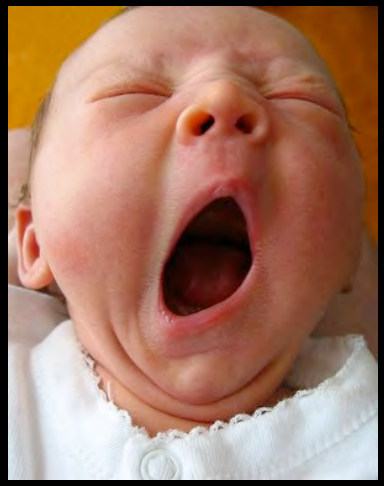
Individual object representations



Outline

≈ 50

Core System 1:
Numerical Approximation

That Strawberry

Core System 2:
Individual object representations

Exactly 53

Gap between core systems and mathematics

Set of 14 strawberries

Core System 3: Need for set-based representations

Core System 1: Numerical Approximation

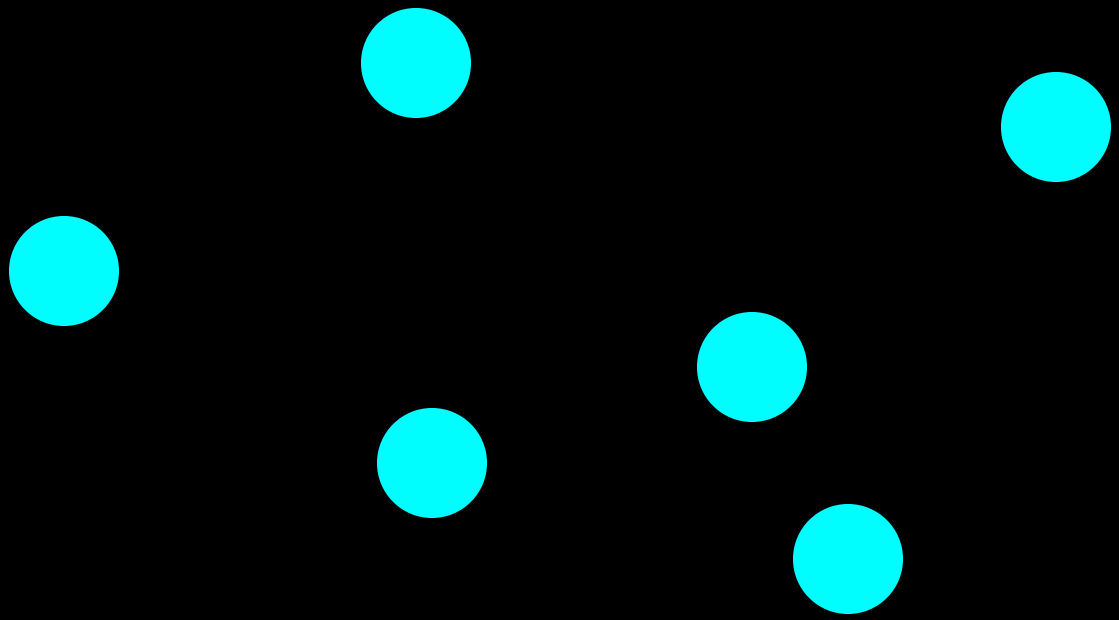
Quick:

How many dots?

Core System 1: Numerical Approximation

Quick:

How many dots?



Core System 1: Numerical Approximation

Quick:

How many dots?

Core System 1: Numerical Approximation

Quick:

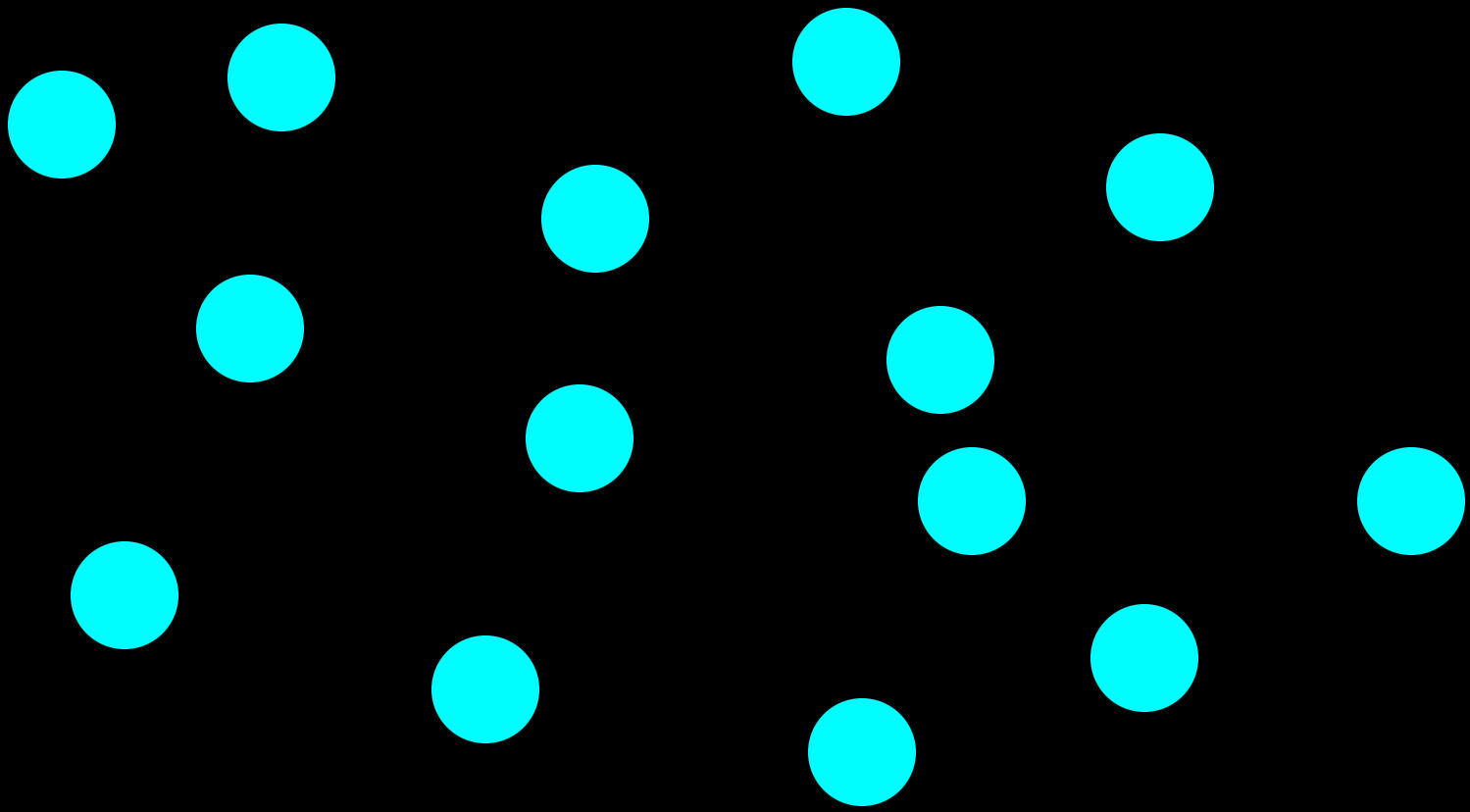
How many dots?

(6)

Core System 1: Numerical Approximation

Quick:

How many dots?



Core System 1: Numerical Approximation

Quick:

How many dots?

Core System 1: Numerical Approximation

Quick:

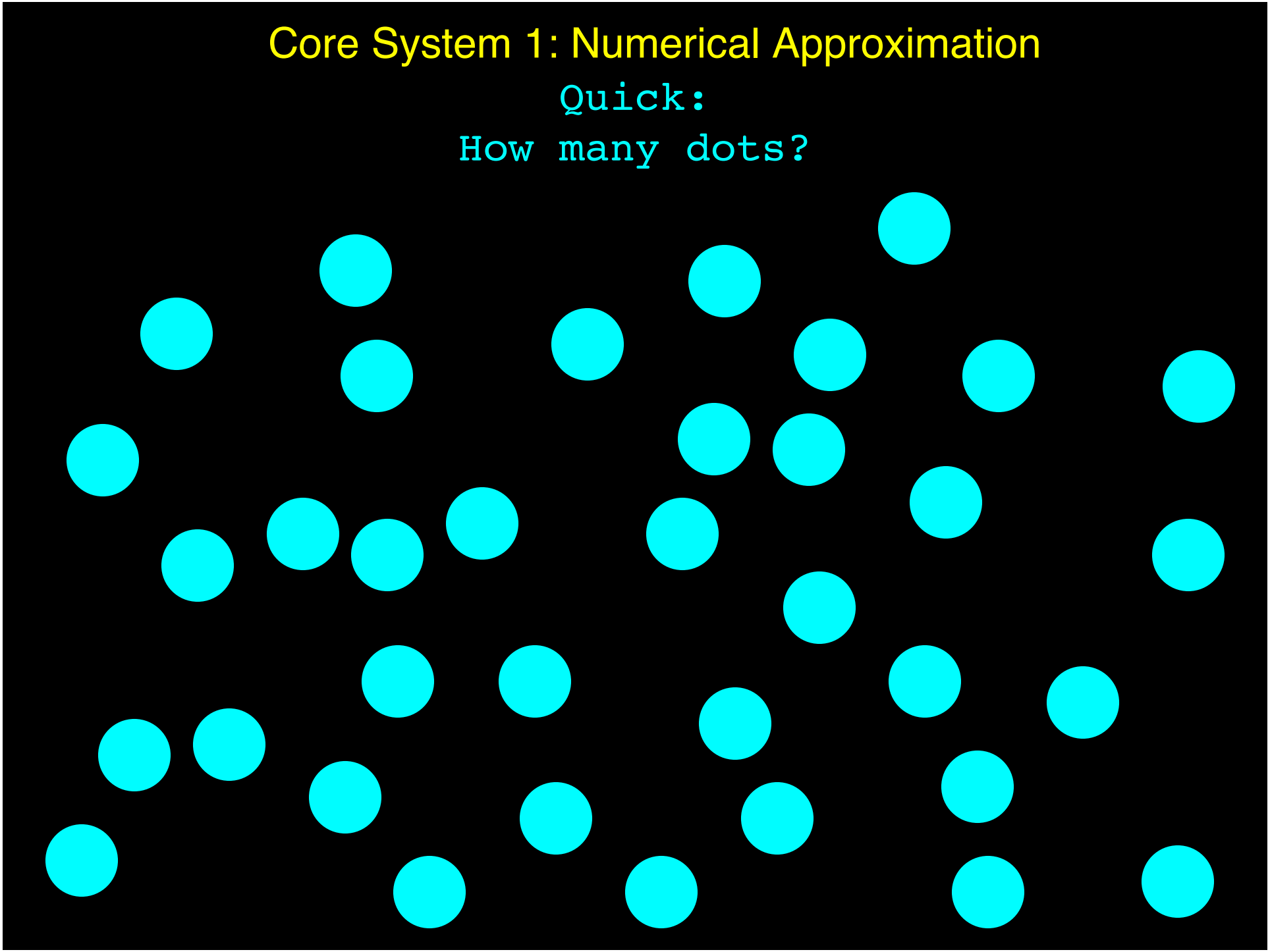
How many dots?

(14)

Core System 1: Numerical Approximation

Quick:

How many dots?



Core System 1: Numerical Approximation

Quick:

How many dots?

Core System 1: Numerical Approximation

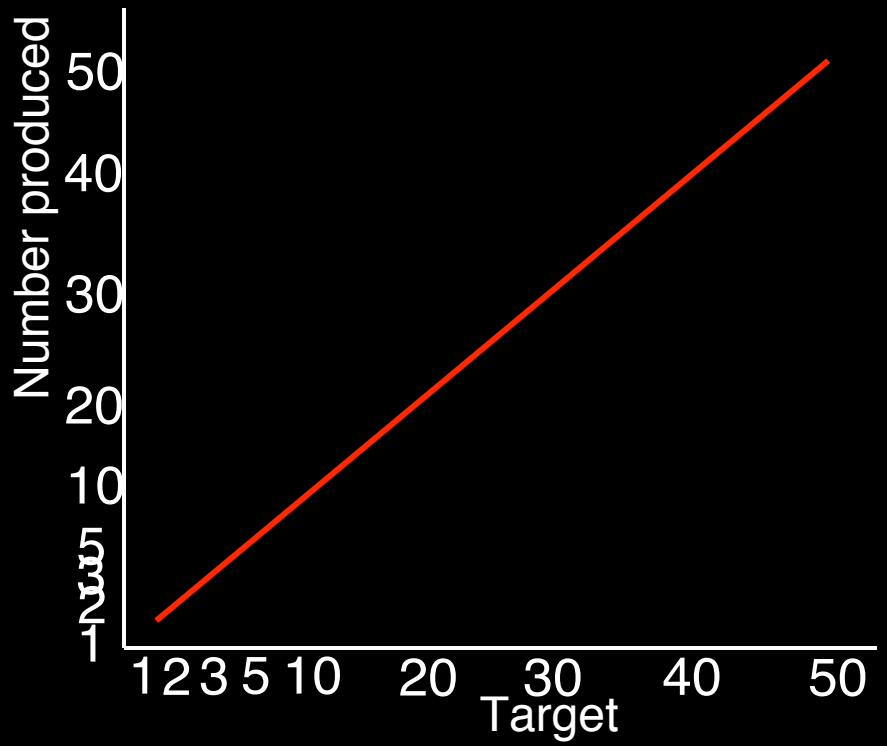
Quick:

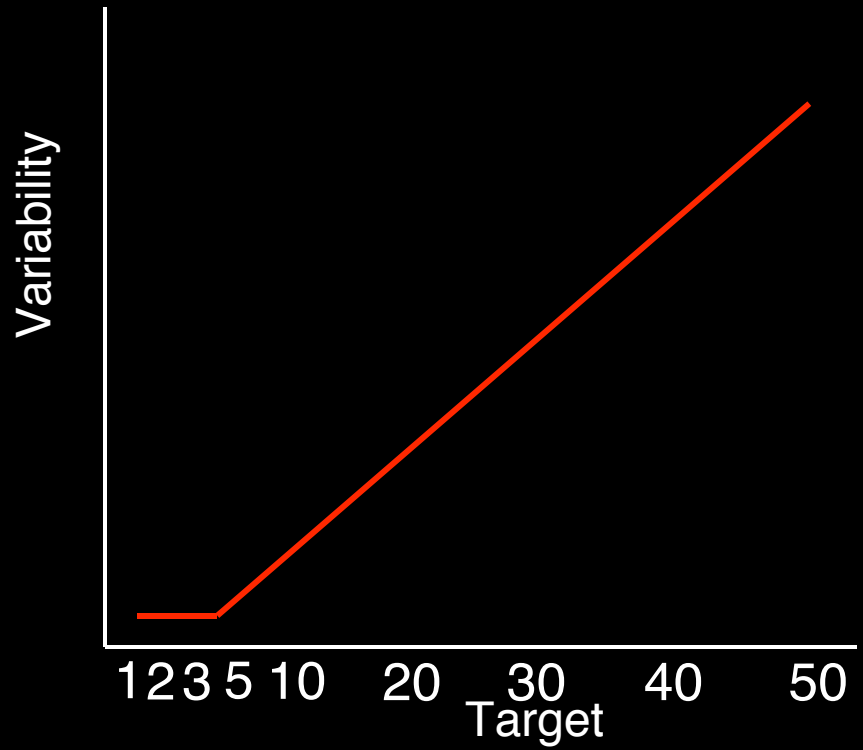
How many dots?

(37)

Core System 1: Numerical Approximation

Adult approximation signatures:

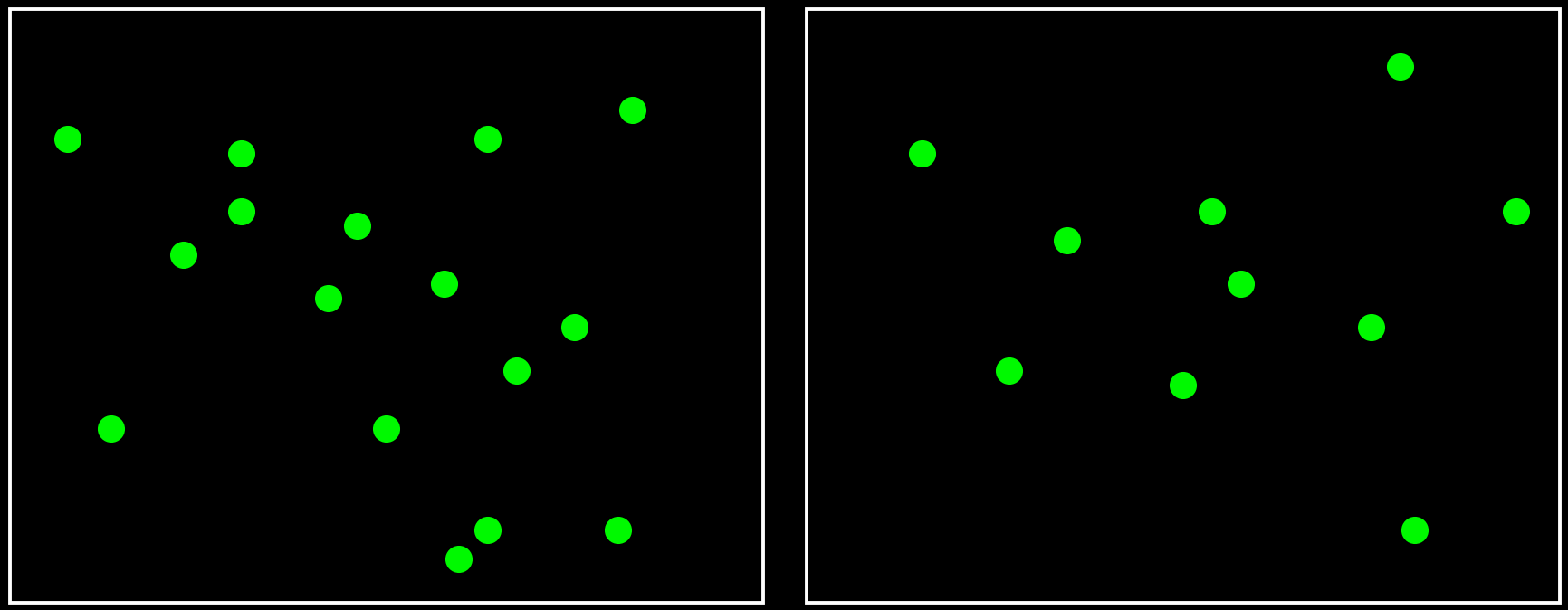




Core System 1: Numerical Approximation

- Adults' performance exhibits **Weber's Law:**

  Ability to discriminate 2 numbers depends on their ratio



EASY

Core System 1: Numerical Approximation

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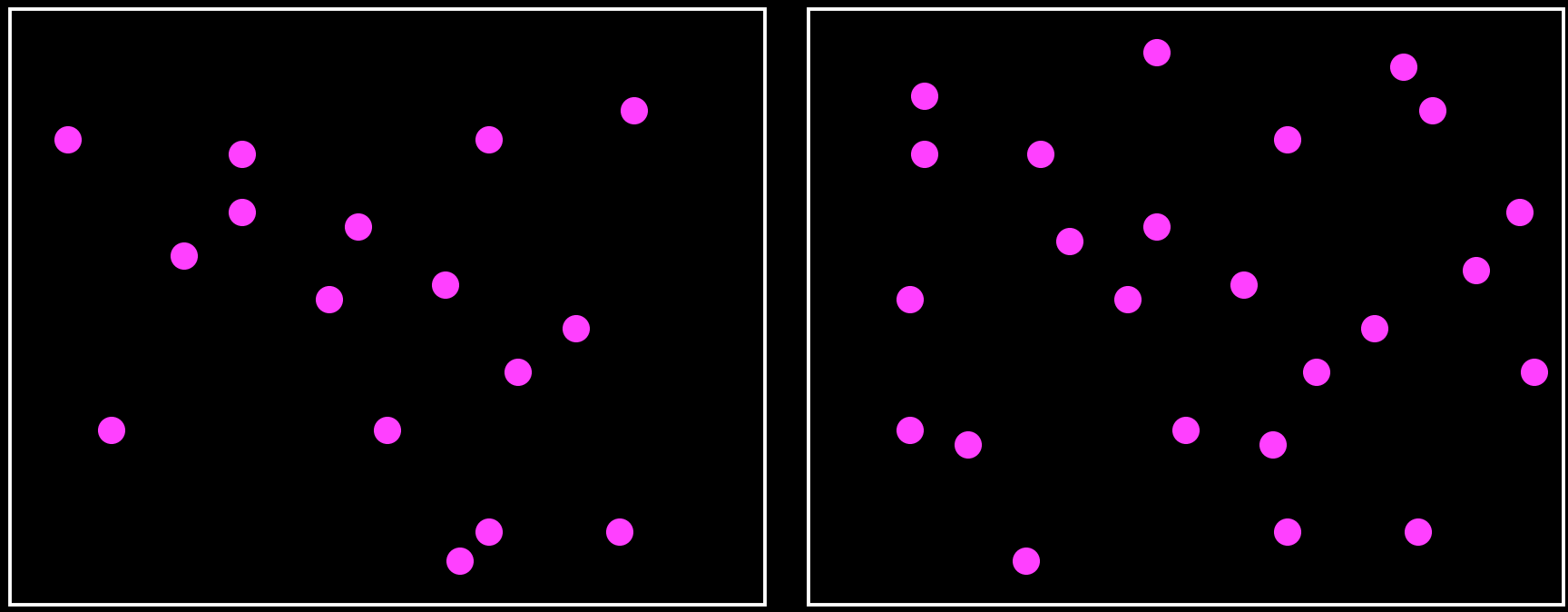
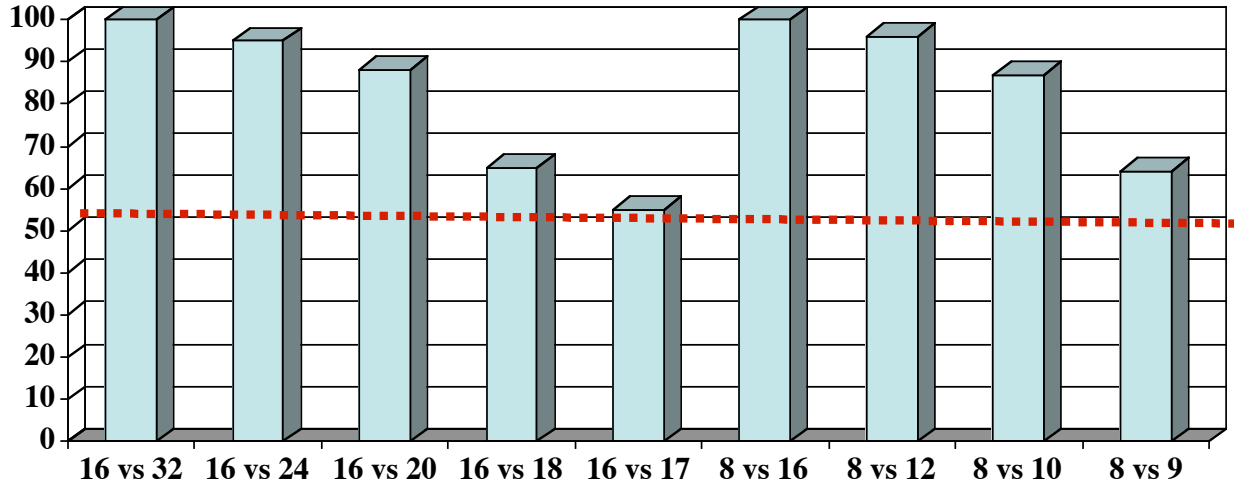
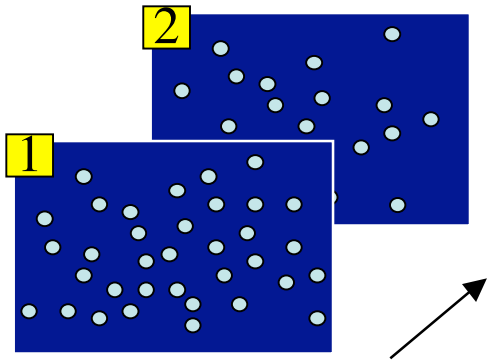


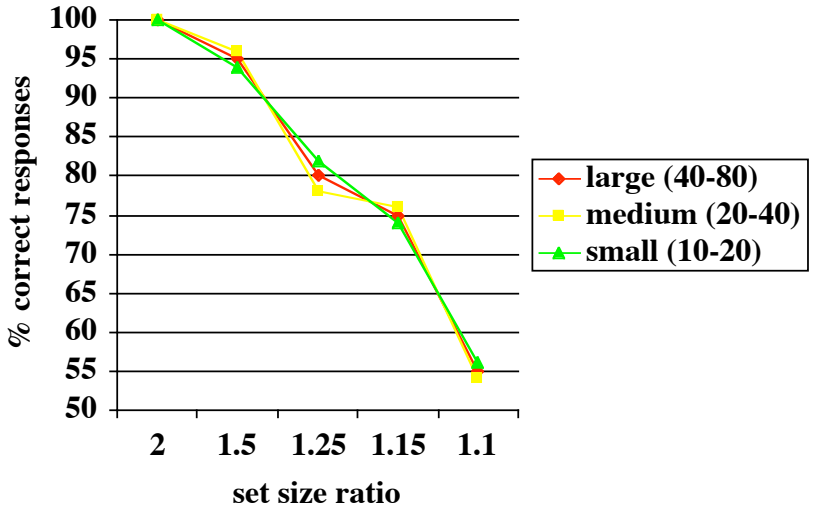
HARD!!!

Core System 1: Numerical Approximation

Numerosity discrimination by adults:







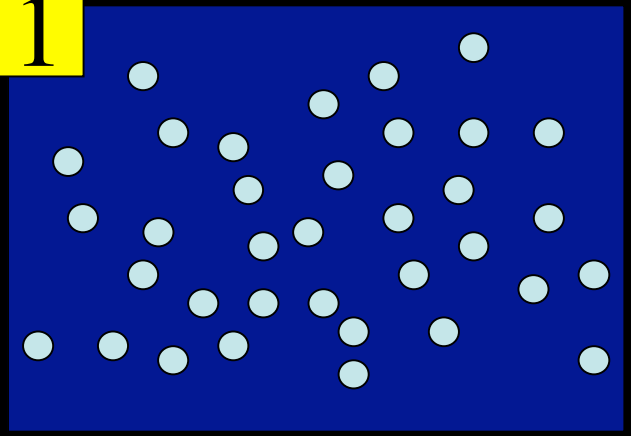
Barth et al., 2003

Core System 1: Numerical Approximation

QUESTION: Are adults' number representations limited to the visual modality? Or are they more abstract? (Barth et al, 2003)

2

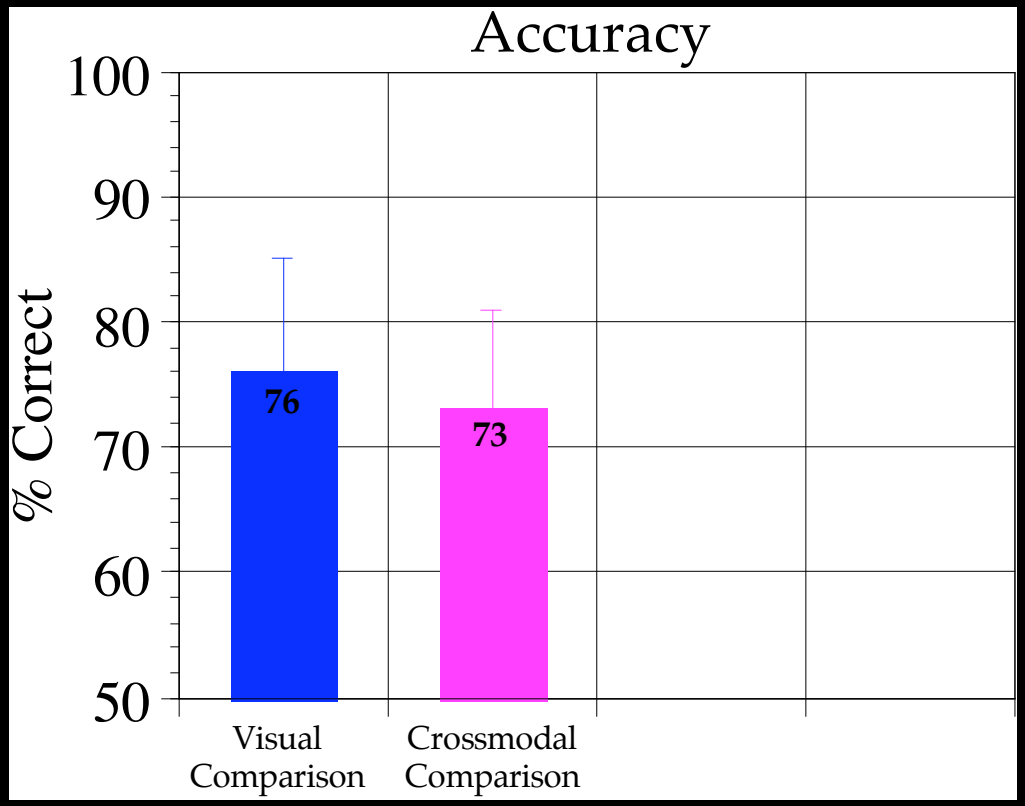
1



"Is 2 fewer or more than 1 ?"

Core System 1: Numerical Approximation

QUESTION: Are adults' number representations limited to the visual modality? Or are they more abstract? (Barth et al, 2003)

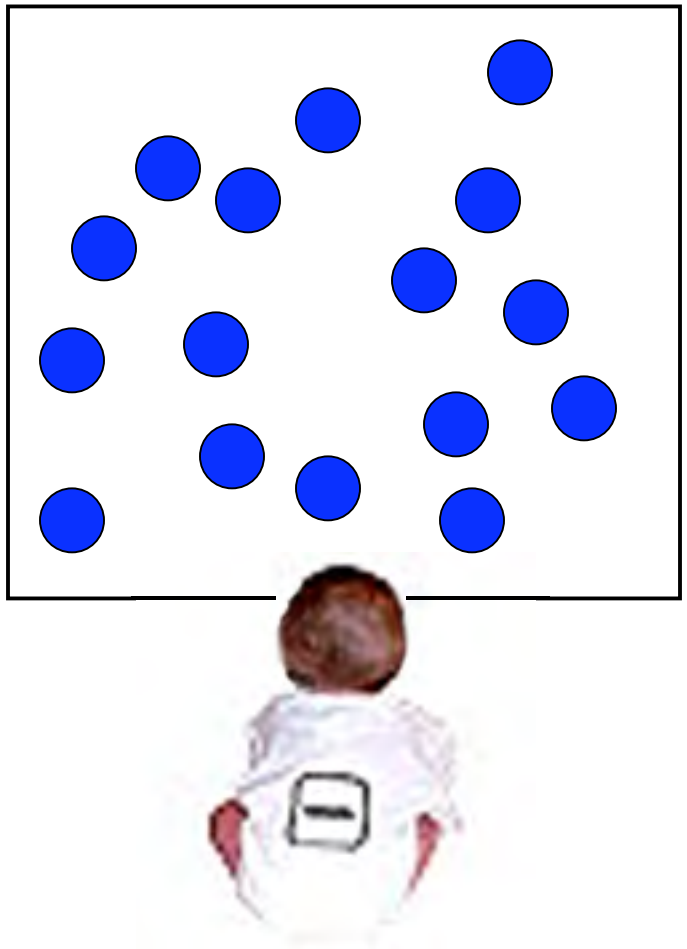


Cross-modal comparisons are as accurate as comparisons within the visual modality alone!

Core System 1: Numerical Approximation

Developmental origins of approximation?

Xu & Spelke (2000): Habituate 6-month olds to either 8 or 16 dots



Core System 1: Numerical Approximation

Developmental origins of approximation?

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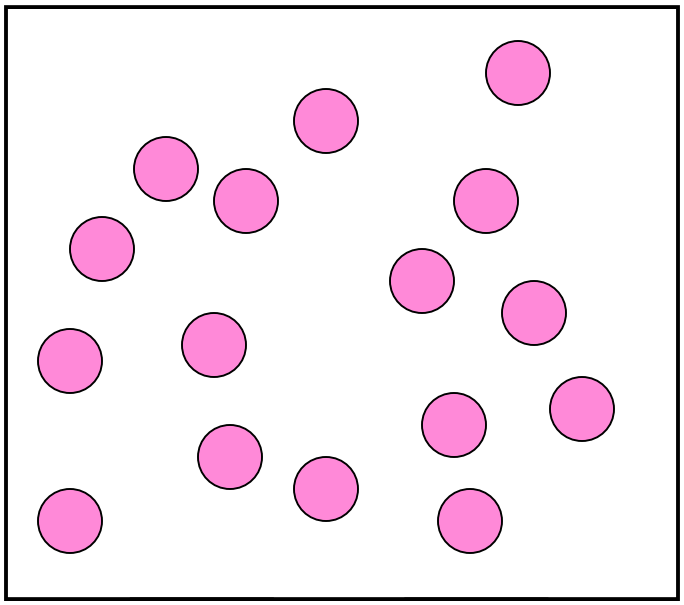
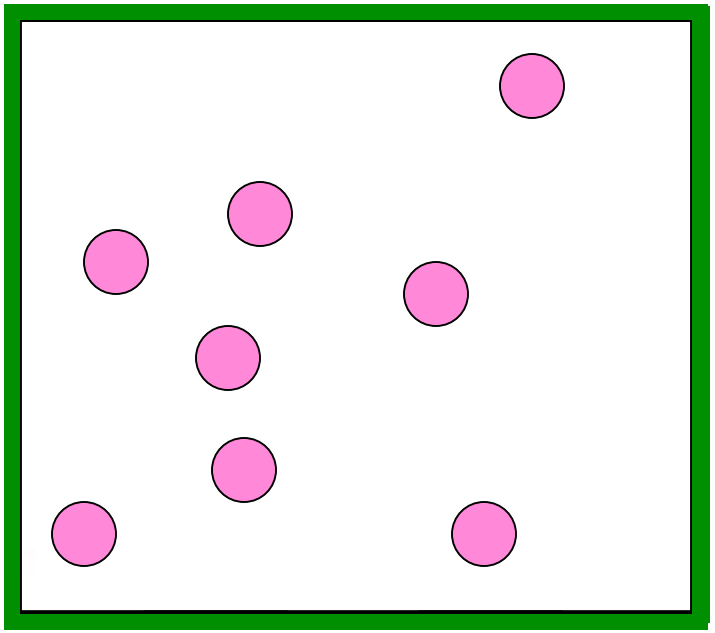
Test with OLD number…



vs. NEW number…



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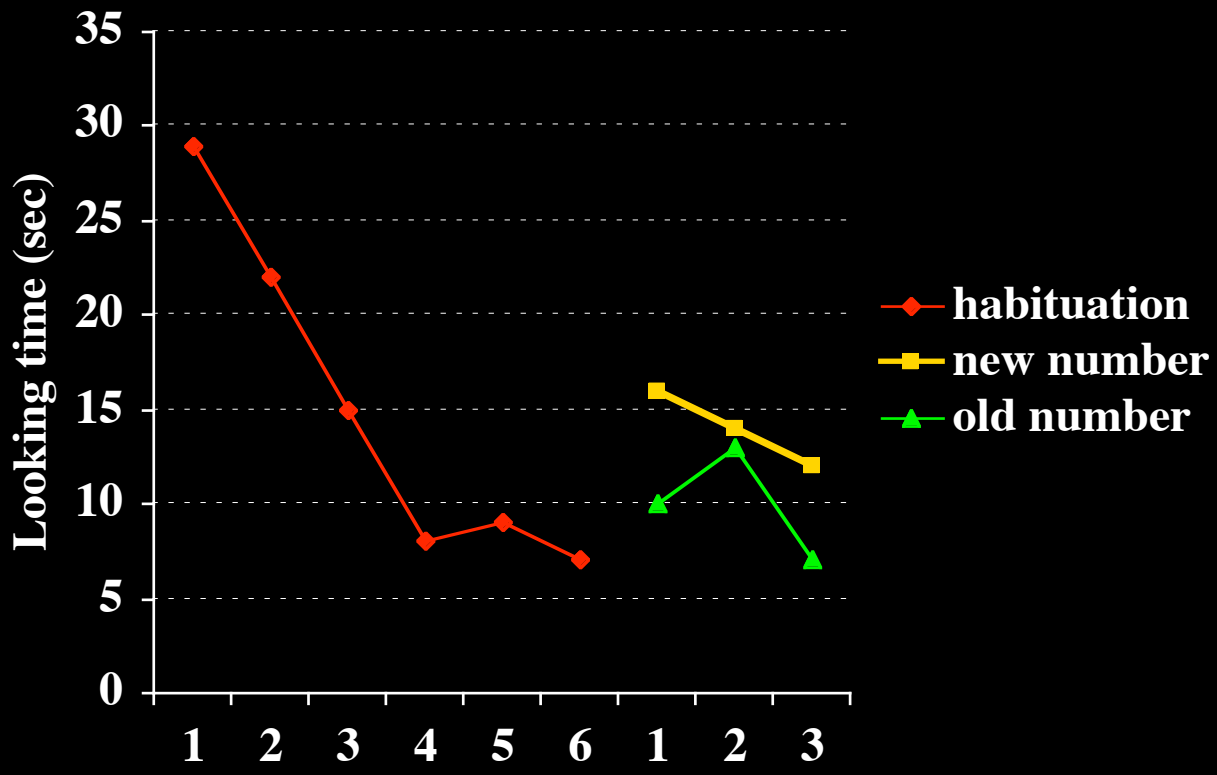
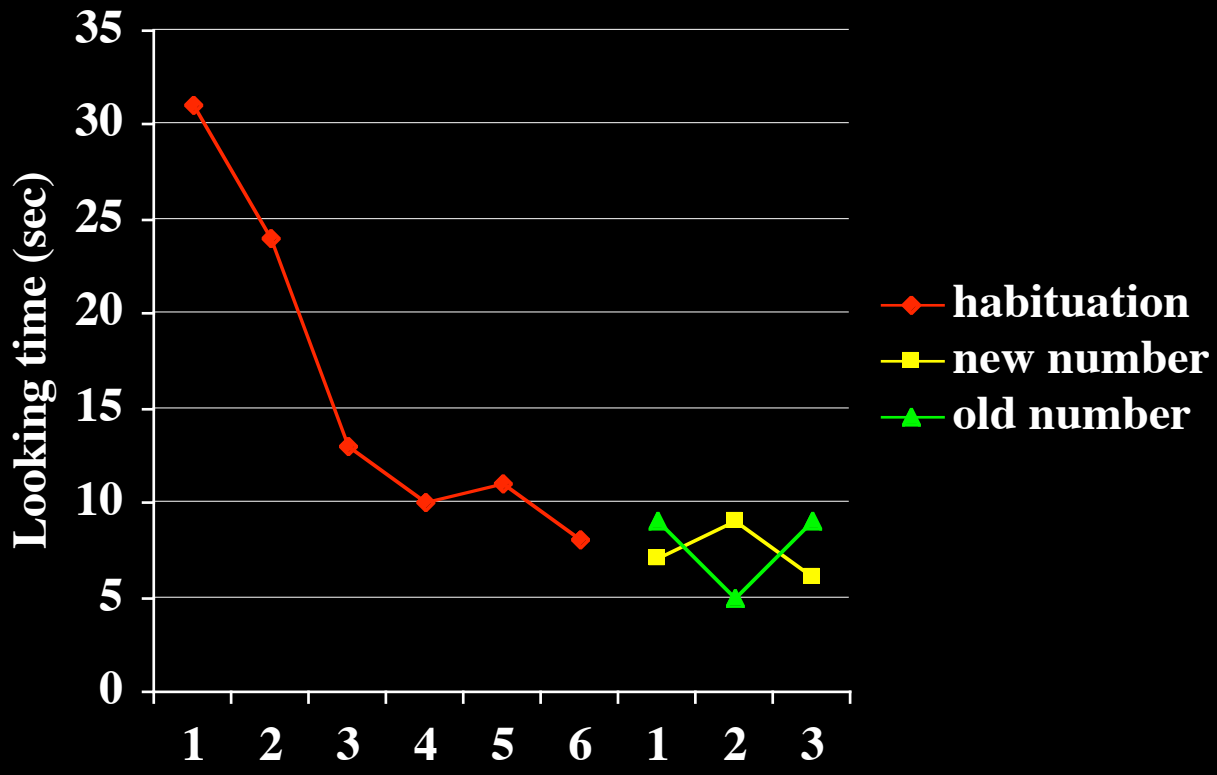


Do infants, like adults, exhibit ratio-dependent performance?

Core System 1: Numerical Approximation

Developmental origins of approximation?

Xu & Spelke (2000): Habituate 6-month olds to either 8 or 12 dots

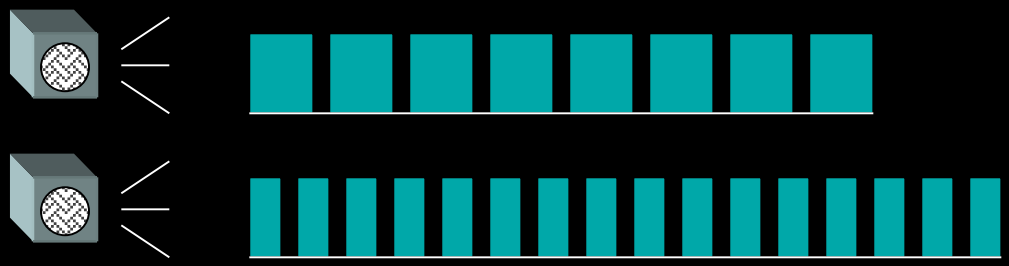


Conclusion: Yes, infants' number representations are imprecise!

Core System 1: Numerical Approximation

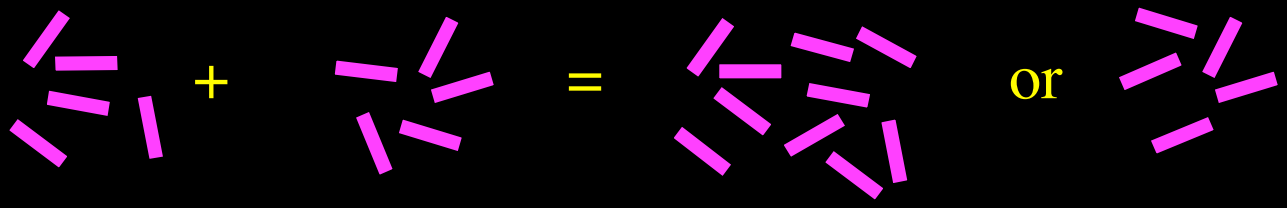
Developmental origins of approximation?

- Like adults, infants' approximations are abstract



Lipton & Spelke, 2003

- Like adults, infants' approximations support arithmetic



McCrink & Wynn, 2005

Core System 1: Numerical Approximation

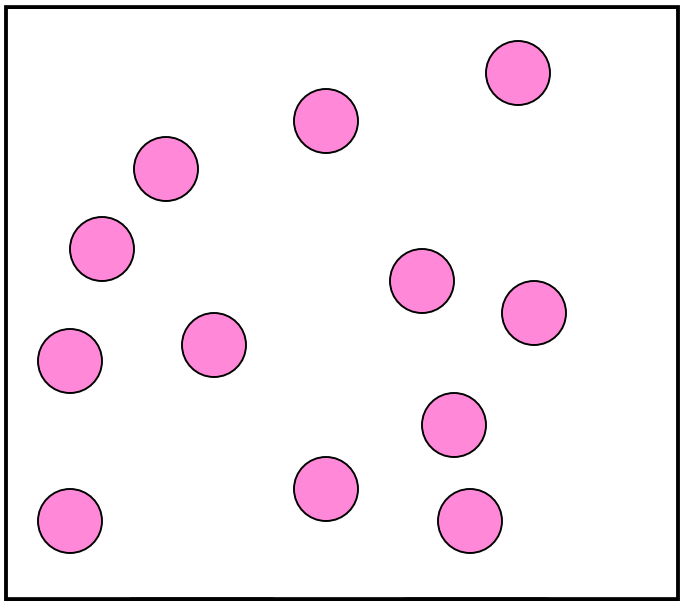
Hallmarks of Approximation:

- Ratio dependent- Weber's Law
- Demonstrated in infants, children, adults (& animals)
- Abstract, amodal
- Supports arithmetic computation

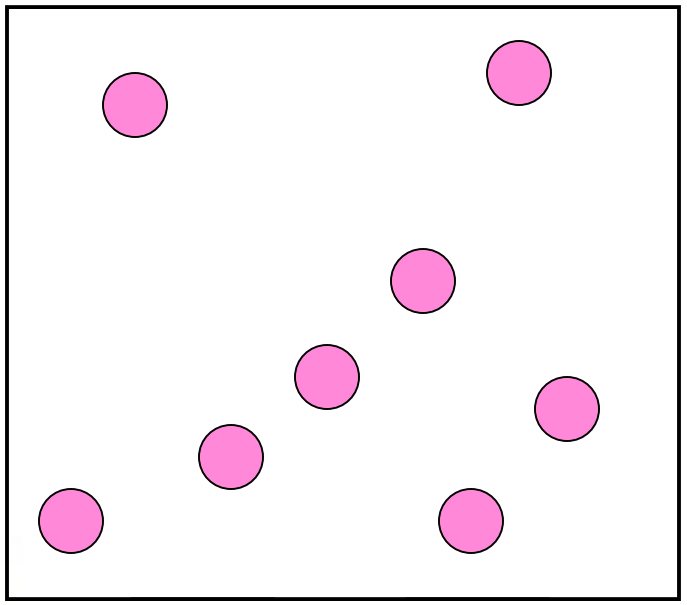
Core System 1: Numerical Approximation

BUT: Numerical approximation does not support representing individual items…

Test with OLD number…



vs. NEW number…



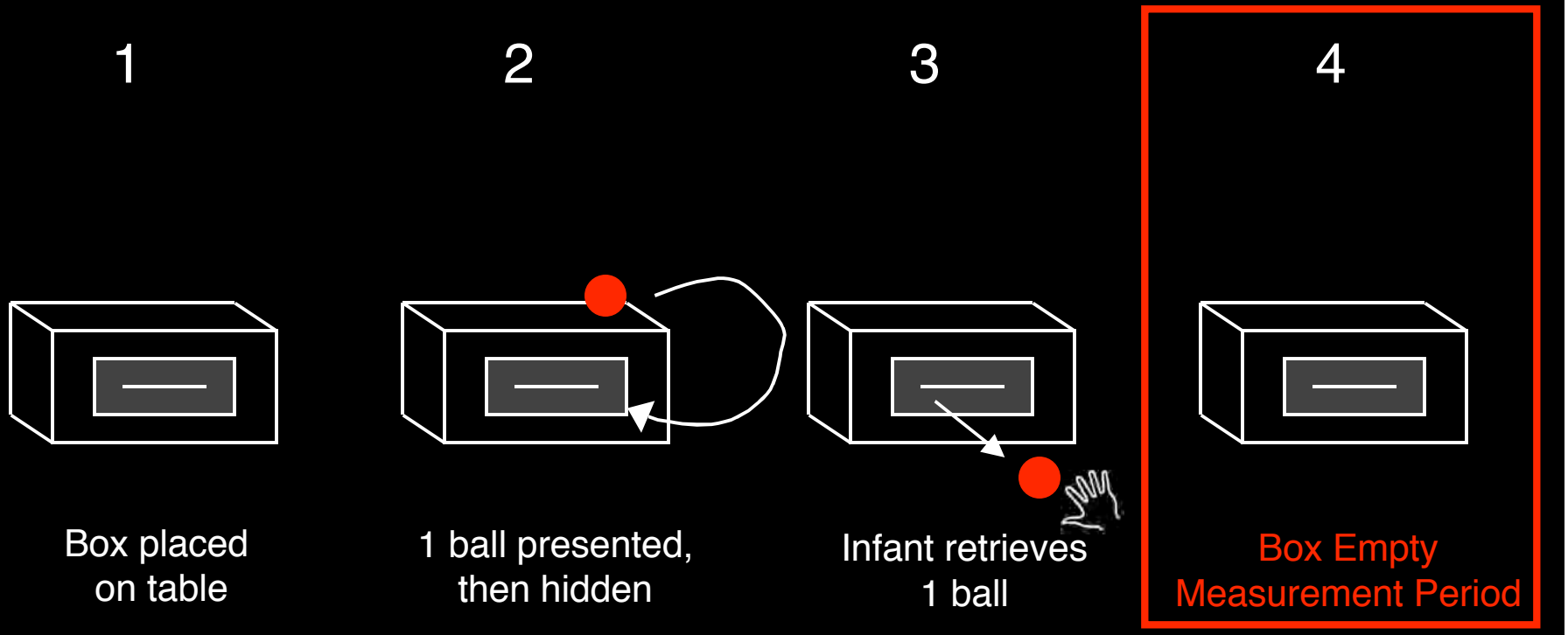
Core System 2: Individual Object Representations

Can infants ever represent numbers of individual items?

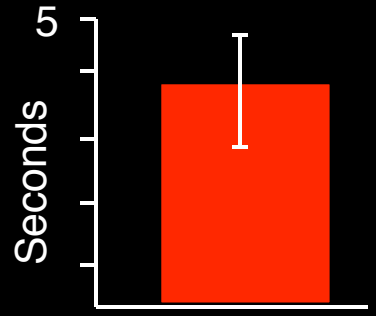
Manual search task

Core System 2: Individual Object Representations

Manual Search Procedure: 1 vs. 2 Objects



Time →



Core System 2: Individual Object Representations

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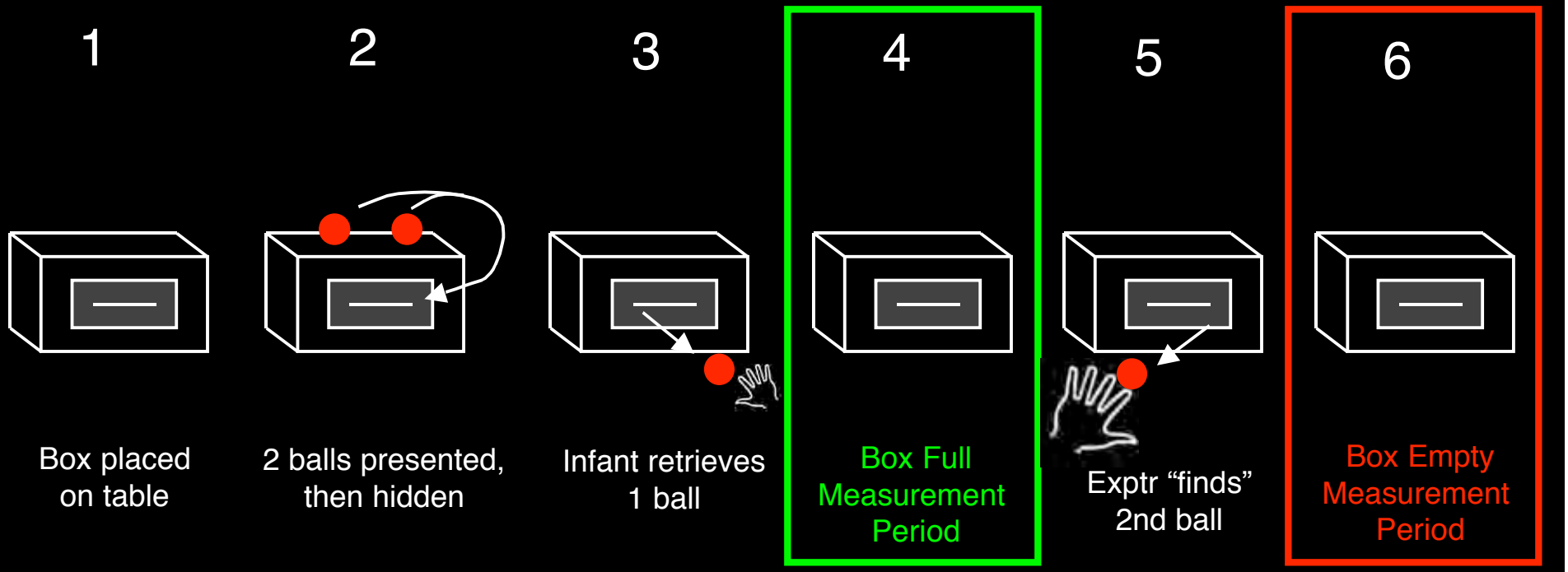
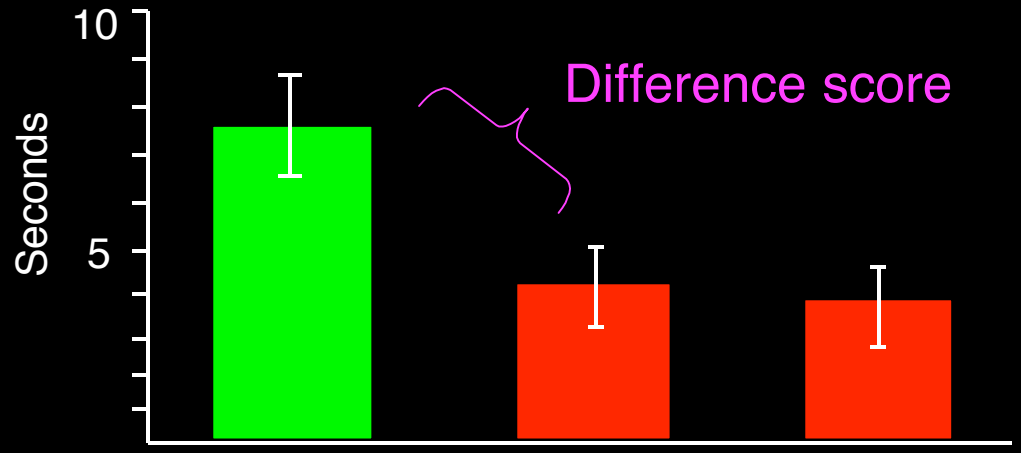
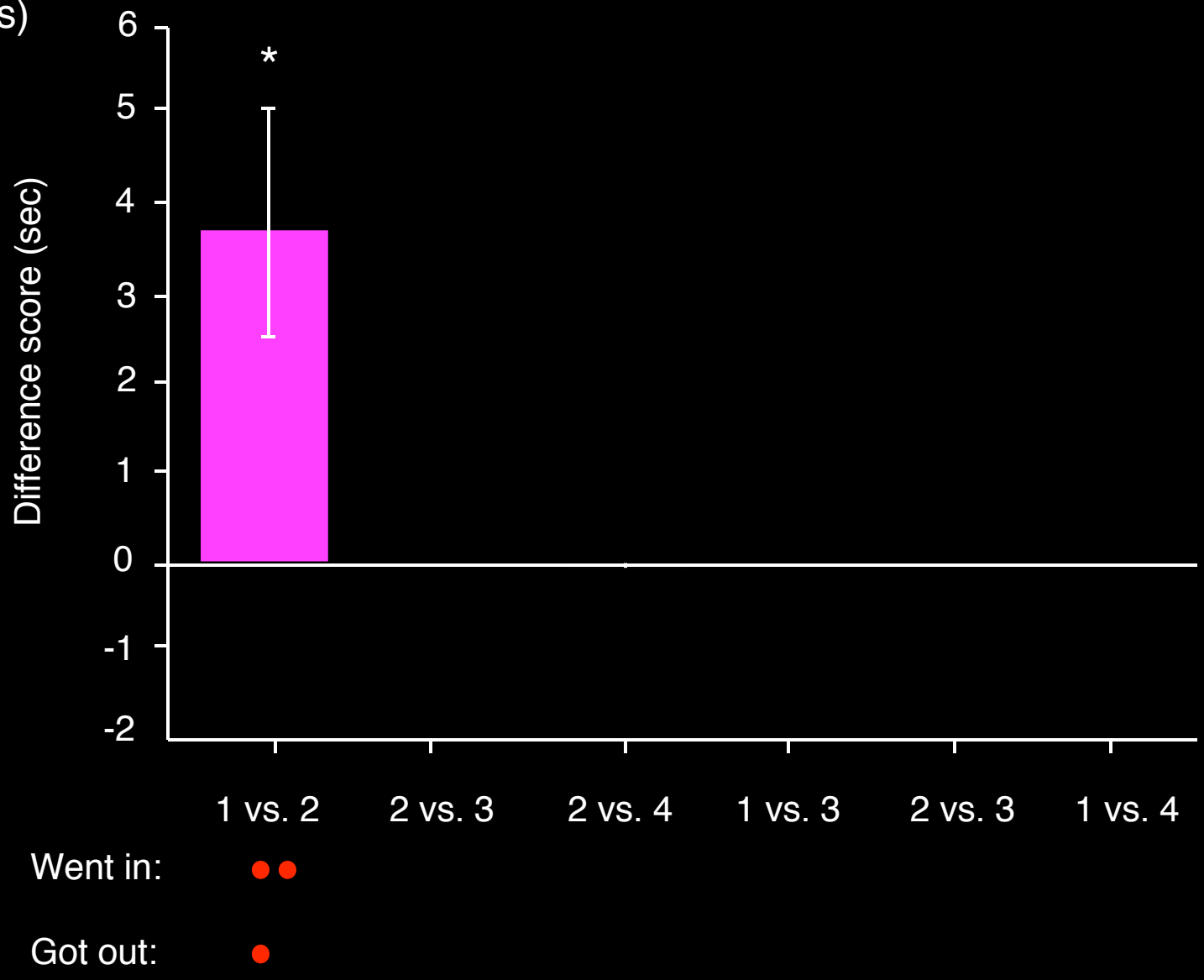


Time →



Core System 2: Individual Object Representations

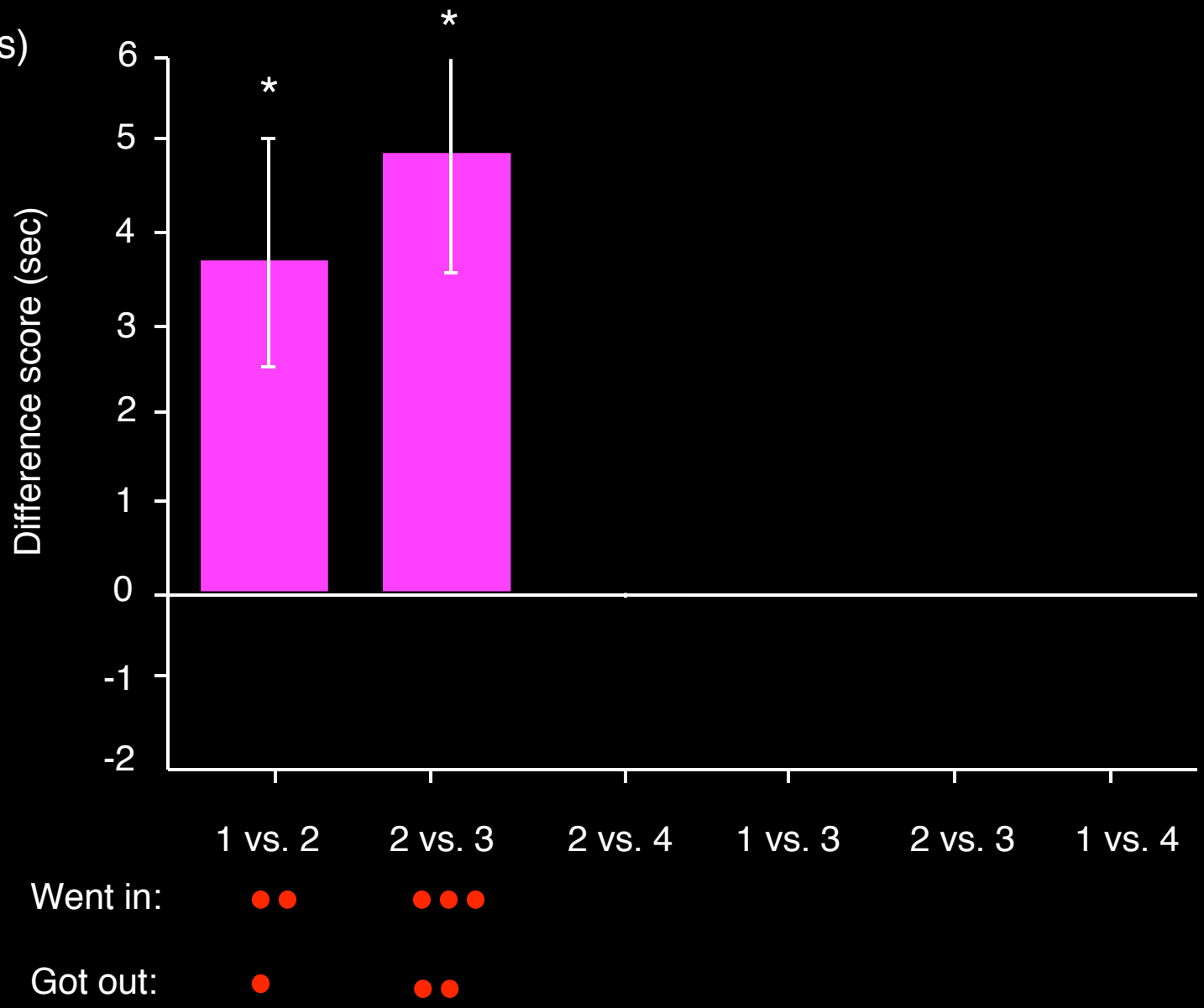
(12-14 mos)



Feigenson & Carey (2003; 2005)

Core System 2: Individual Object Representations

(12-14 mos)



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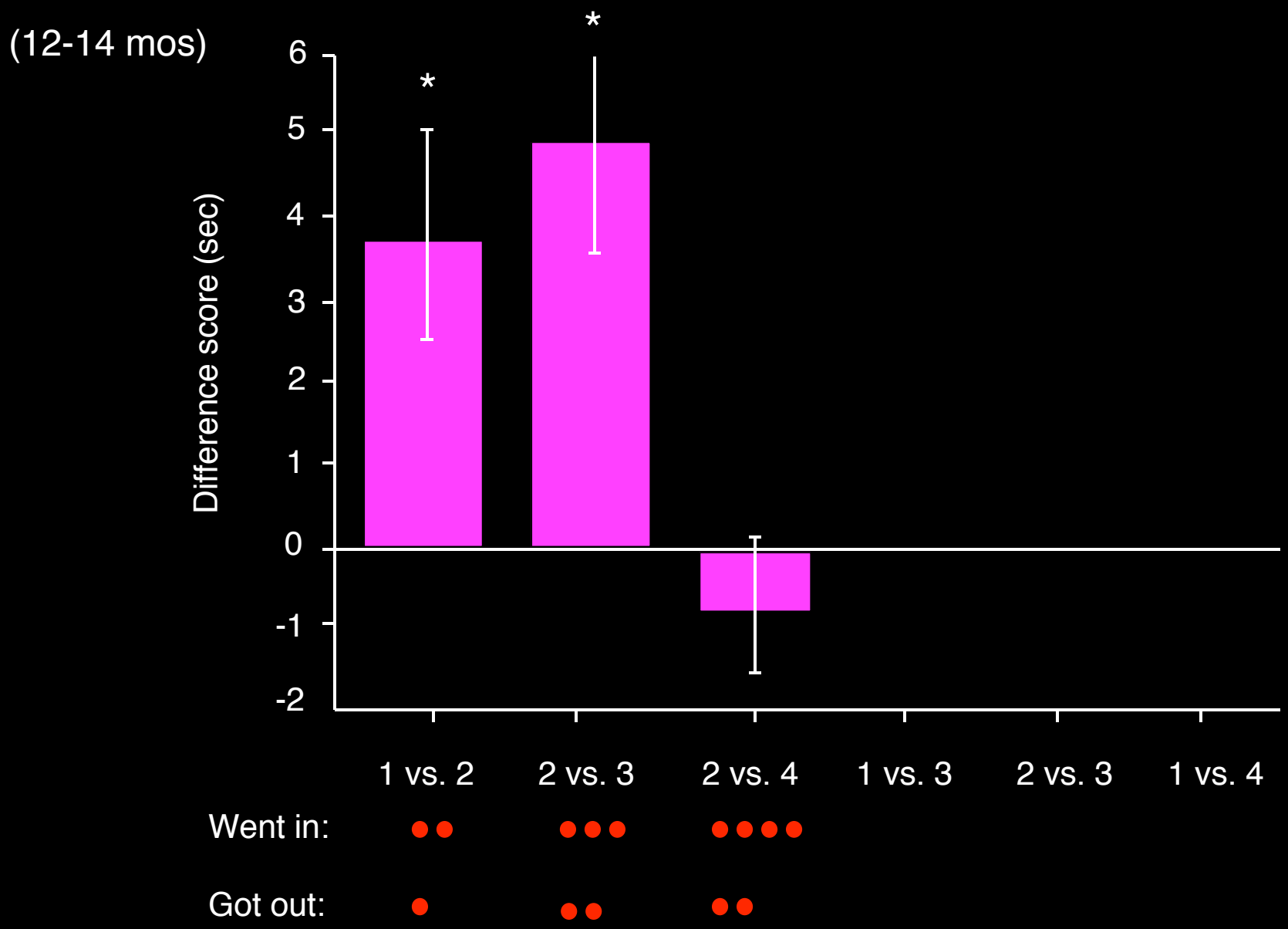
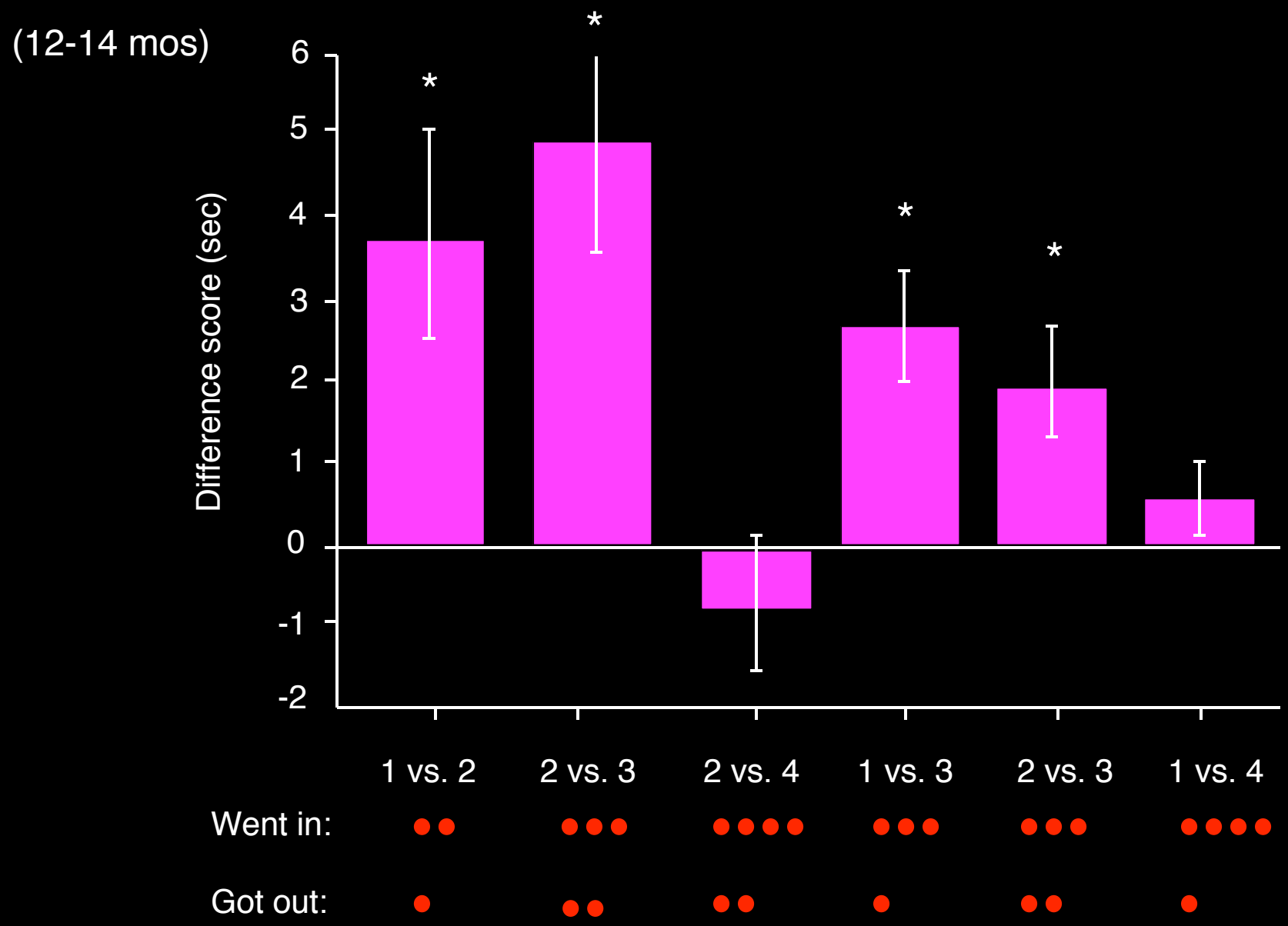


Feigenson & Carey (2003; 2005)

Core System 2: Individual Object Representations



Feigenson & Carey (2003; 2005)

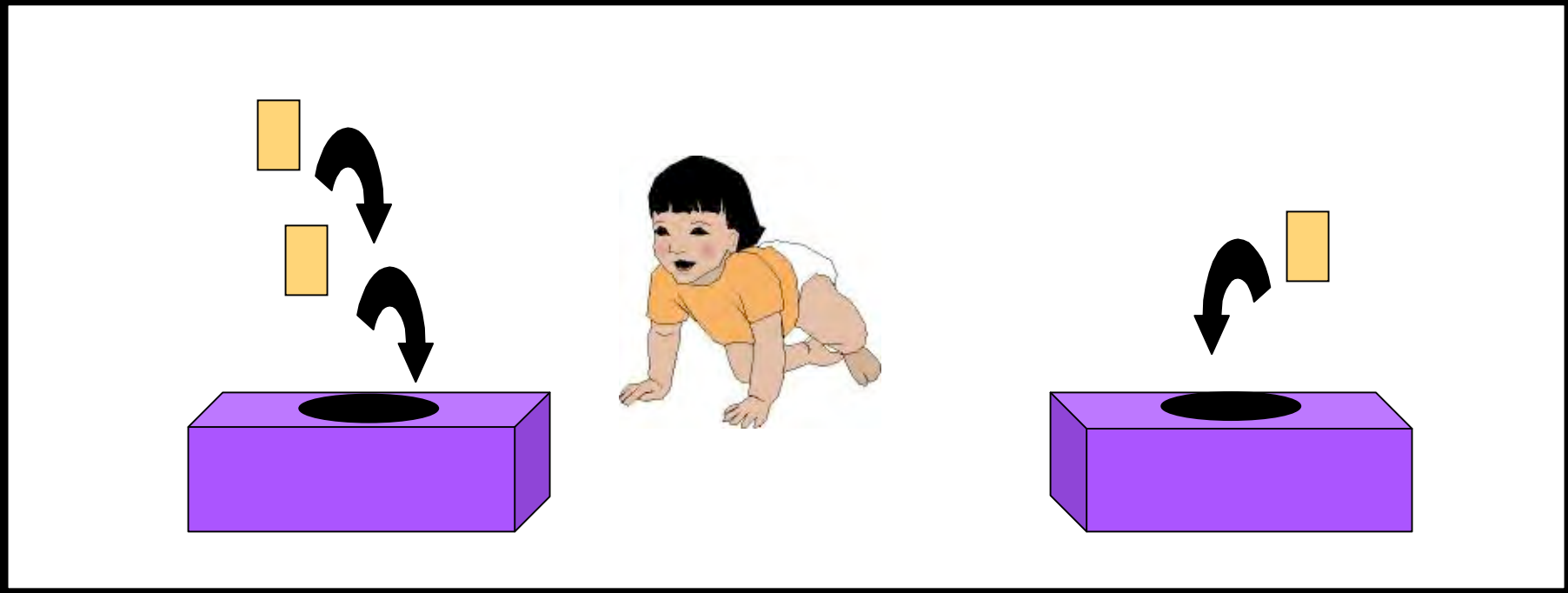
Core System 2: Individual Object Representations

12-14 month infants limited to tracking 3 objects at a time…

Is this due to memory demands or reaching demands of manual search task?

Core System 2: Individual Object Representations

Cracker choice task:

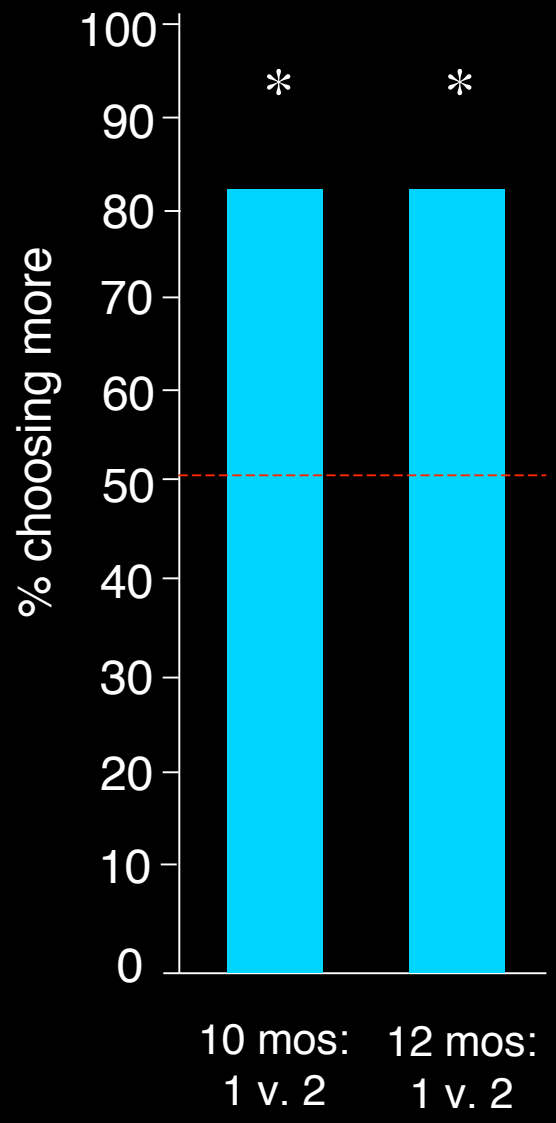


Measure 10- & 12-month olds' spontaneous abilities to track & compare two quantities;
Vary quantity sizes to probe infants' abilities

Feigenson et al., 2002

Core System 2: Individual Object Representations

Cracker choice task:



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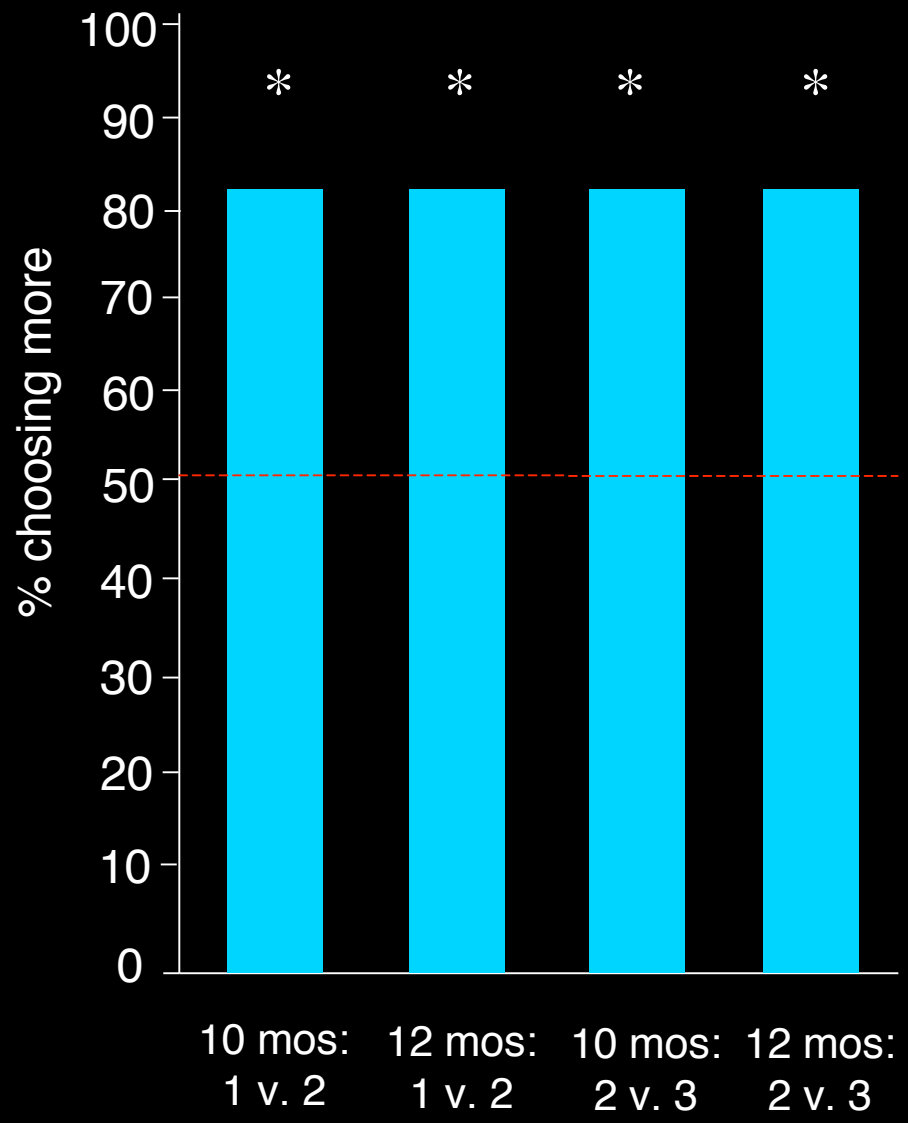

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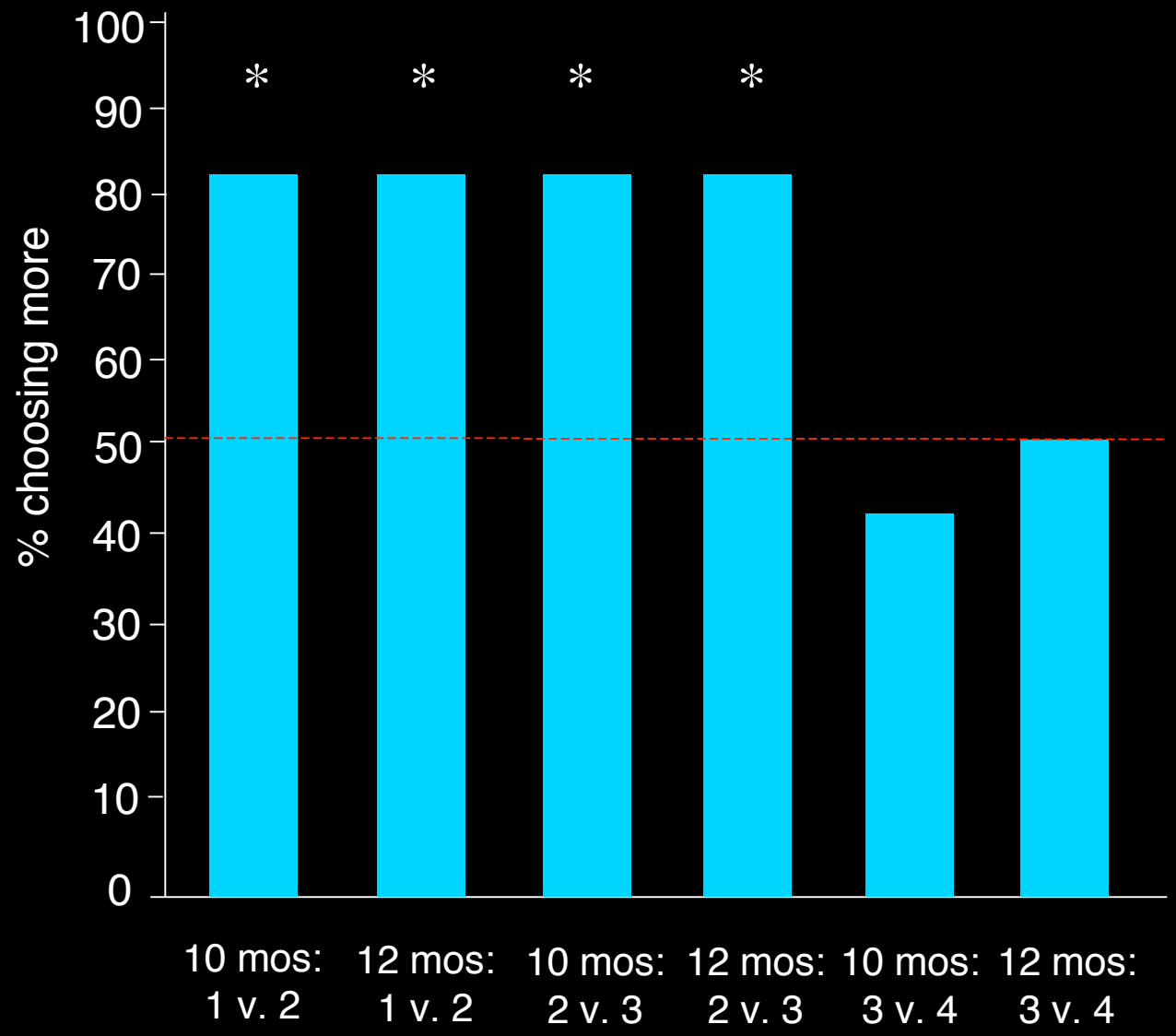

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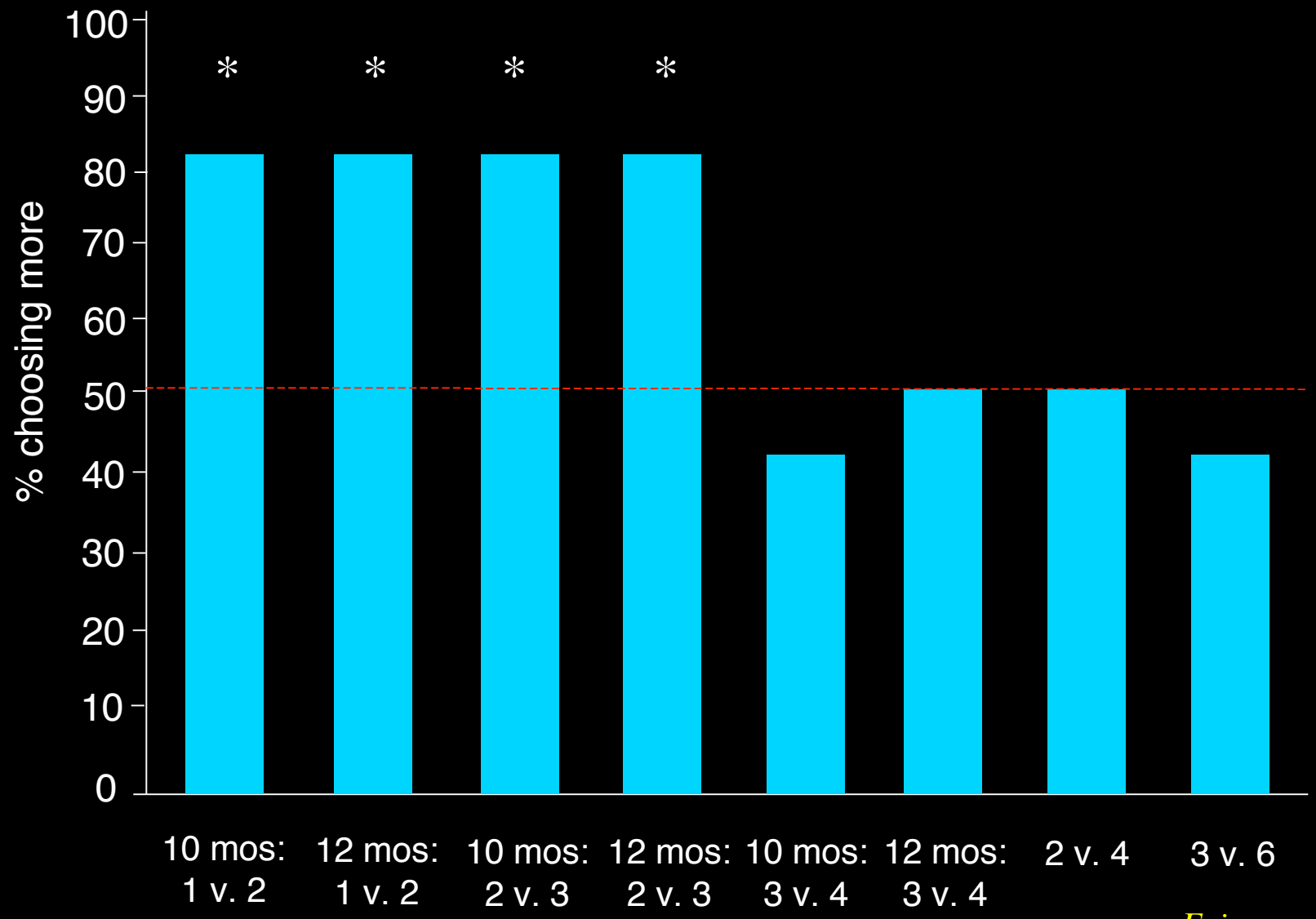

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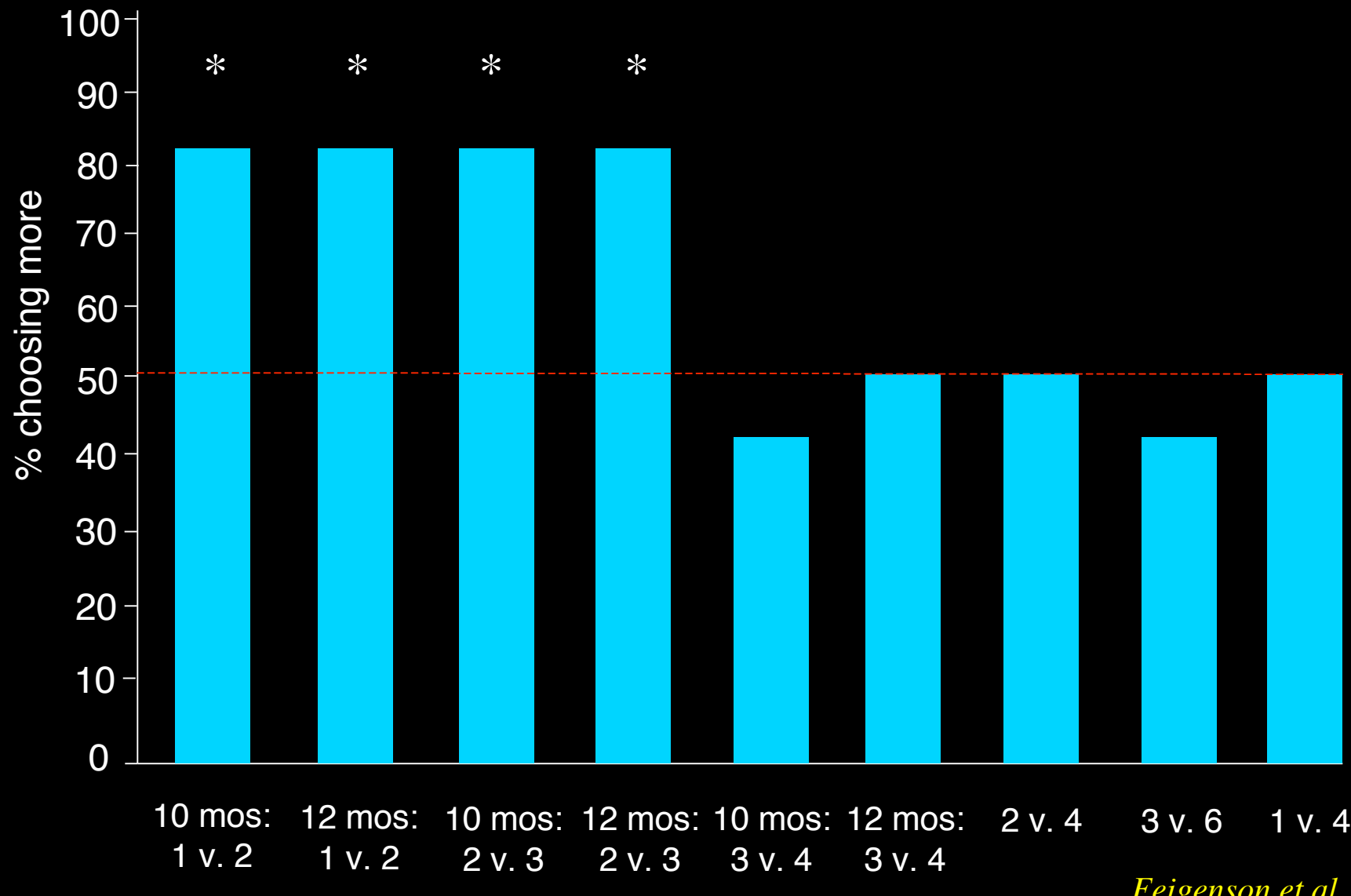


Feigenson et al., 2002

Core System 2: Individual Object Representations

Hallmarks of Individual Object Representation:

- Subject to abrupt set-size limit (maximum = 3 items)
- Demonstrated in infants, children, adults (& animals)

3rd Core System: Set Representations

- Core System 1 produces numerical approximations
- Core System 2 produces precise representations of individual items
- But neither supports precise large numbers or many mathematical concepts

~~*Exactly 53*~~

~~*{Strawberries} - {Strawberries} = {ø}*~~

3rd Core System: Set Representations

Do young children represents **sets** of items?

Note: Sets ≠ groups

3rd Core System: Set Representations

Does thinking about SETS help infants represent
more than simply thinking about INDIVIDUAL ITEMS?

3rd Core System: Set Representations

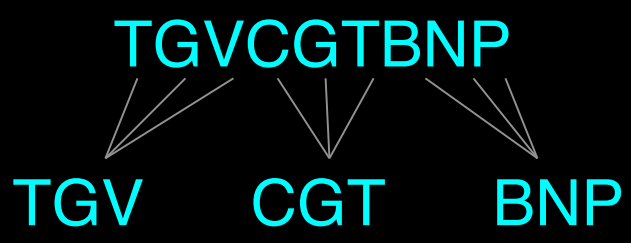
Does thinking about SETS help infants represent more than simply thinking about INDIVIDUAL ITEMS?

3 Sources of Evidence for Set-building

Spatiotemporal sets

01 23 45 67 89

Conceptual sets

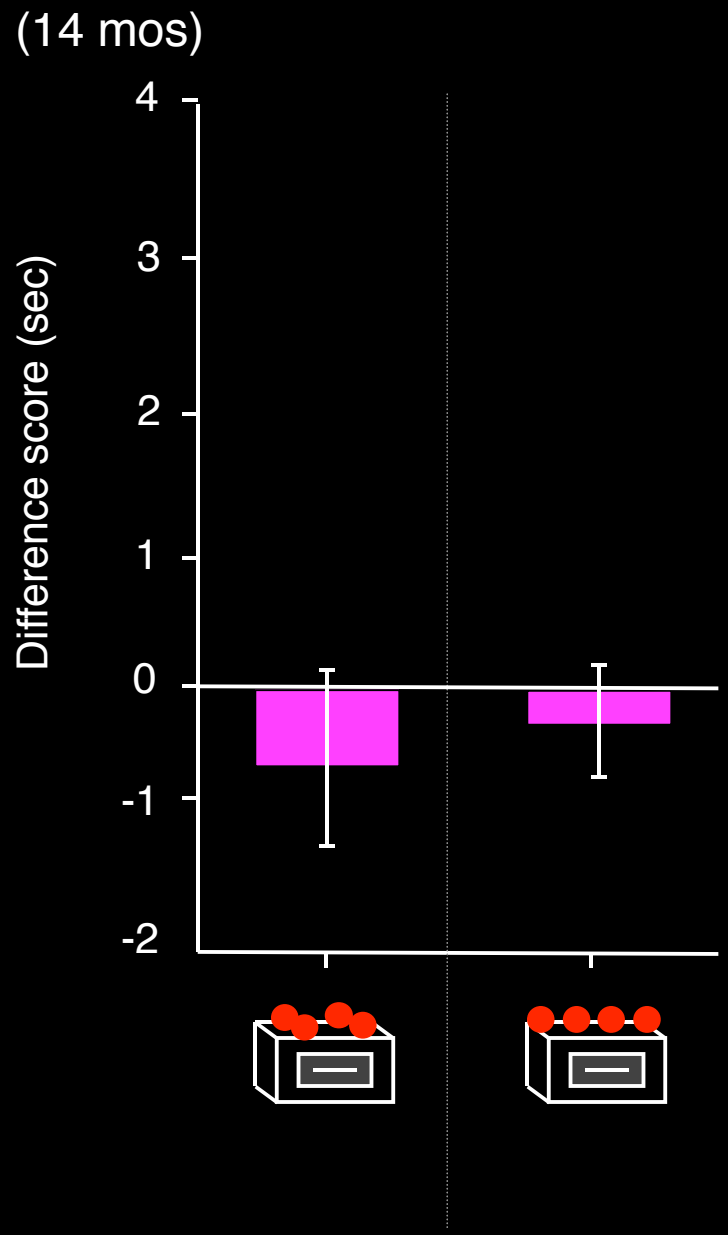


Linguistic sets

Spatial Set-building by Infants?

Feigenson & Halberda (2005)

Spatial Set-building by Infants?



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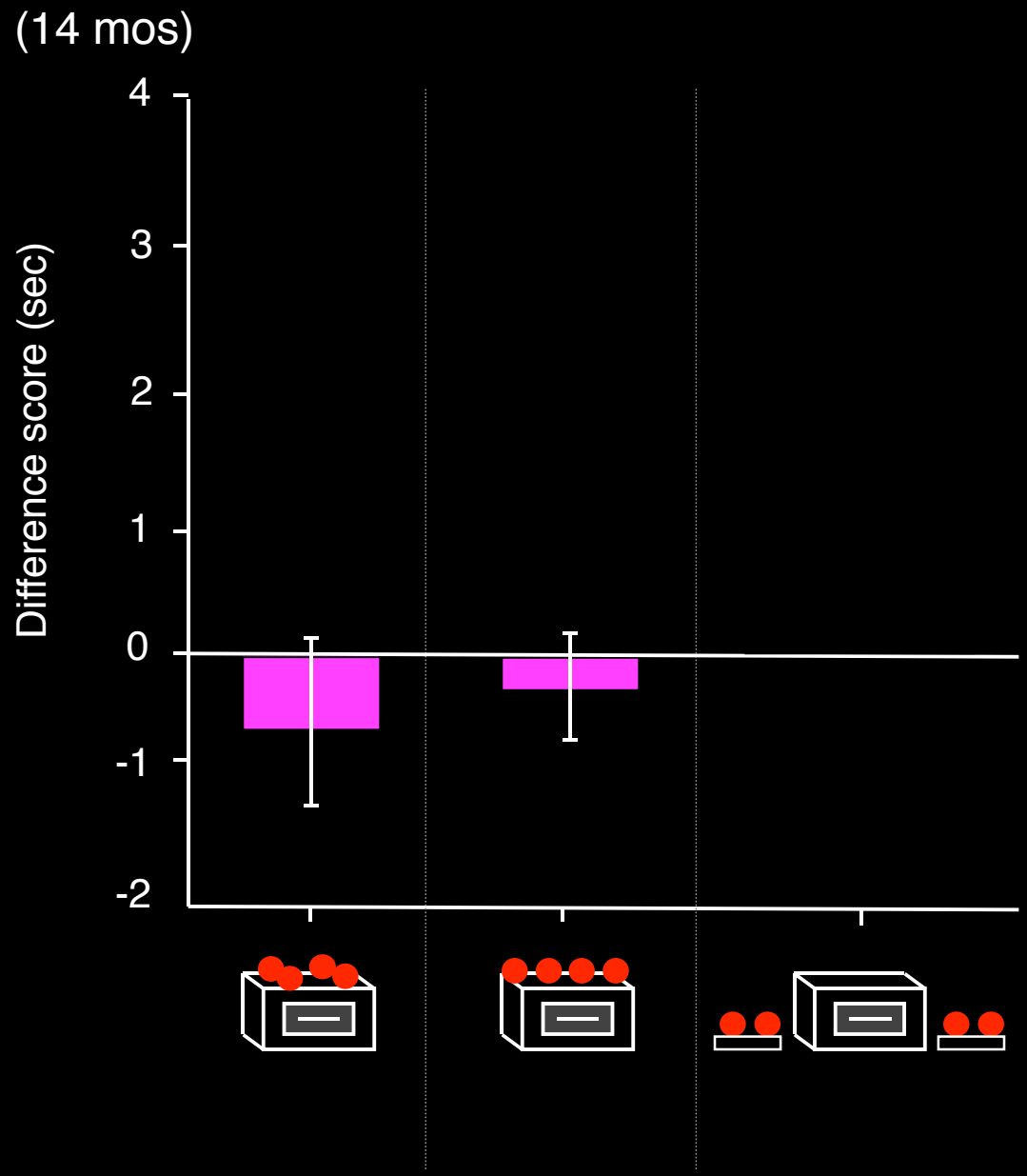

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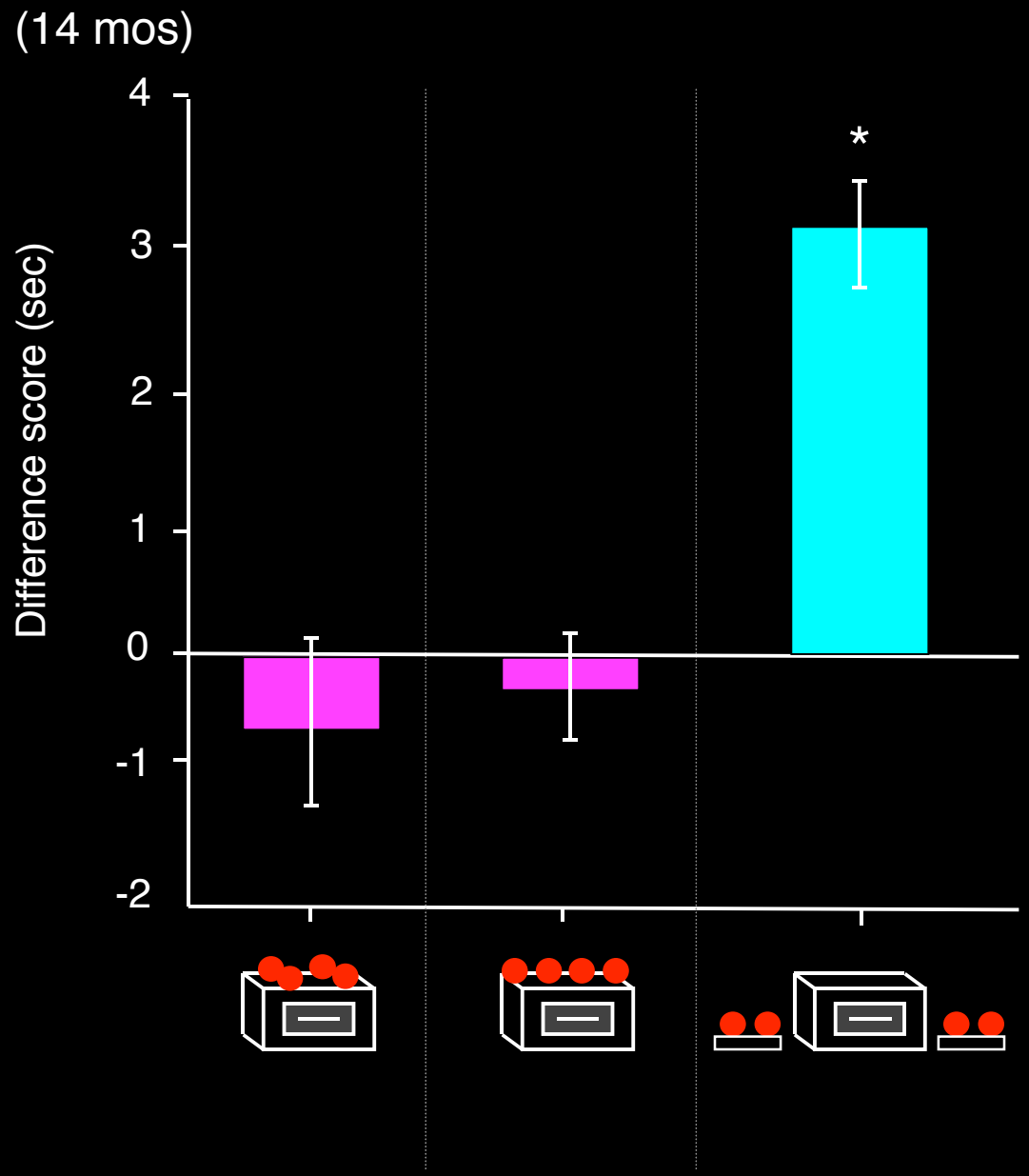

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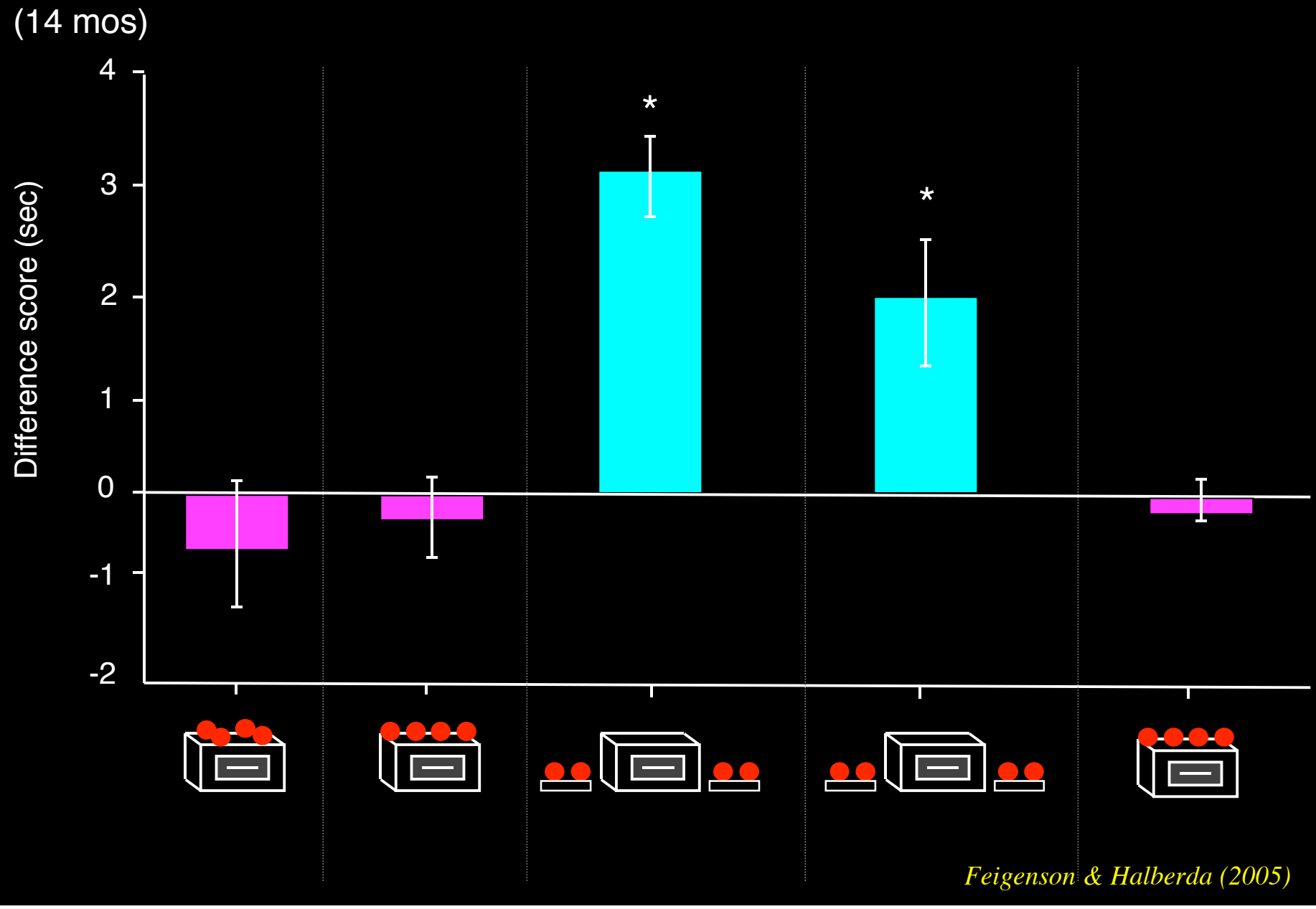

Feigenson & Halberda (2005)

Perceptual and Conceptual Set-building by Infants?

- Conceptual sets???

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- Conceptual sets???

TGVCGTBNP

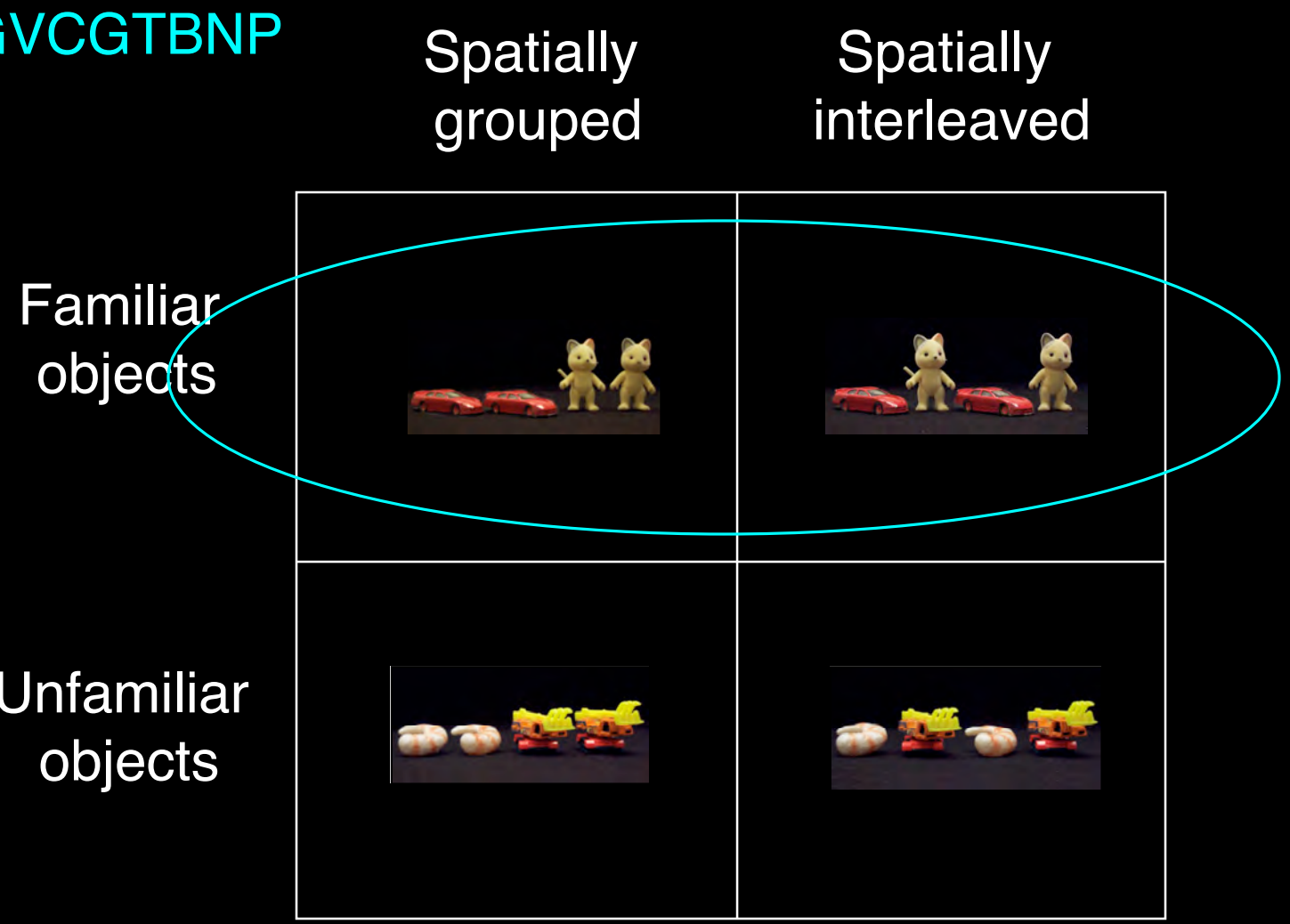
Familiar objects

Unfamiliar objects

Perceptual and Conceptual Set-building by Infants?

- Conceptual sets???

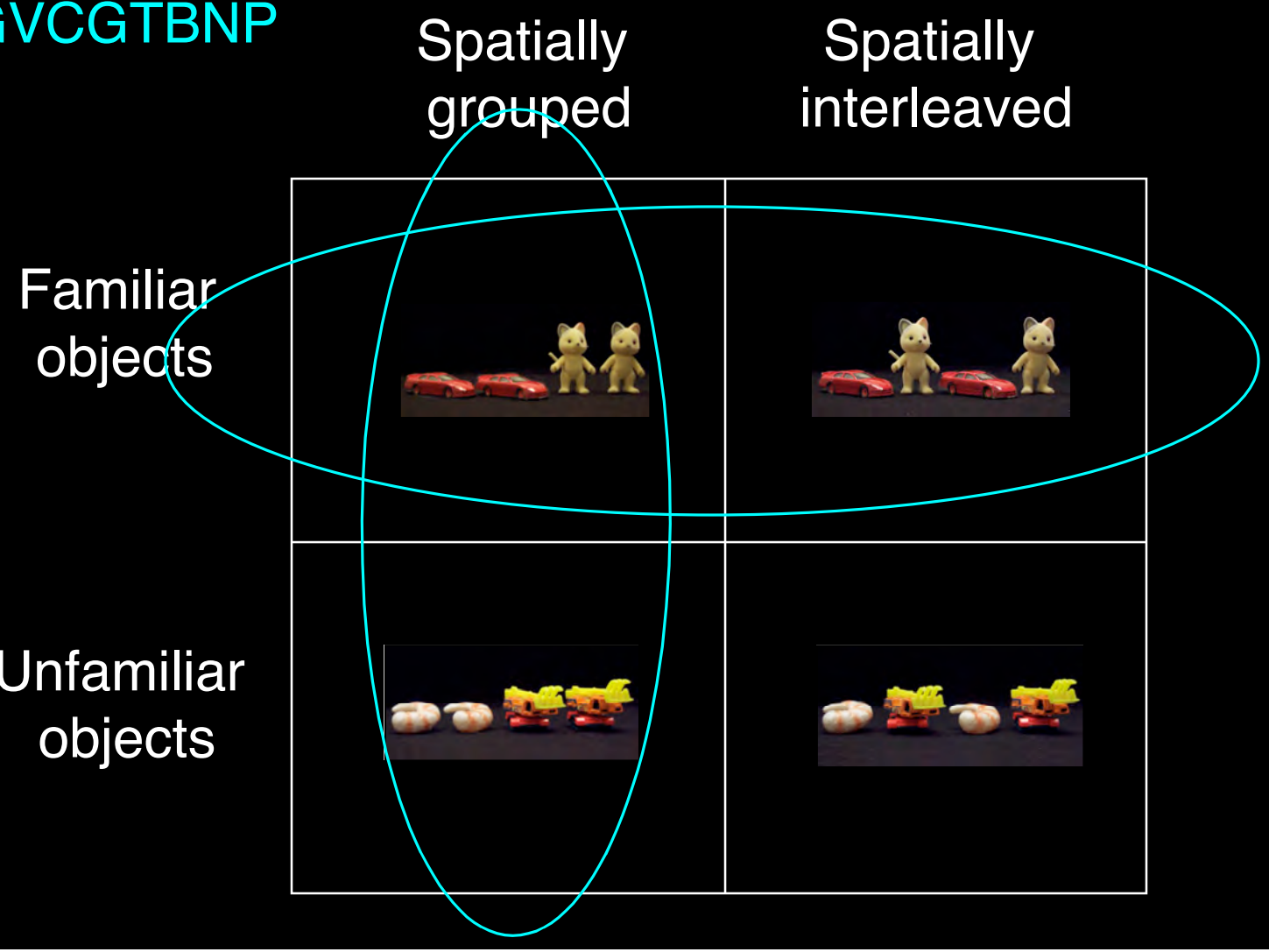
TGVCGTBNP



Perceptual and Conceptual Set-building by Infants?

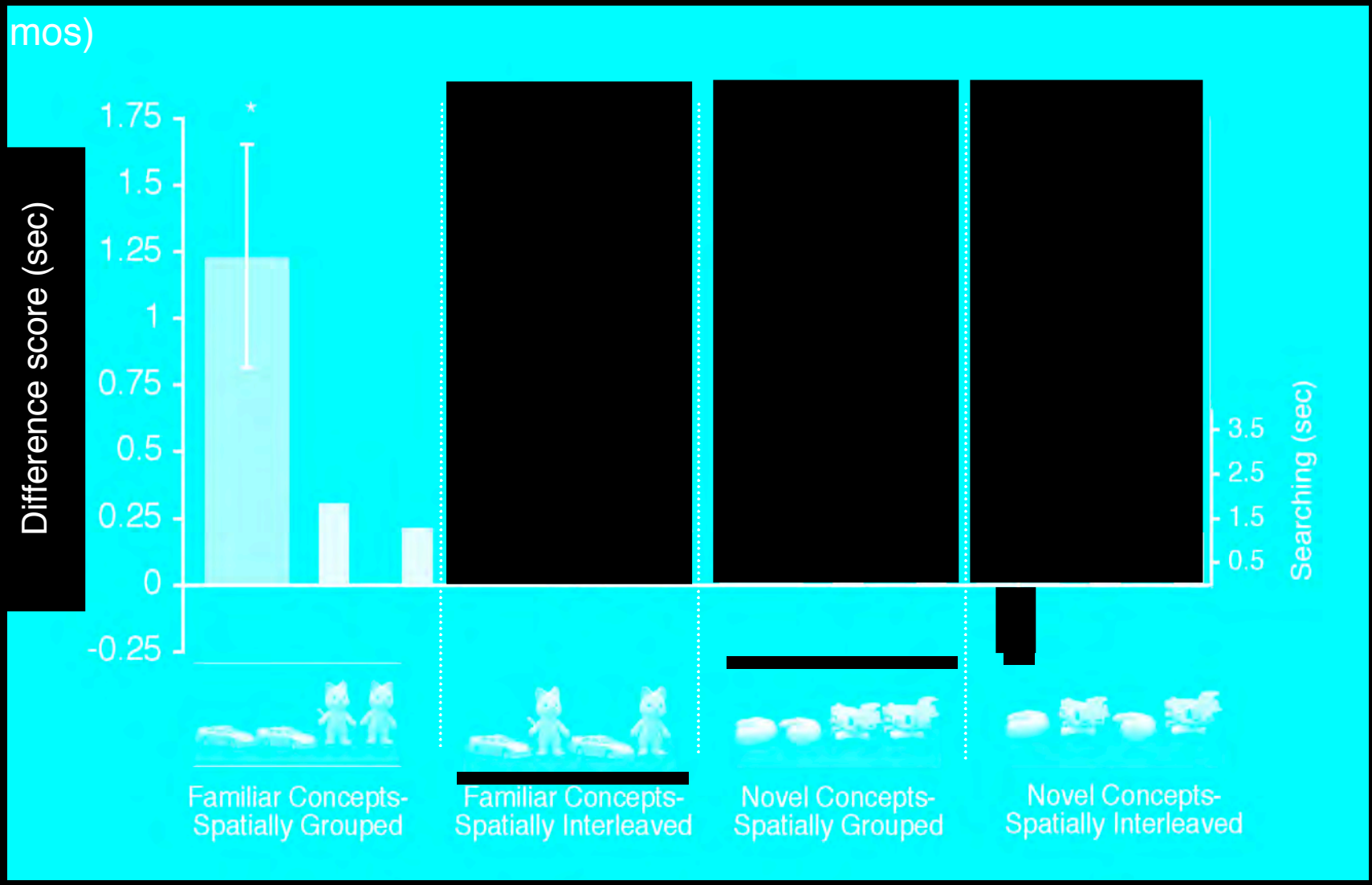
- Conceptual sets???

TGVCGTBNP



Perceptual and Conceptual Set-building by Infants?

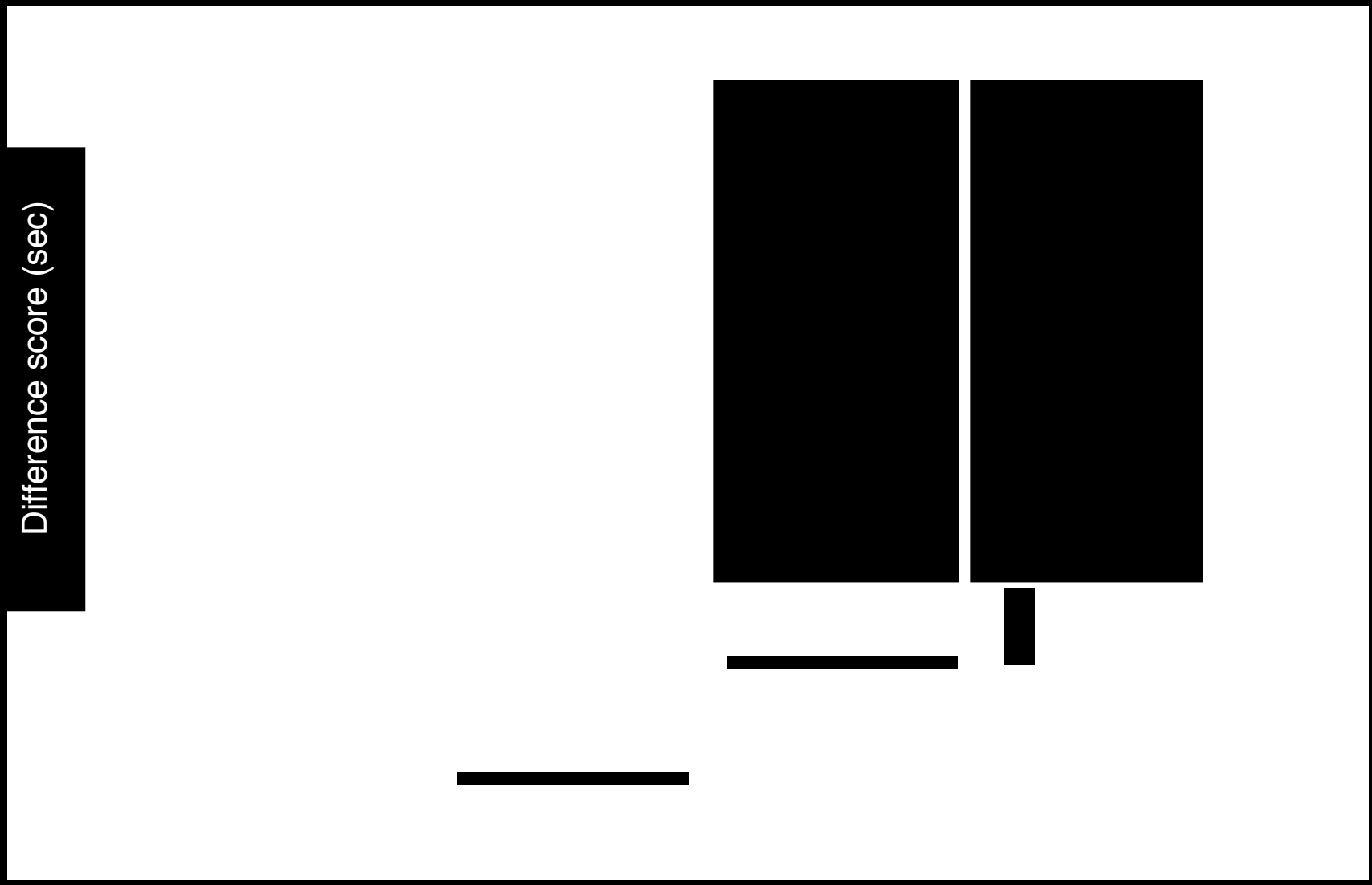
(14 mos)



Feigenson & Halberda (submitted)

Perceptual and Conceptual Set-building by Infants?

(14



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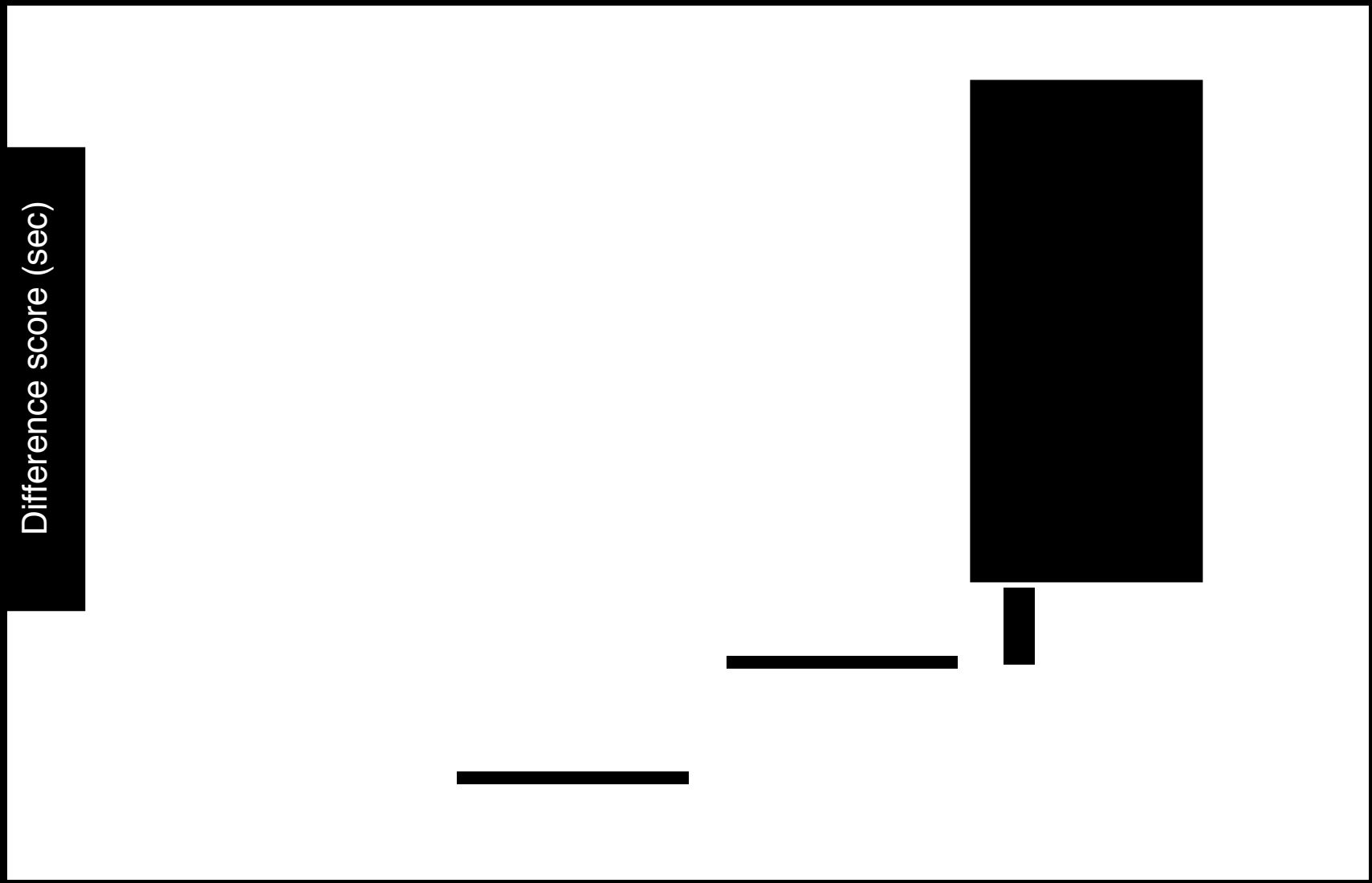
Perceptual and Conceptual Set-building by Infants?

(14



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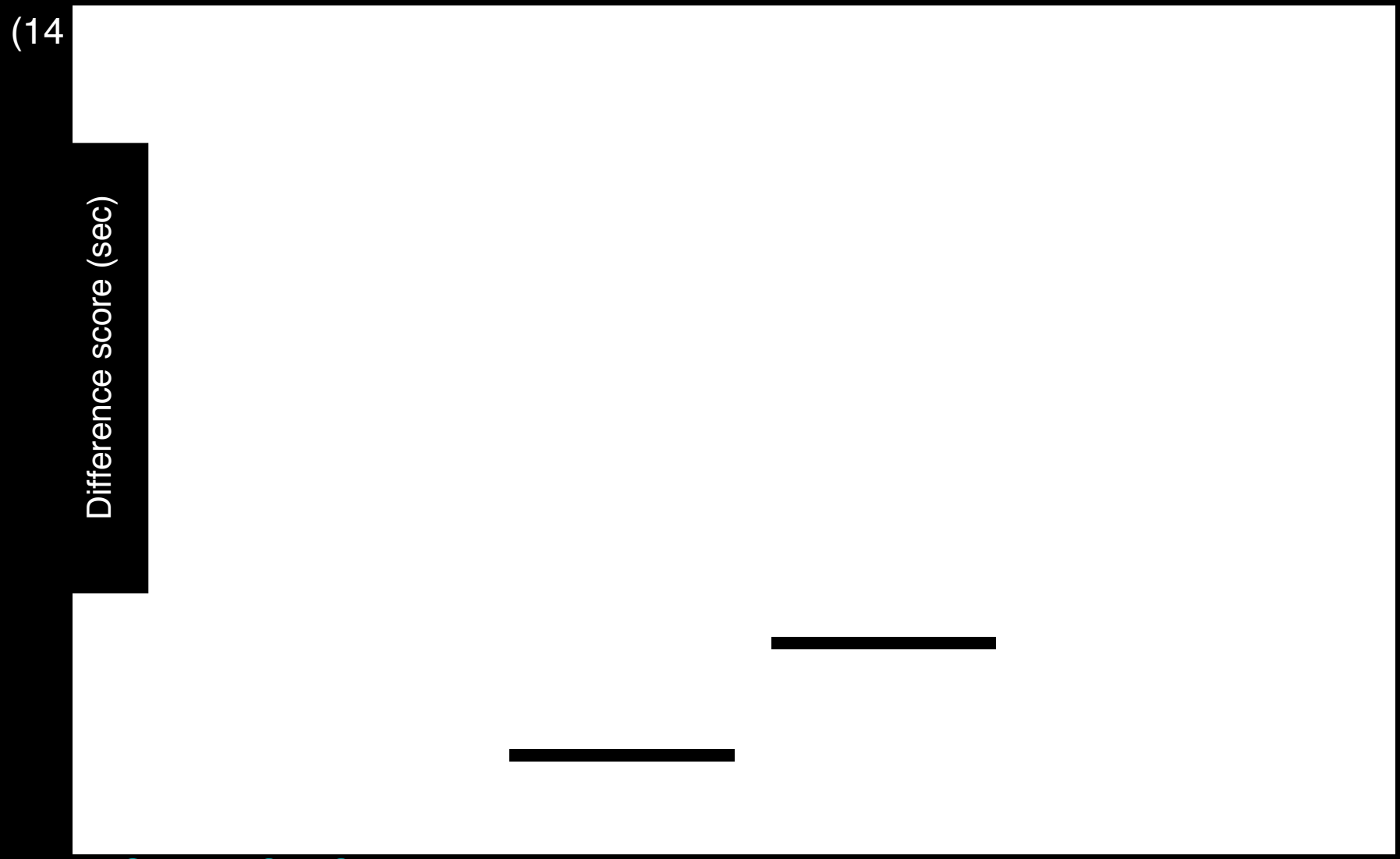
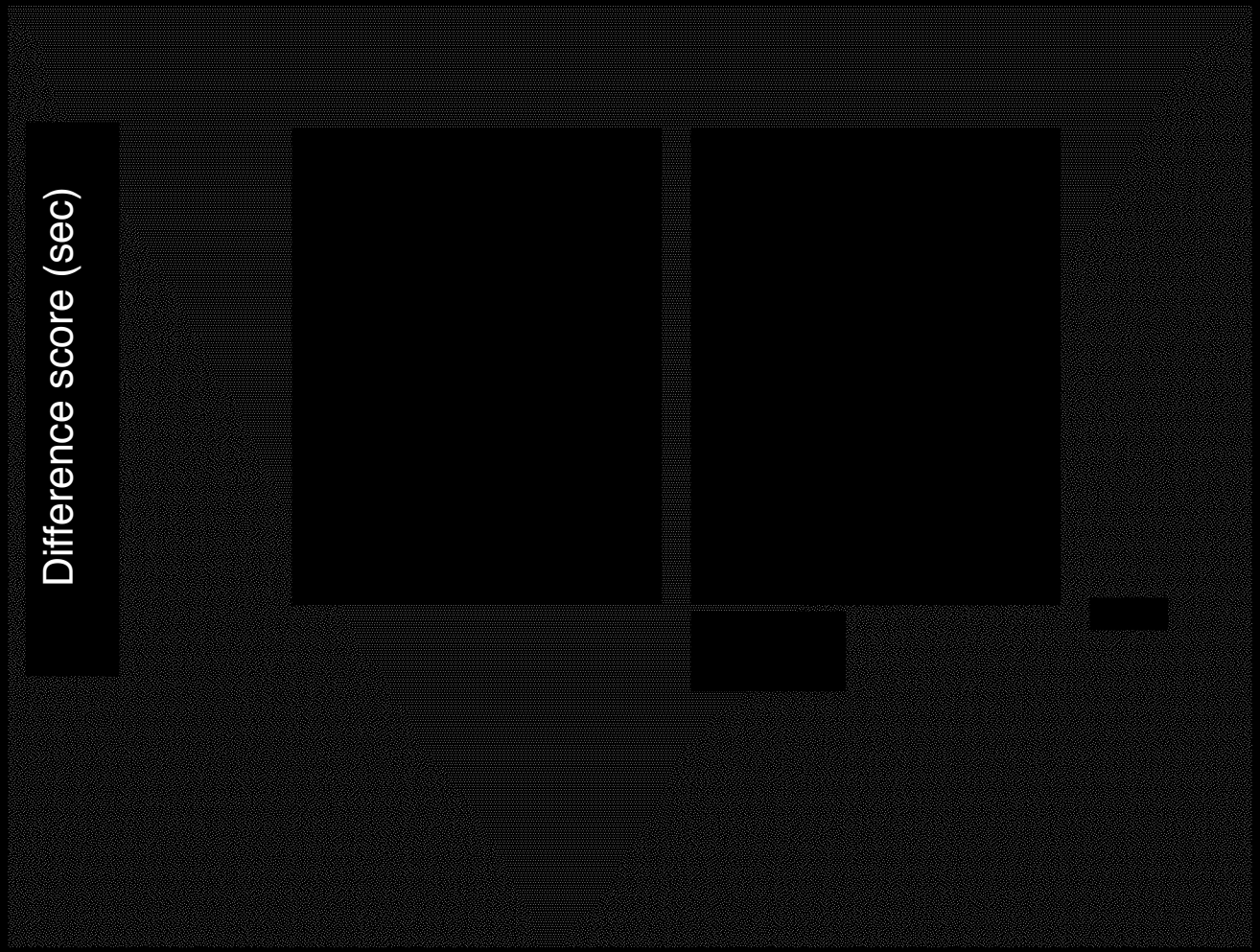
Perceptual and Conceptual Set-building by Infants?



Feigenson & Halberda (submitted)

Set Binding of Non-identical Items?

(14 mos)



Feigenson & Halberda (submitted)

Set Binding of Non-identical Items?

(14 mos)

Feigenson & Halberda (submitted)

Linguistic Set-building by Infants?

(14 mos)

Feigenson & Halberda (submitted)

Linguistic Set-building by Infants?

(14 mos)

Feigenson & Halberda (submitted)

3rd Core System: Set Representations

Does thinking about SETS help infants represent more than simply thinking about INDIVIDUAL ITEMS?

3 Sources of Evidence for Set-building

Spatiotemporal sets

01 23 45 67 89

Conceptual sets

TGVCGTBNP

TGV CGT BNP

Linguistic sets

3 Core Systems

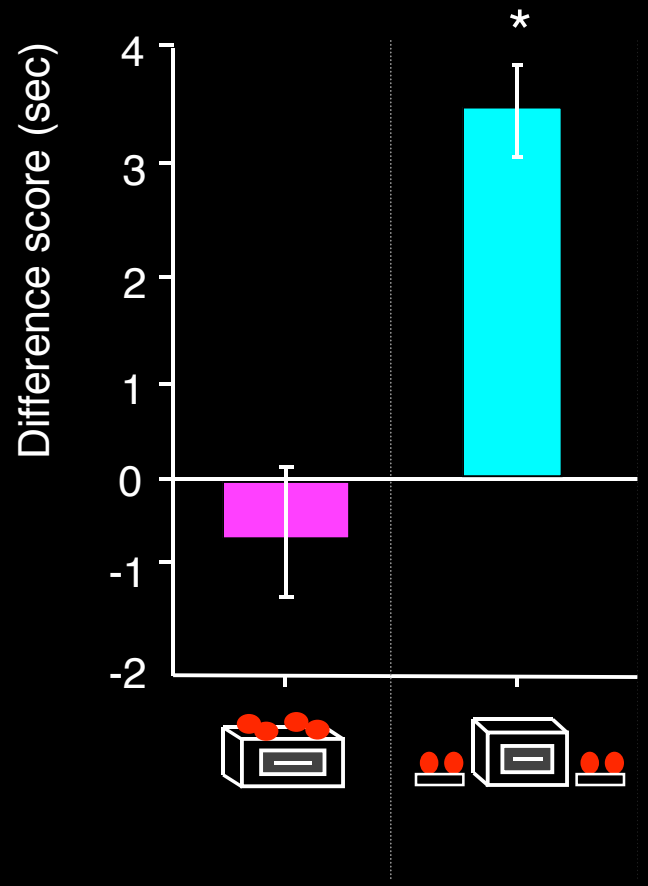
Core System 1:
Numerical Approximation

Core System 2:
Individual object representations

Core System 3:
Set based representations

3 Core Systems

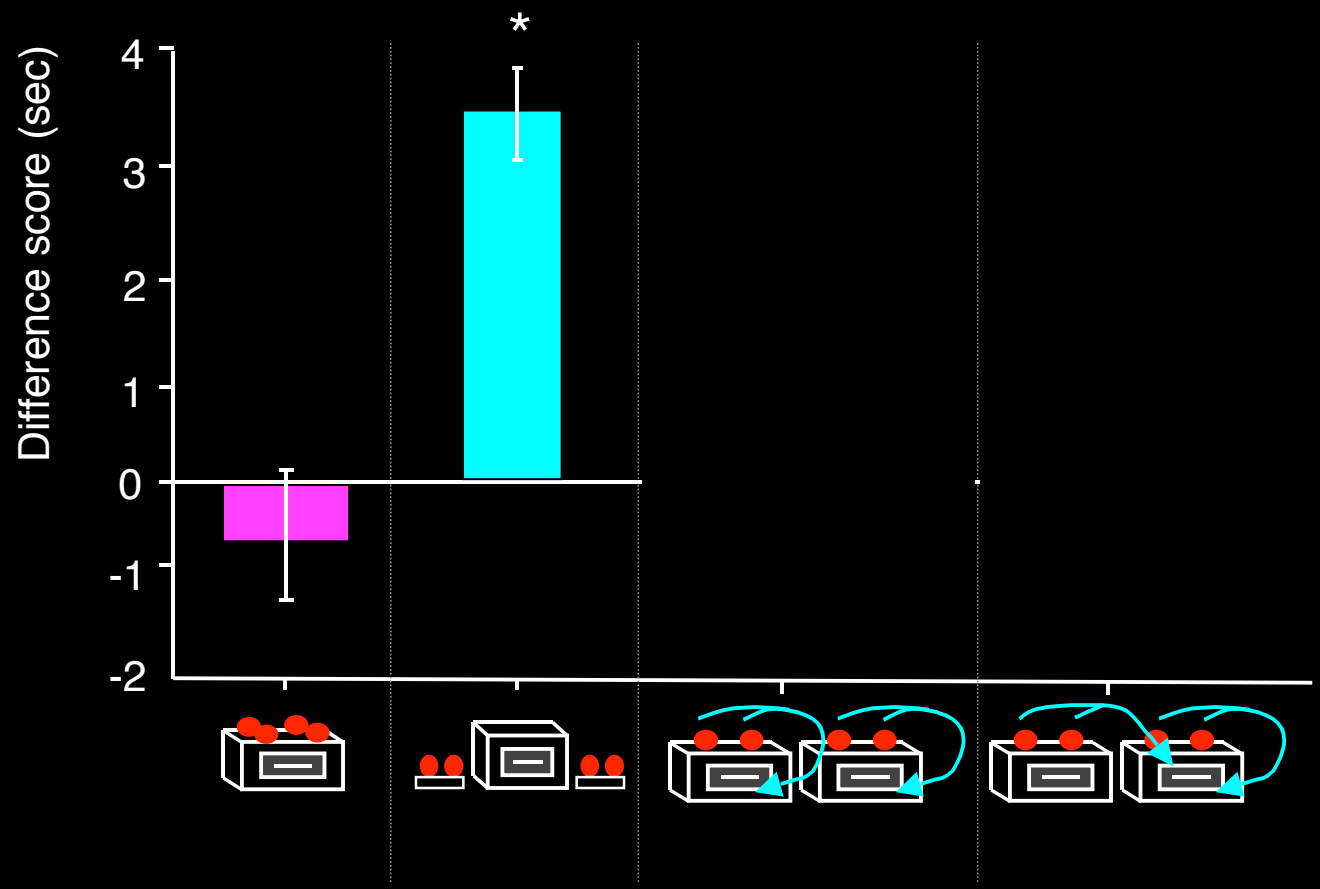
Interaction of Core Systems 2 and 3:



Feigenson & Halberda, 2004

3 Core Systems

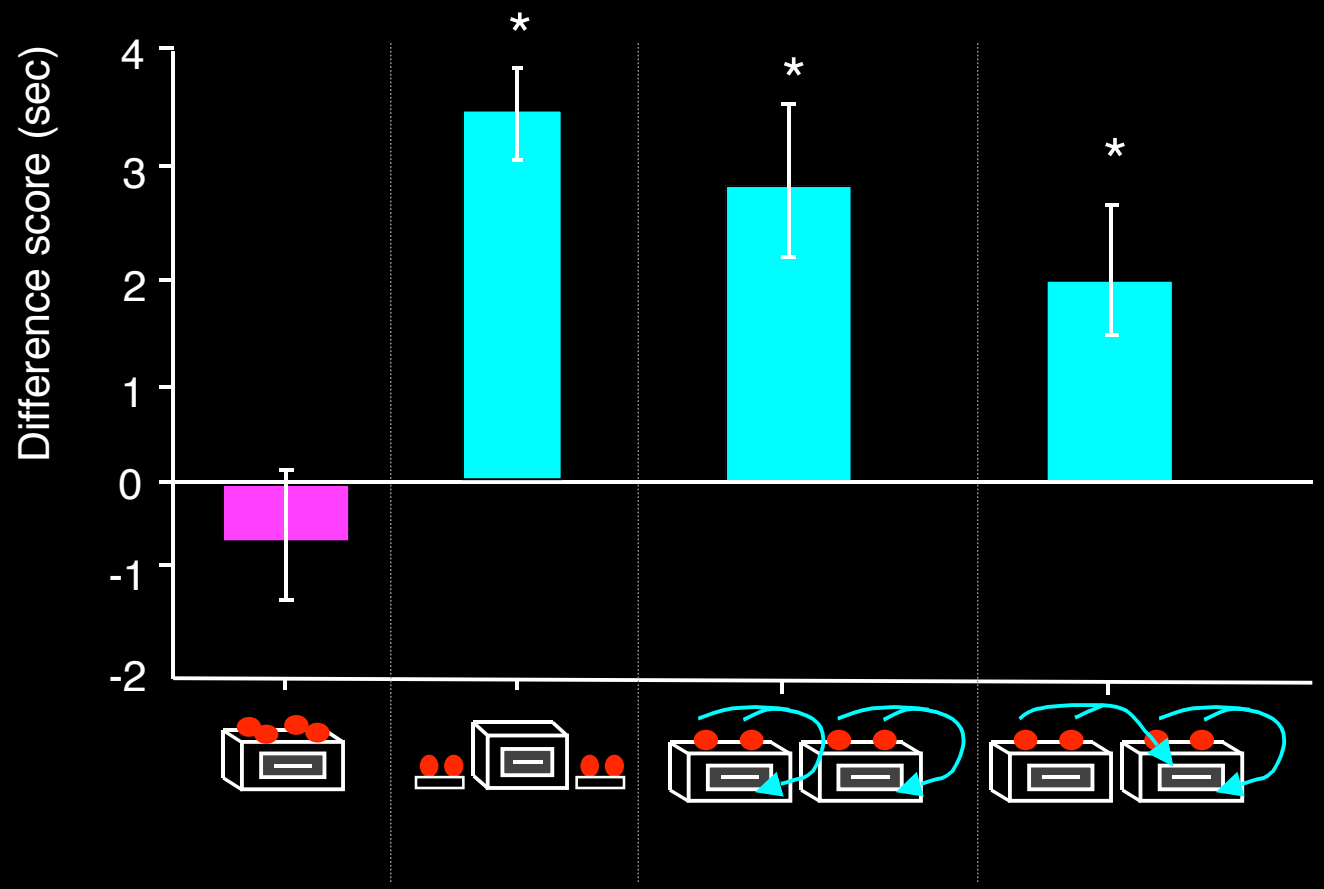
Interaction of Core Systems 2 and 3:



Feigenson & Halberda, 2004

3 Core Systems

Interaction of Core Systems 2 and 3:

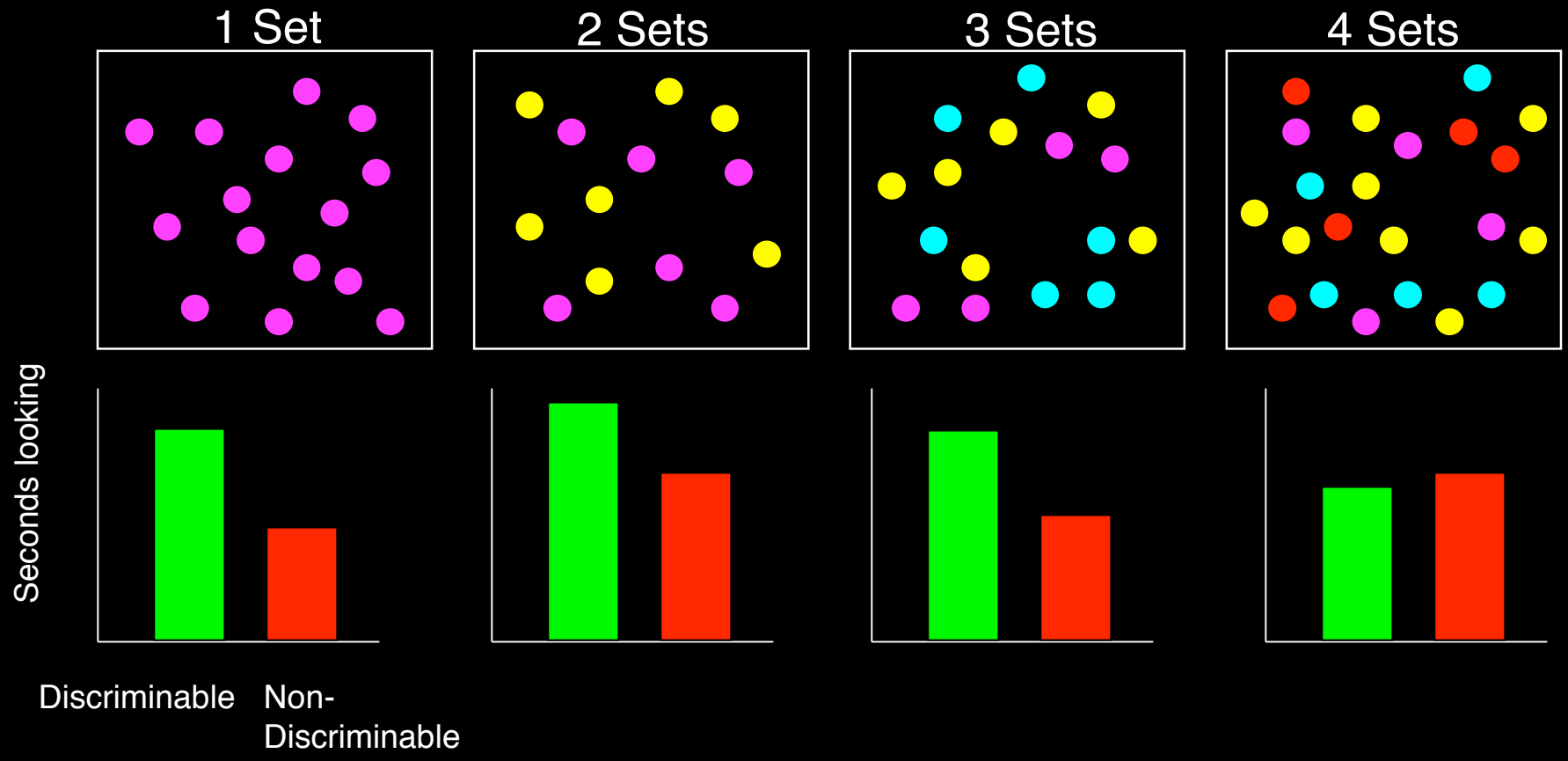


Infants can track the separate locations of two sets, treating them as individuals

Feigenson & Halberda, 2004

3 Core Systems

Interaction of Core Systems 1 and 2:



Infants can represent up to *3 numerical approximations*, just as they can represent up to *3 individual objects*

Halberda, Sires, & Feigenson, 2006; Feigenson & Zosh, in preparation

3 Core Systems

≈ 50

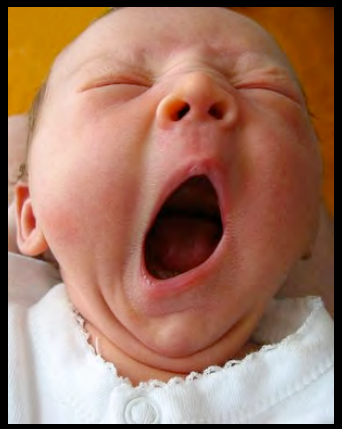
Core System 1:
Numerical Approximation

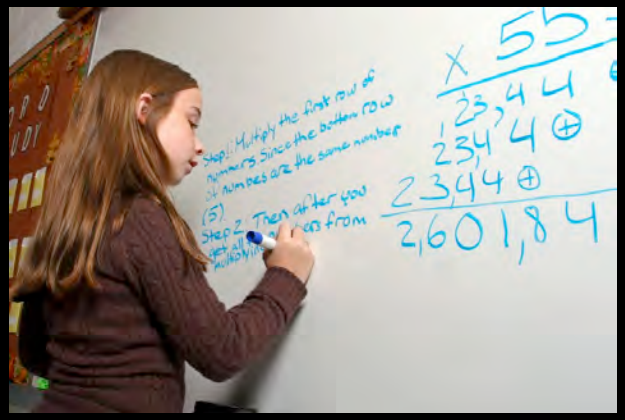
That Strawberry

Core System 2:
Individual object representations

Set of 14 strawberries

Core System 3:
Set based representations





Acknowledgements

With support from:
- the James S. McDonnell Foundation
- the National Institutes of Health