Disorders of the 'Mathematical Brain': Developmental Dyscalculia & Mathematics Anxiety

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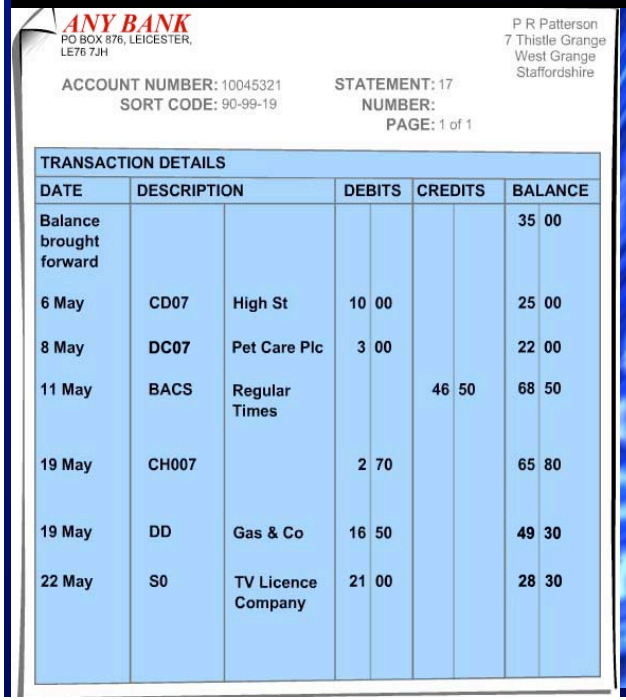
Western

The Art and Science of Math Education, University of Winnipeg, November 19th 2011

Medals Table

1.	Canada	14	7	5
2.	Germany	10	13	7
3.	USA	9	15	13
4.	Norway	9	8	6
5.	South Korea	6	6	2
6.	Switzerland	6	0	3
7.	China	5	2	4
7.	Sweden	5	2	4
9.	Austria	4	6	6
10.	Netherlands	4	1	3



ANY BANK
PO BOX 876, LEICESTER,
LE76 7JH

P R Patterson
7 Thistle Grange
West Grange
Staffordshire

ACCOUNT NUMBER: 10045321
SORT CODE: 90-99-19

STATEMENT NUMBER: 17
PAGE: 1 of 1

TRANSACTION DETAILS

DATE	DESCRIPTION		DEBITS	CREDITS	BALANCE
Balance brought forward					35 00
6 May	CD07	High St	10 00		25 00
8 May	DC07	Pet Care Plc	3 00		22 00
11 May	BACS	Regular Times		46 50	68 50
19 May	CH007		2 70		65 80
19 May	DD	Gas & Co	16 50		49 30
22 May	S0	TV Licence Company	21 00		28 30

Outline

- **The importance of basic number processing**
- Behavioral and Brain-Imaging evidence
- Disordered Basic Number Processing in Dyscalculia
- Disordered Basic Number Processing in Mathematics Anxiety
- Implications, Future Directions and Conclusions

Basic Numerical Processing

- What is numerical magnitude processing?

→ **3**

Nonsymbolic ***Symbolic***

- Total number of items in a set

Measuring basic number processing
or ‘ Number Sense’

Number Comparison

EXAMPLE STIMULI

Distance 1
SMALL

2 ▪ 1

Distance 7
LARGE

1 ▪ 8

Time

Which is larger?

Distance Effect

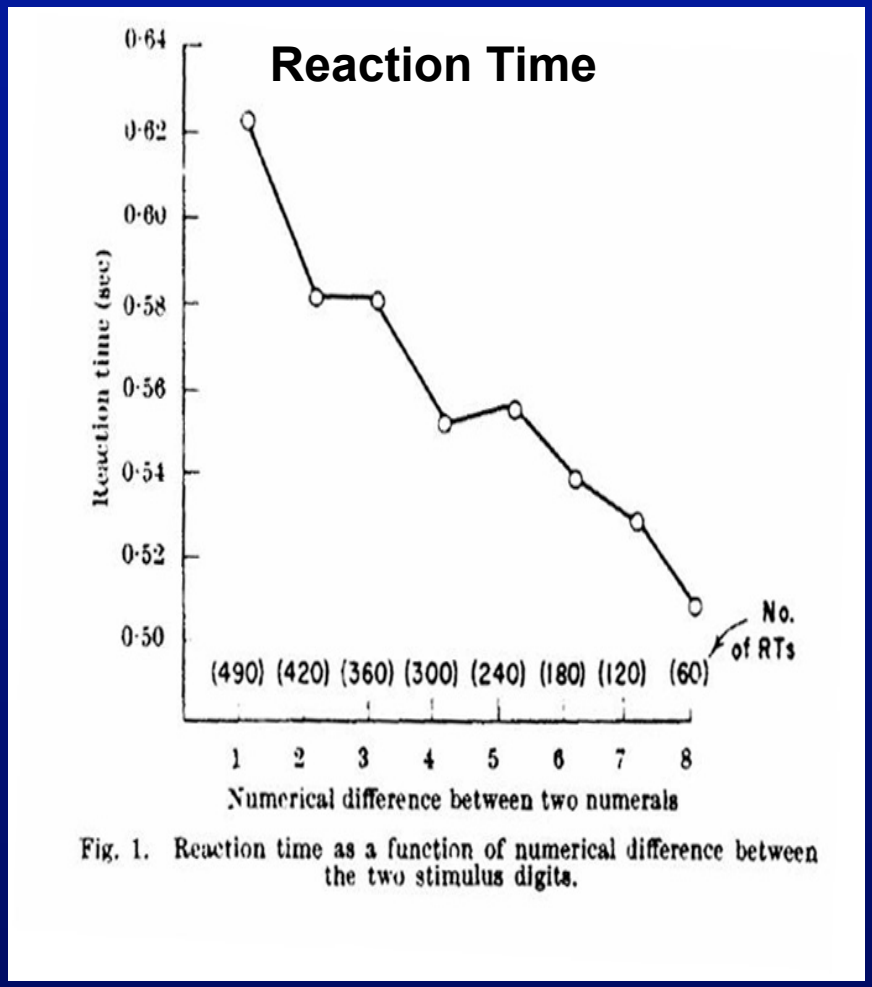


Fig. 1. Reaction time as a function of numerical difference between the two stimulus digits.

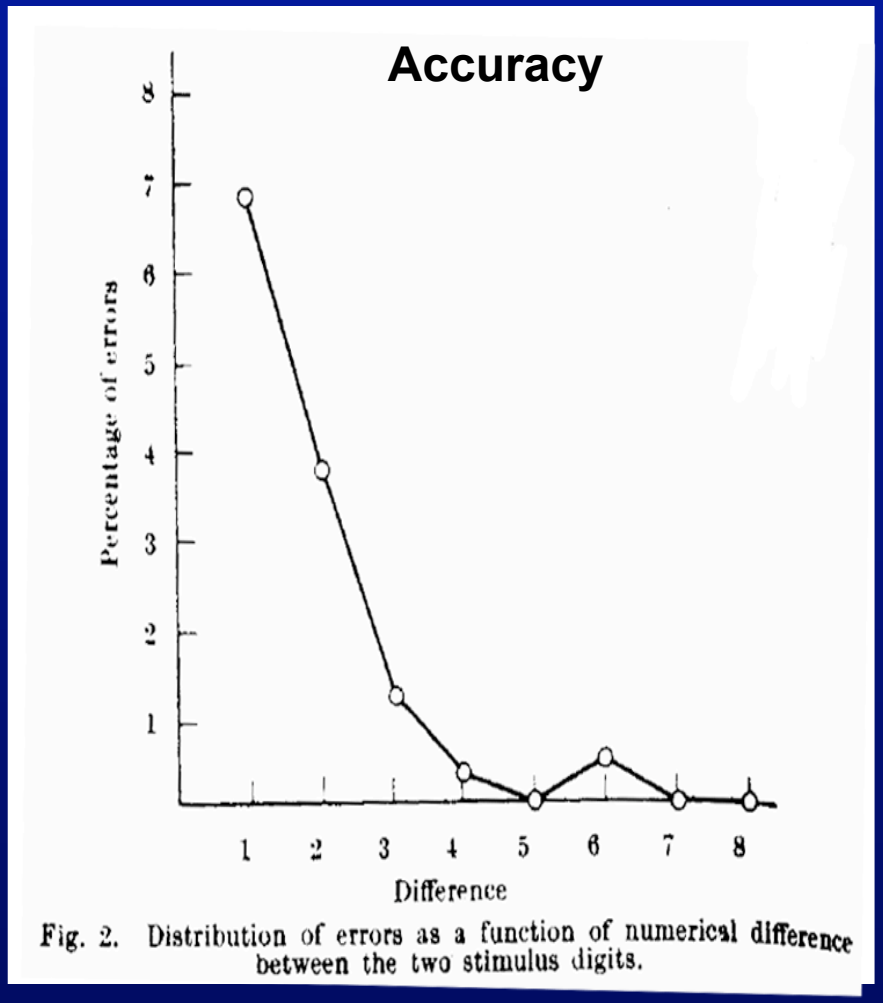
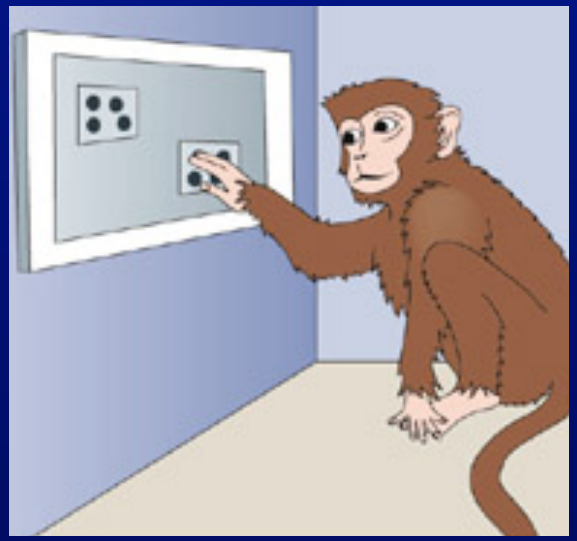


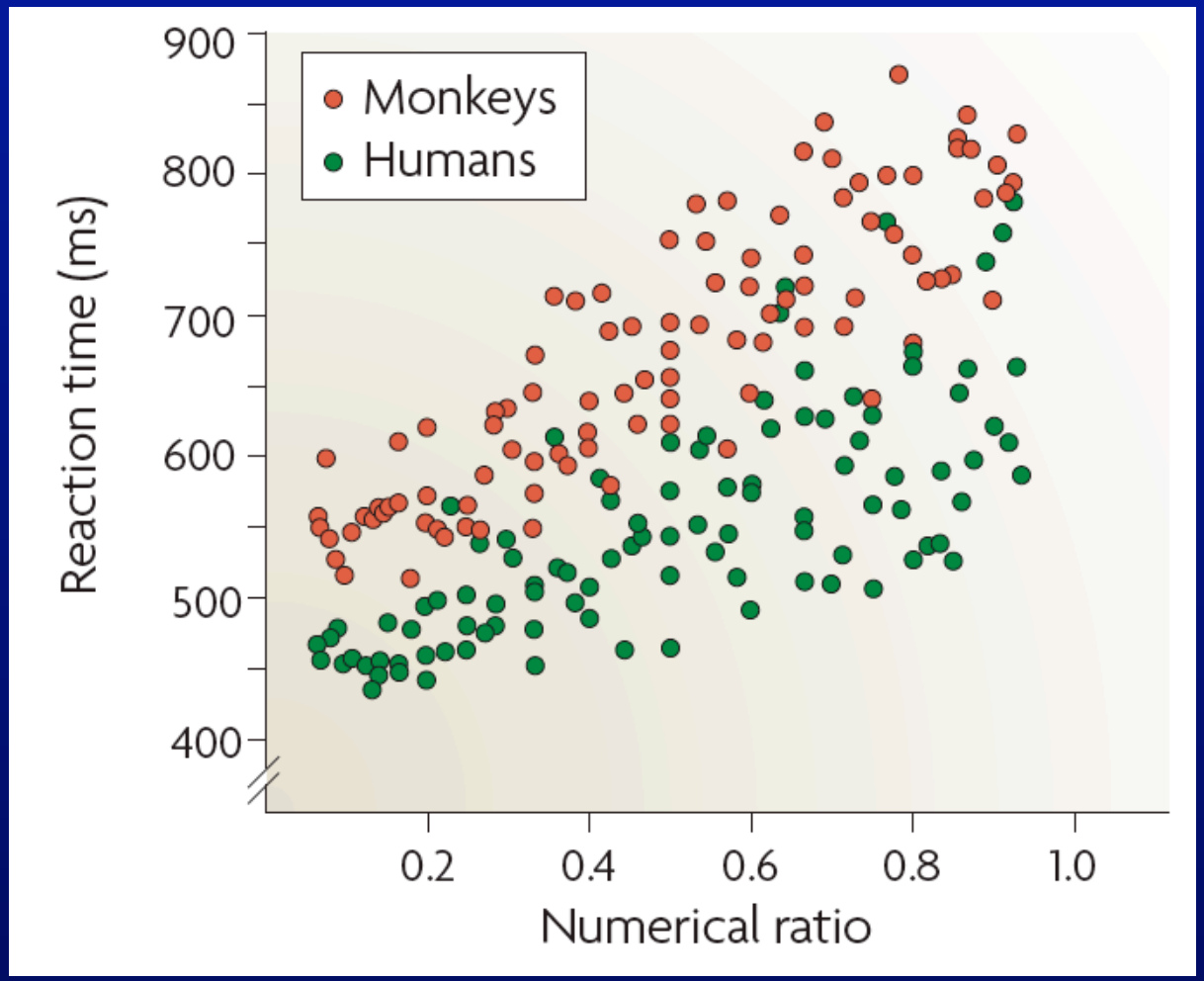
Fig. 2. Distribution of errors as a function of numerical difference between the two stimulus digits.

Moyer & Landauer(1967)

Size (ratio) effect

	Distance	Ratio
1 - 2	1	0.5
9 - 8	1	0.88

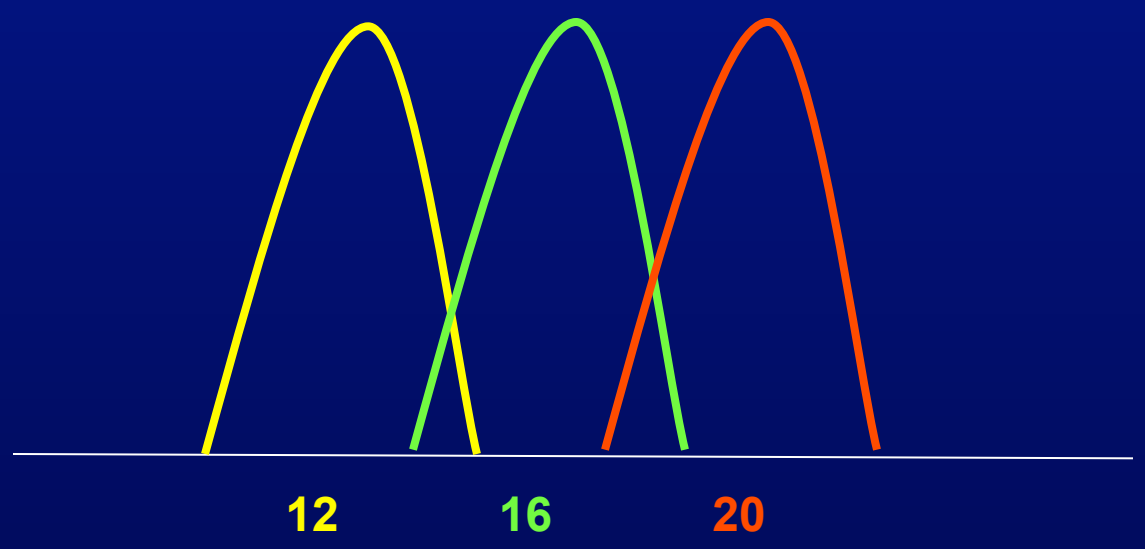




Cantlon & Brannon (2006)

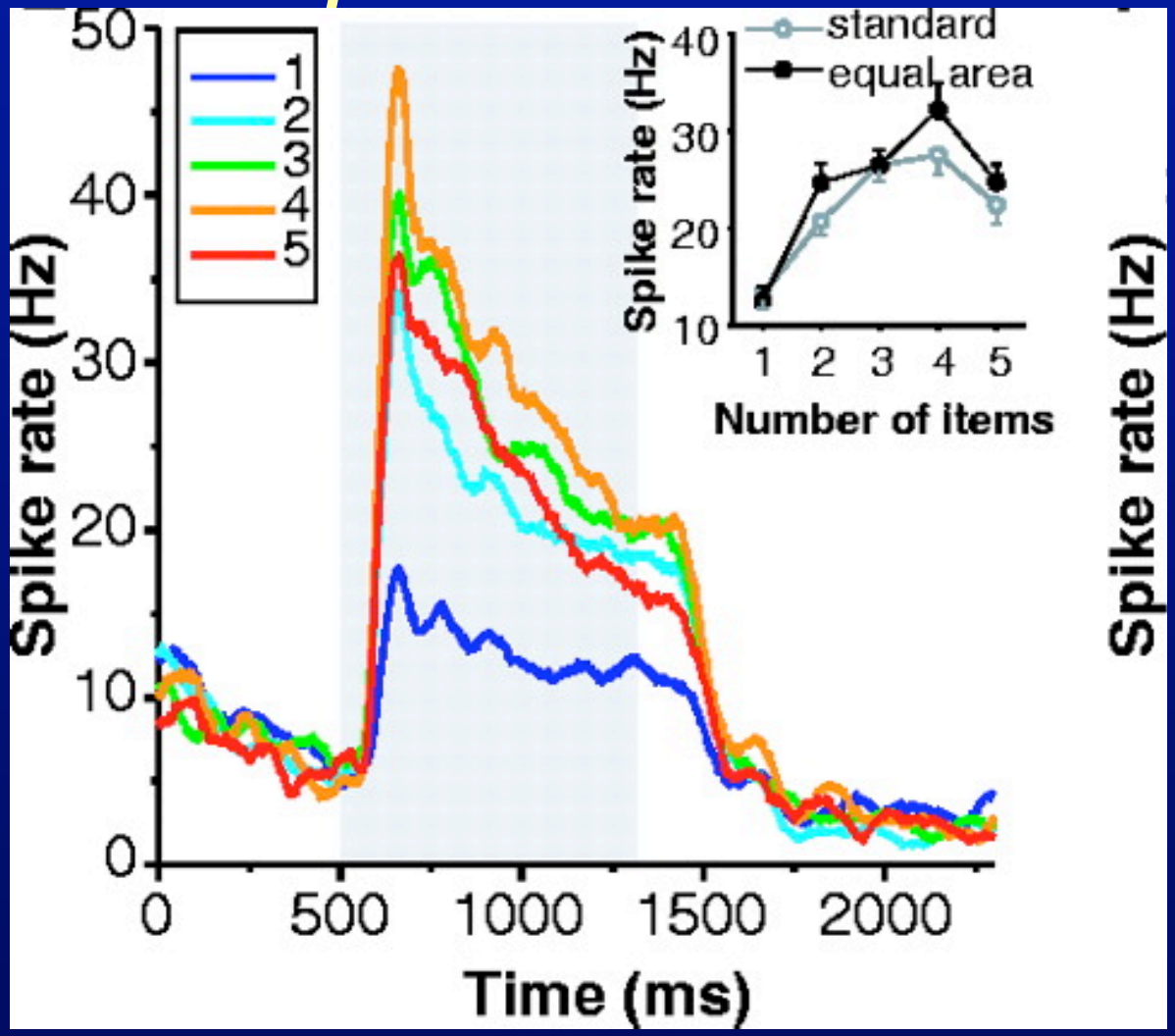
Behavioral Effects

- Distance effect reveals features of underlying ***quantity*** system
- Noisy mental "Number Line" (Dehaene, 1997)



Number Neurons

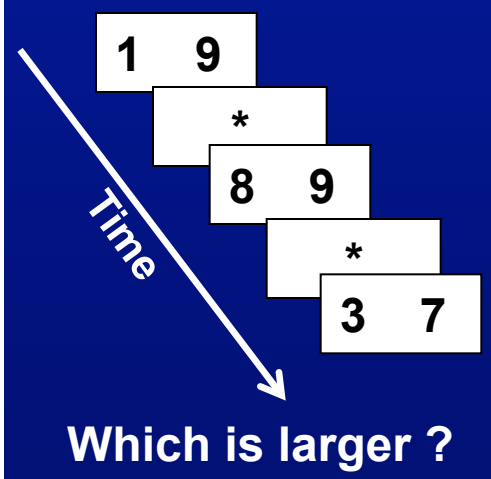
Example: A "4" Neuron

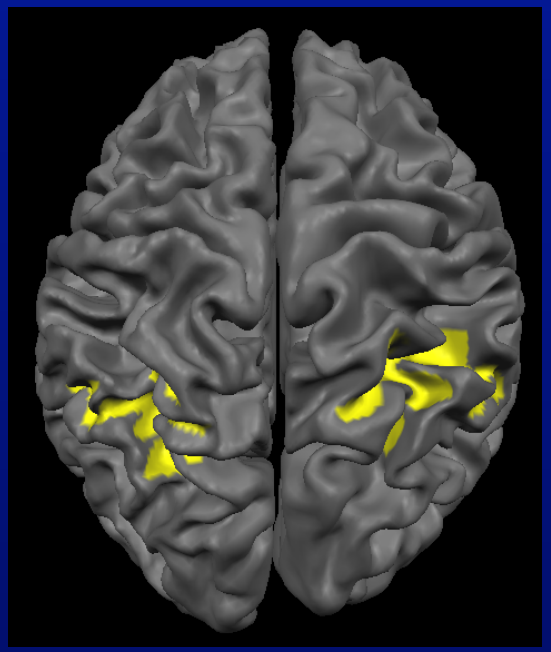


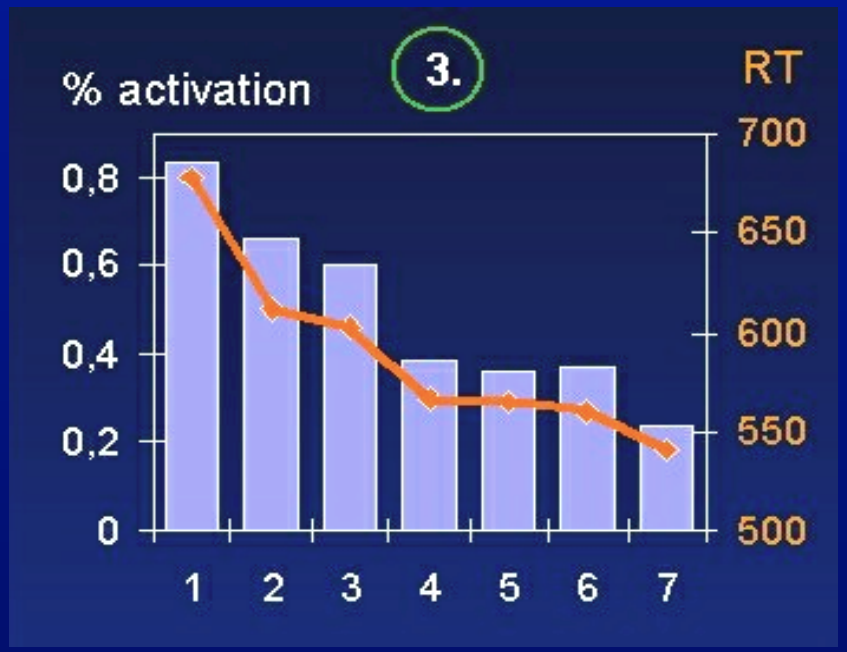
Nieder & Miller (2002)

Distance Effect
Neural Correlates

Distance modulates a network of parietal areas







(Pinel et al., 1999, 2001, 2004; Kaufmann et al., 2006; Ansari et al;, 2006)

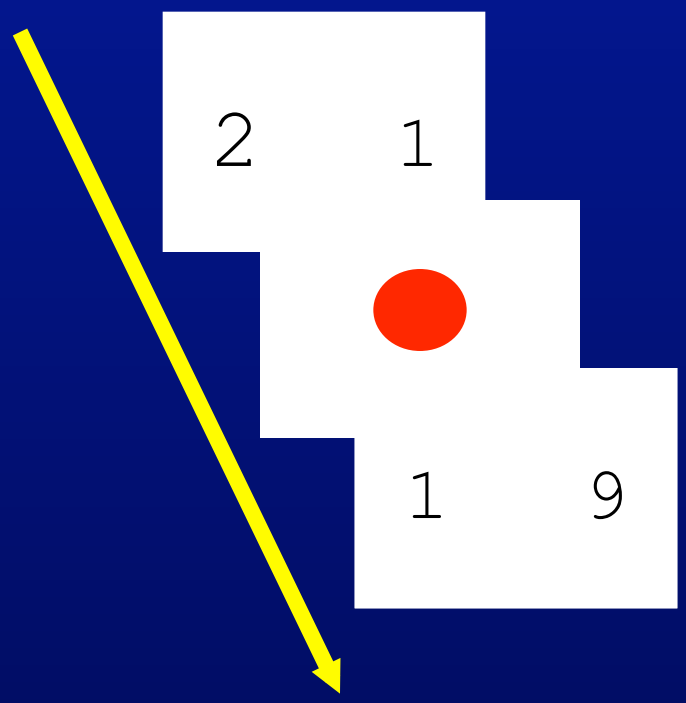
Functional Significance?

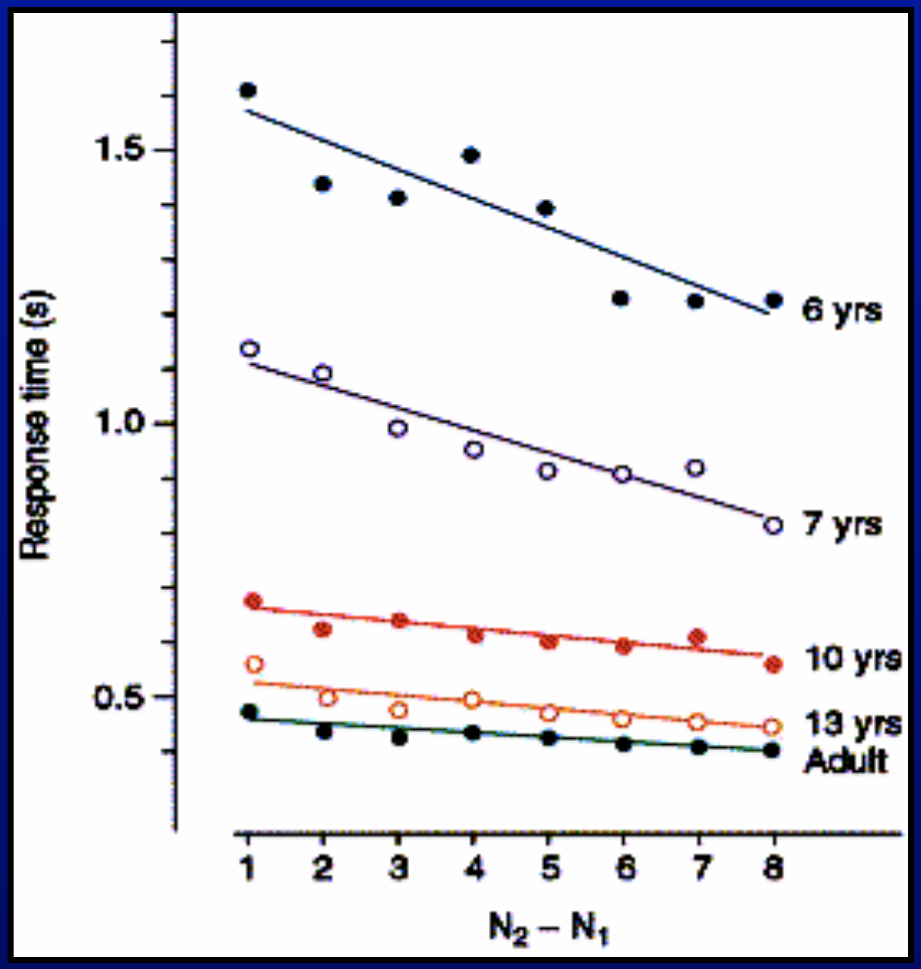
- Developmental Changes?

- Relationship to higher-level skills?

Distance Effect

Development

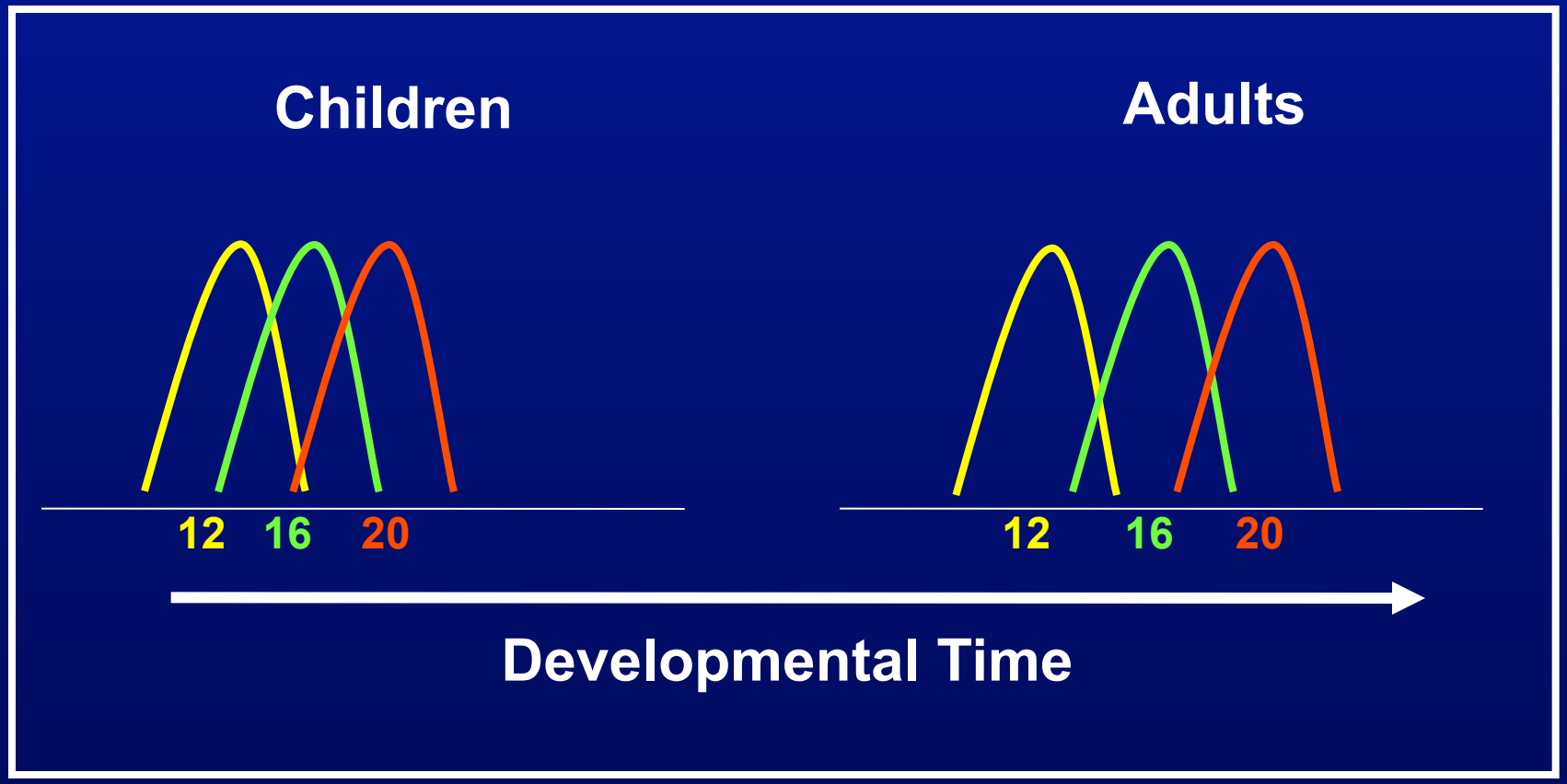




Sekuler & Mierkiewz (1977); Holloway & Ansari (2008)

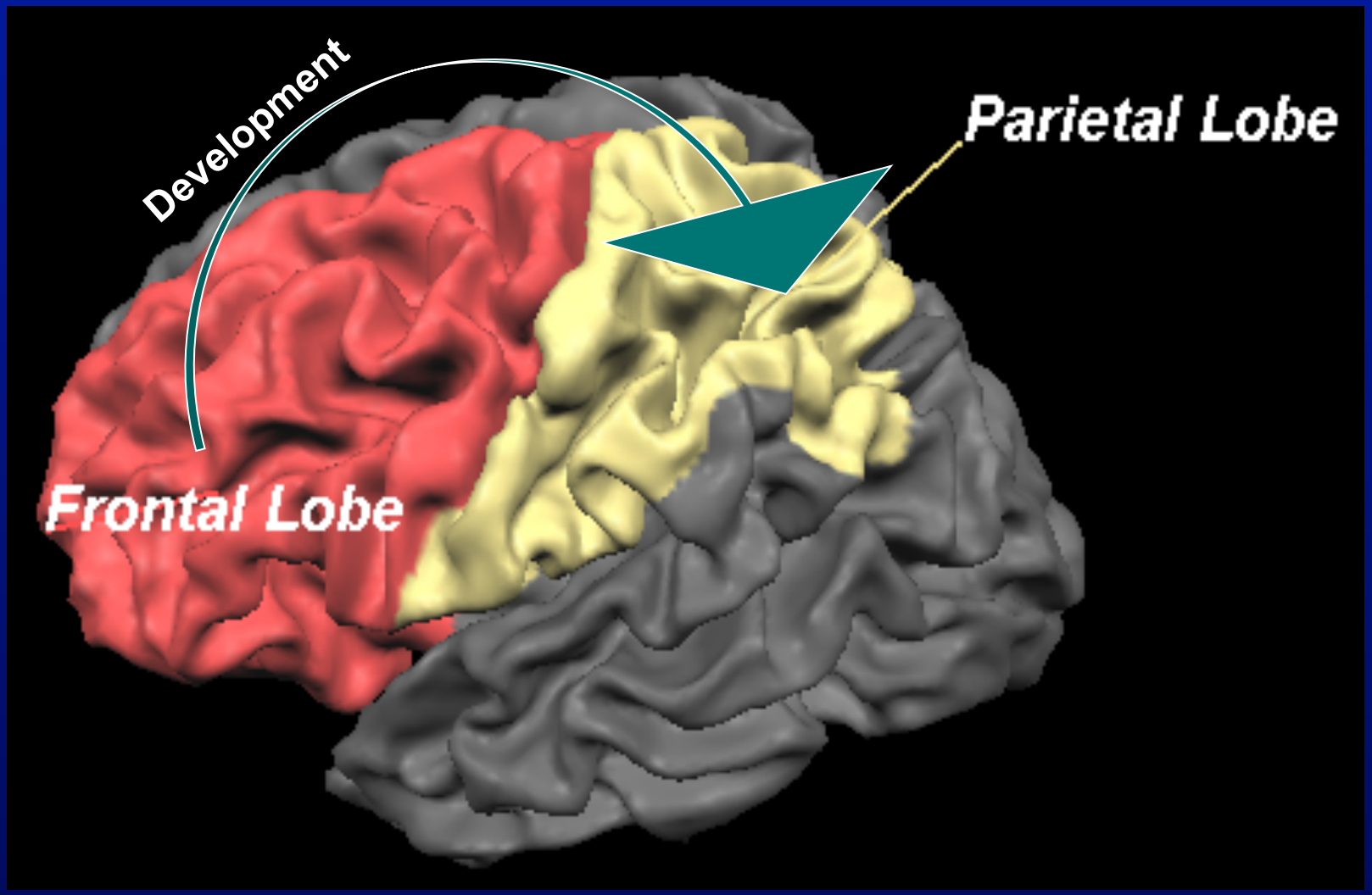
Behavioral Effects

- Decrease of distance effect over dev. time
- Decrease in noise → increase in precision



Developmental changes in the neural correlates of the distance effect?

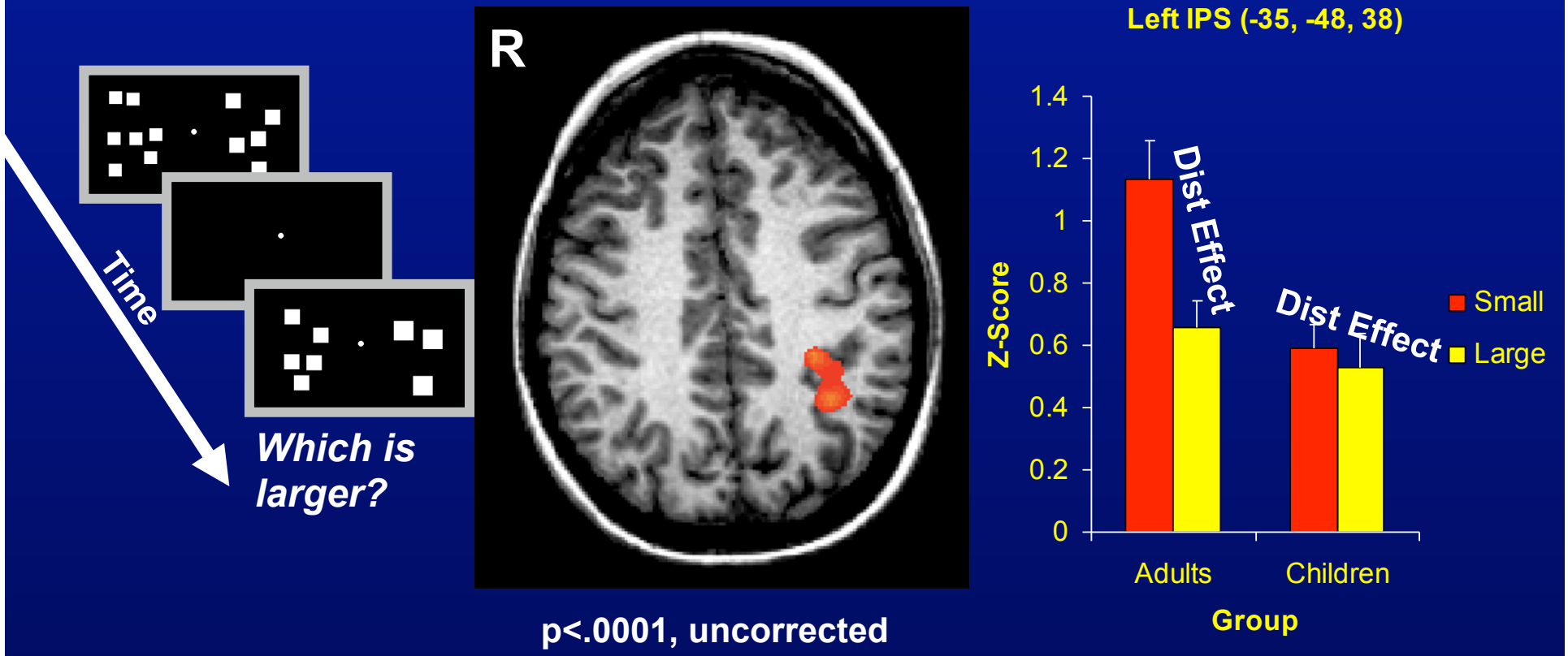
Age-related specialization



Rivera et al. (2005) Ansari et al. (2005); Ansari & Dhital (2006)

Age-related cortical specialization

Distance (small vs. large) X Age (Children vs. Adults)

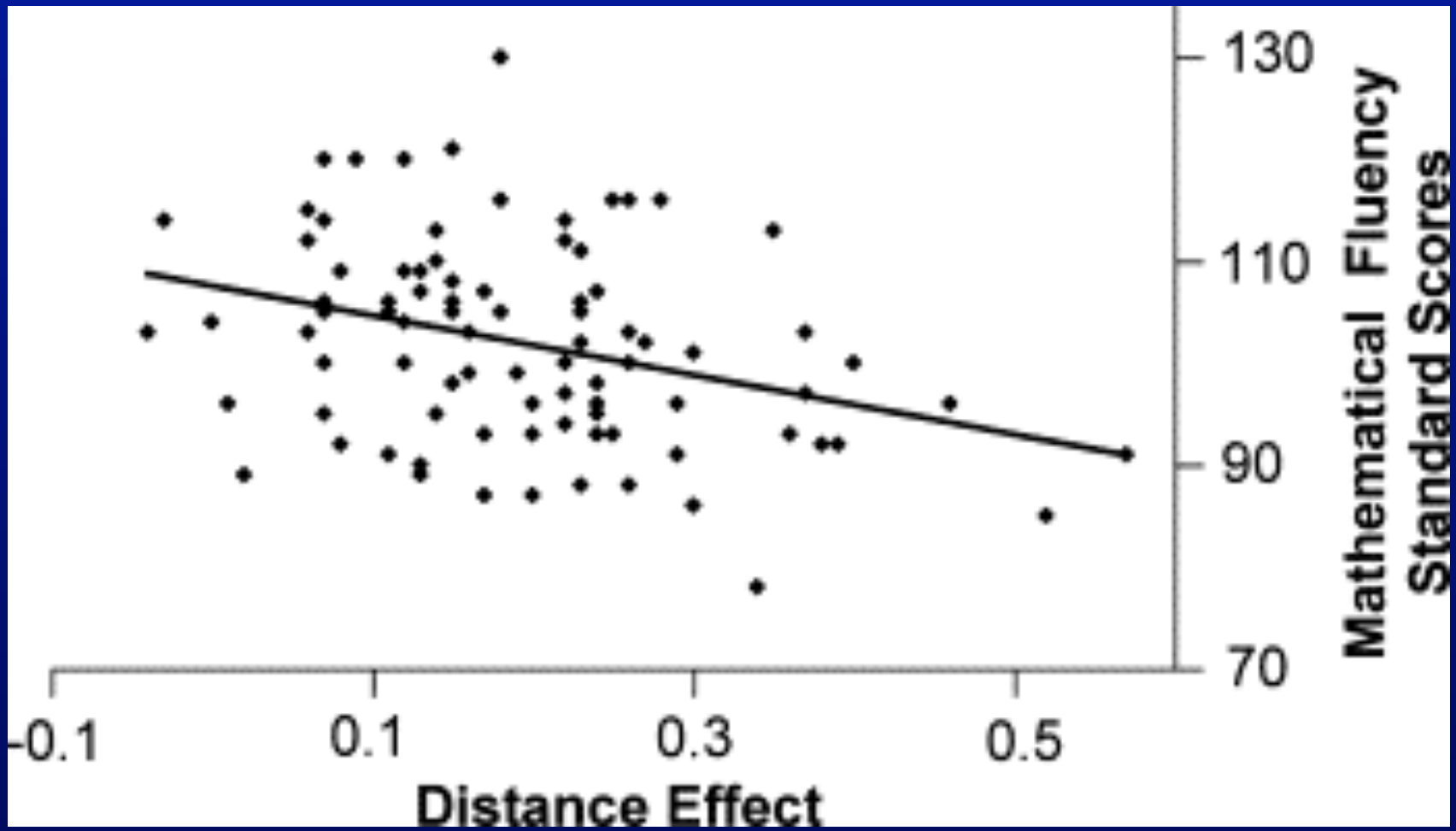


p<.0001, uncorrected

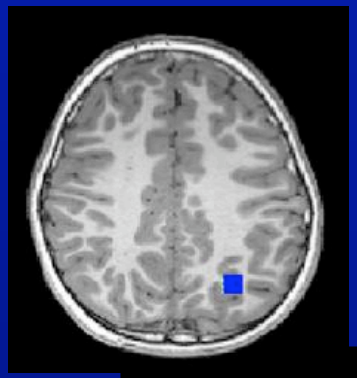
Ansari & Dhital (2006) *Journal of Cognitive Neuroscience*

Relationship to individual differences in math achievement?

Functional Significance

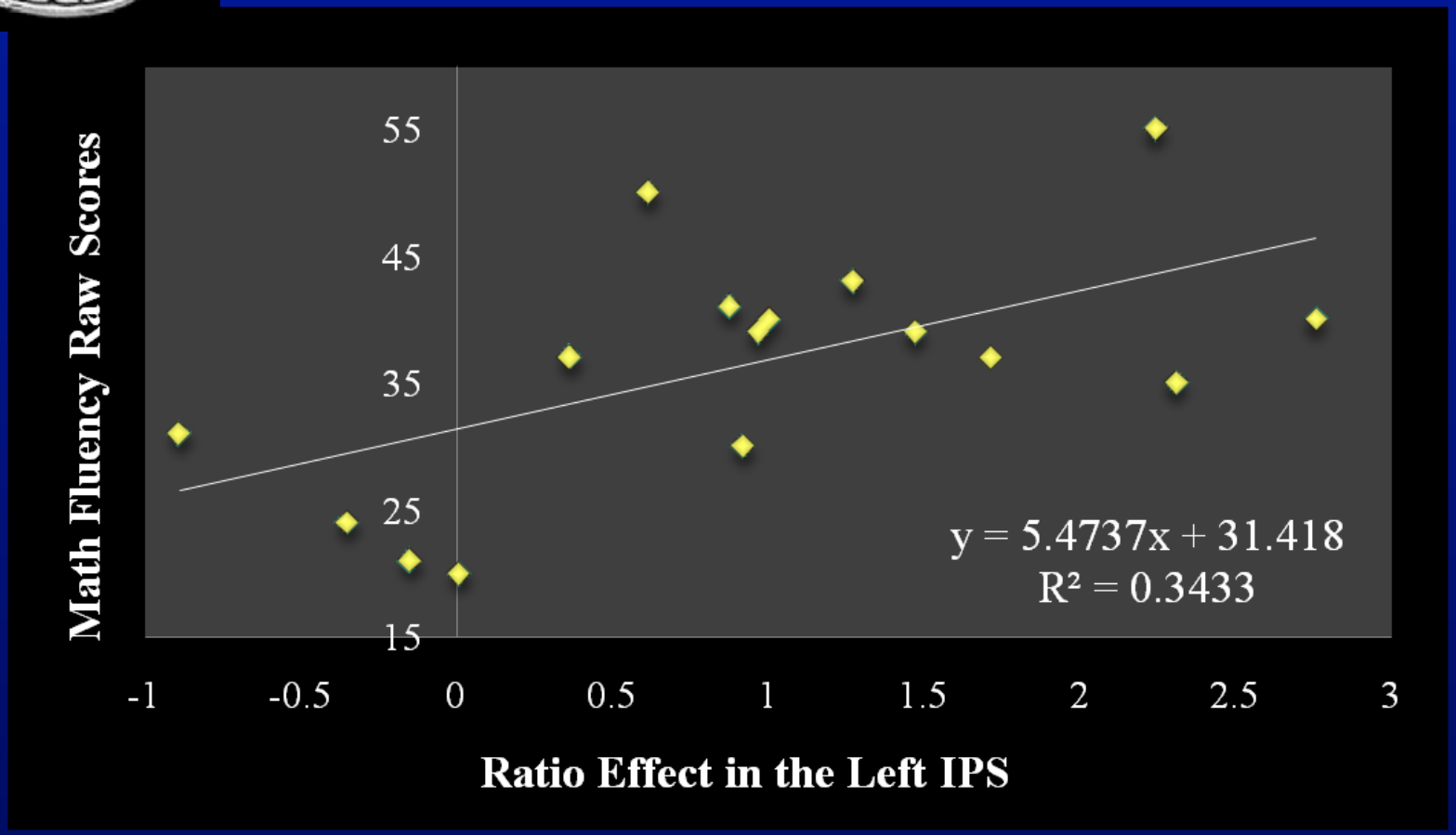


Holloway & Ansari (2009)



Brain-behavior

Stephanie Budgen

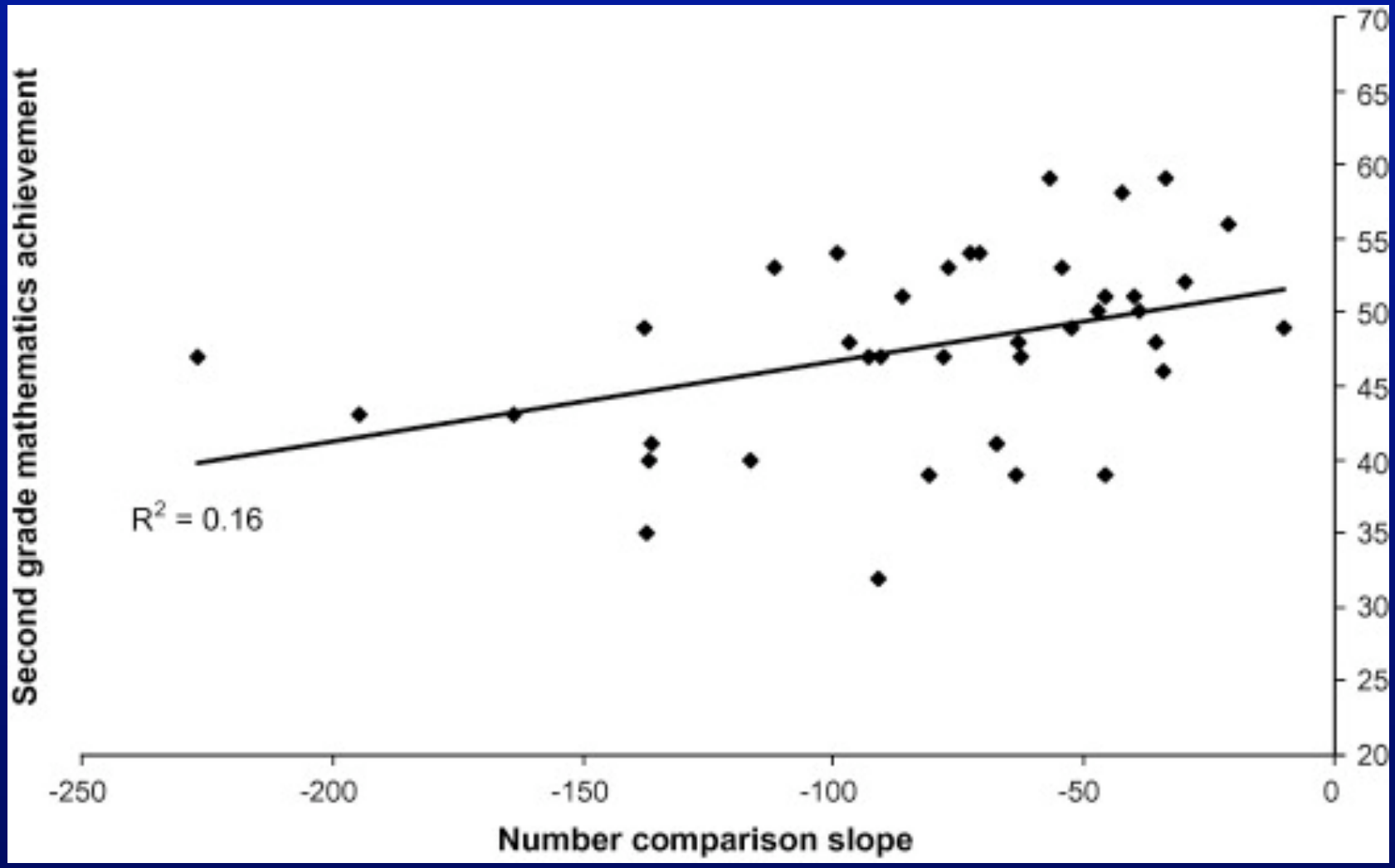


No correlation with reading score, verbal and non-verbal IQ

Bugden, Price, McLean & Ansari (under review)

Predictive Measure?

Functional Significance

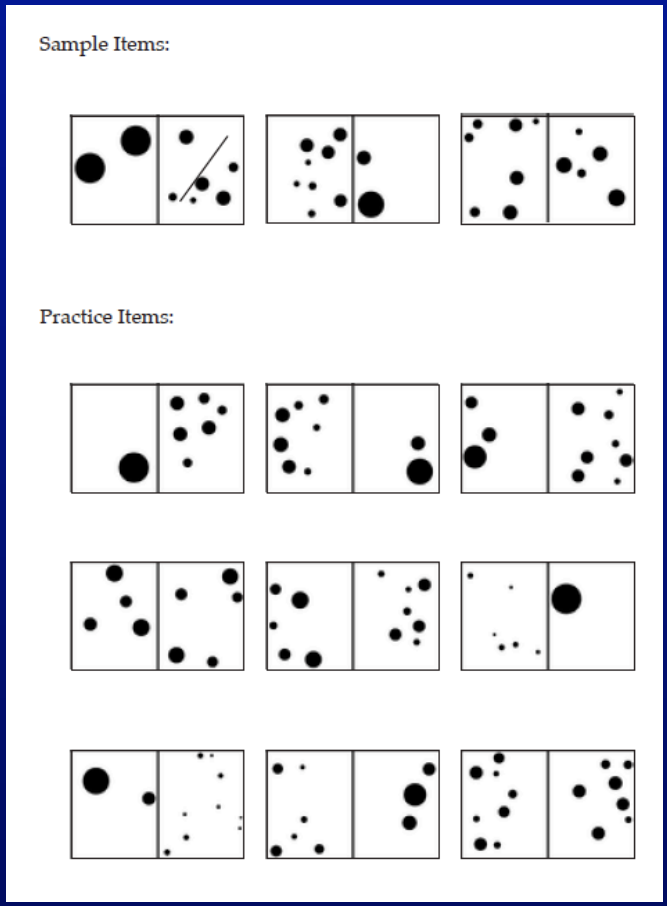


De Smedt et al. (2010)

Functional Significance
A Paper and Pencil Test

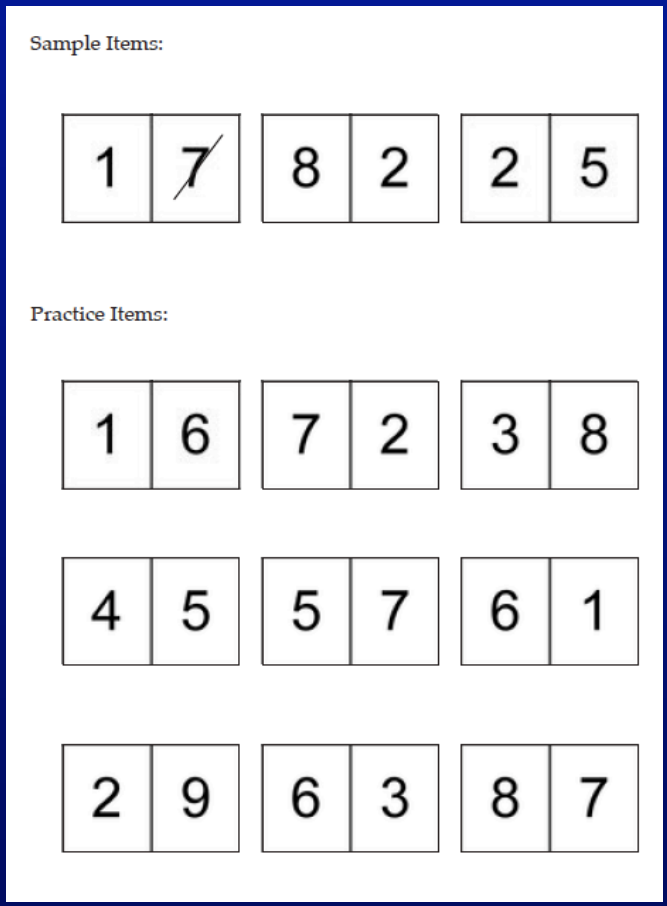
Nadia Nosworthy

NON-SYMBOLIC (56 items)



1 minute per condition

SYMBOLIC (56 items)



Nosworthy & Ansari (in preparation)

Functional Significance
A Paper and Pencil Test

Nadia Nosworthy

- ***179, 1st-3rd grade***

- ***Accuracy explains significant variance in Math Standard Scores***

- ***over and above age, phonological processing & working memory***

Nosworthy & Ansari (in preparation)

Developmental Dyscalculia

Developmental Dyscalculia

- Common diagnosis:
  - divergence between IQ and mathematics
  - Percentile rank (25th or 30th)
  - Assignment to special educational programs
  - Combination of the two
  - **Consistency important**

Developmental Dyscalculia

- Population studies vary in their estimates from 3-10%
- 5% is often cited by researchers in the field
- Comorbidity with ADHD and Dyslexia
- **Prevalence comparable to dyslexia or RD**

Developmental Dyscalculia

Ratio of publication on Dyslexia : Dyscalculia

14:1

Berch & Mazzocco (2007)

Developmental Dyscalculia

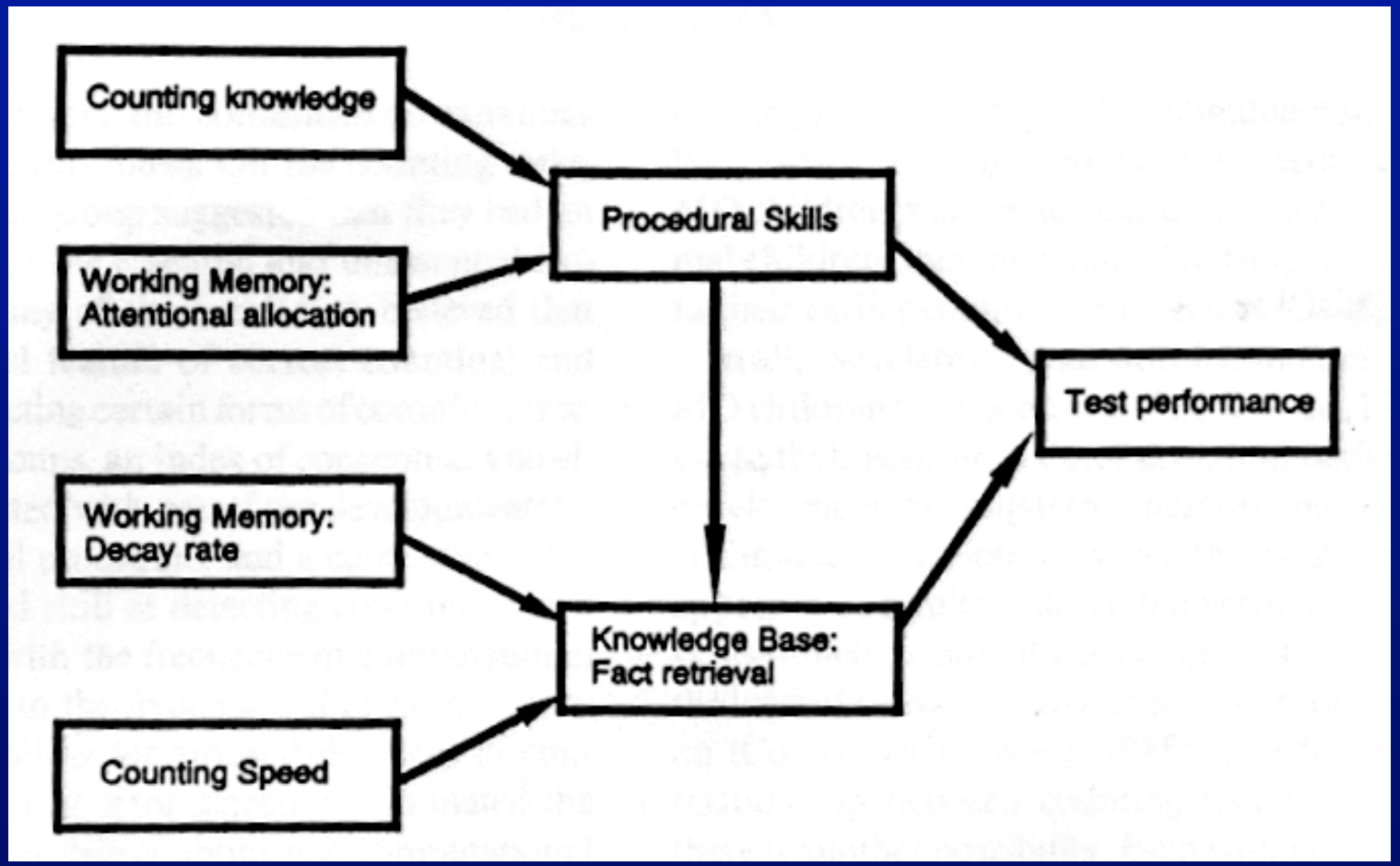
- **Symptoms?**

- Until recently focus on:

- Working memory
- Procedural Deficits
- Executive functioning

- Calculation-related, domain-general, processes

Developmental Dyscalculia



Geary (1993)

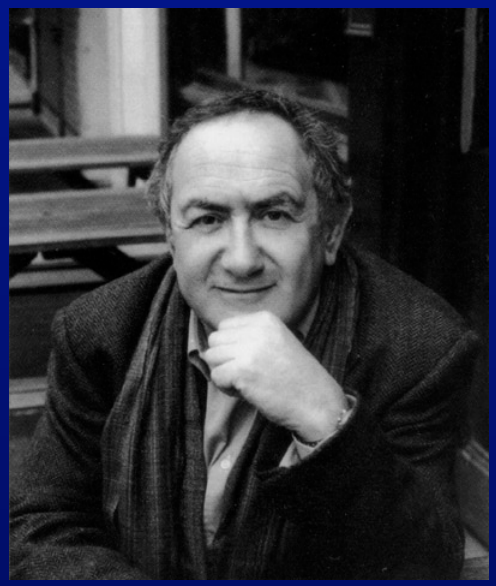
What about the underlying representation of number?

Developmental Dyscalculia

- Landerl, Bevan & Butterworth (2004)

- Focus on Basic Tasks

- Strict classification criterion
- Groups
  - Control
  - Dsylexic
  - Dyscalculic
  - Double Deficit



Developmental Dyscalculia

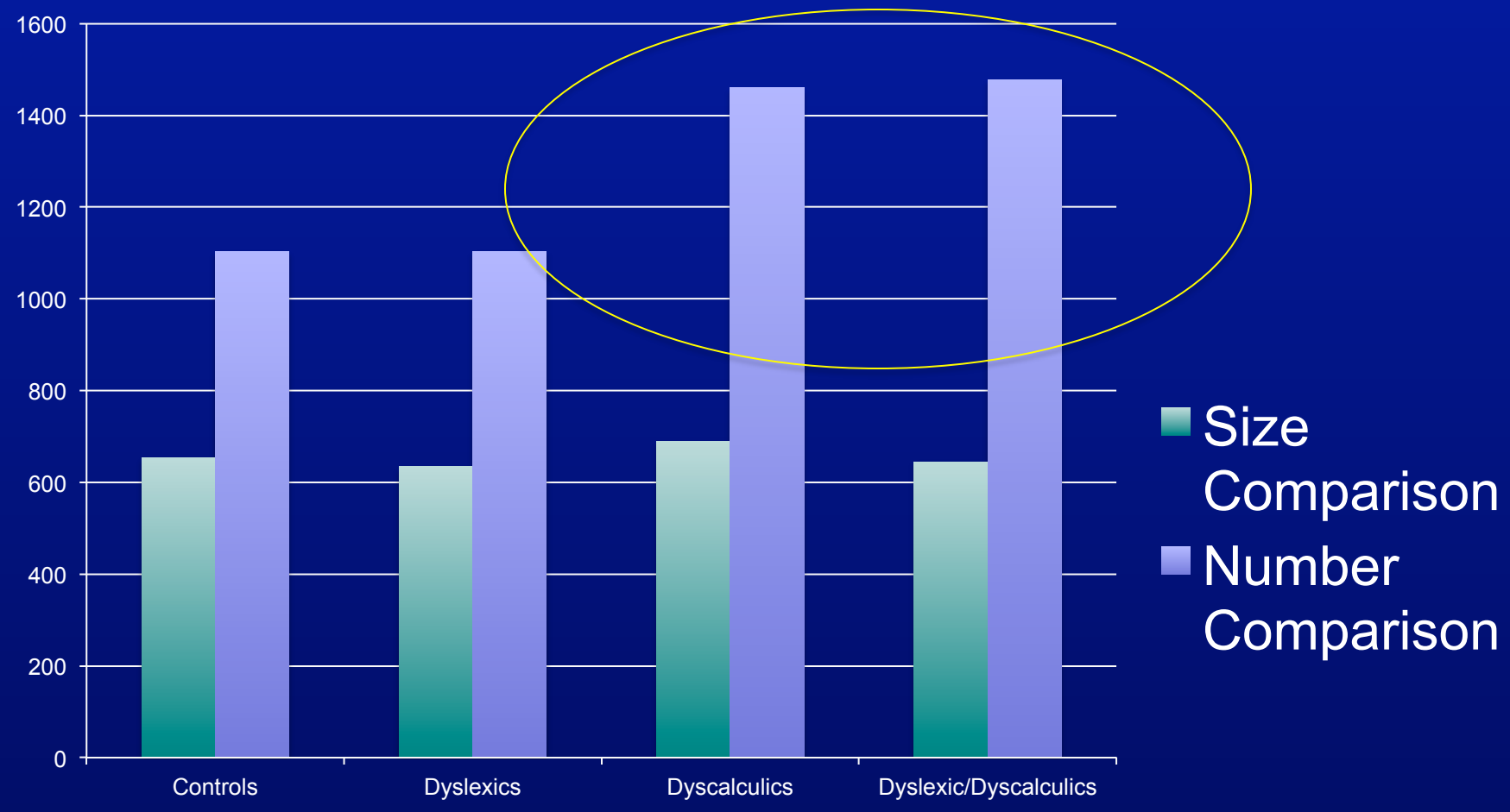
- Task:

1 **9** **2** 8

1. Which number is number is **NUMERICALLY** larger?

2. Which number is **PHYSICALLY** larger?

Developmental Dyscalculia



Landerl et al. (2004)

Developmental Dyscalculia

- Findings show that dyscalculia is specific to processing of numerical information
- **<u>Argument:</u>**

Dyscalculia is a deficit to represent and process numerical magnitude in a normal way

- Less of a domain-general – more domain specific deficit

Developmental Dyscalculia

Lack of understanding numerical magnitude

→

Difficulties to learn the meaning of numerical expressions and their maintenance in memory

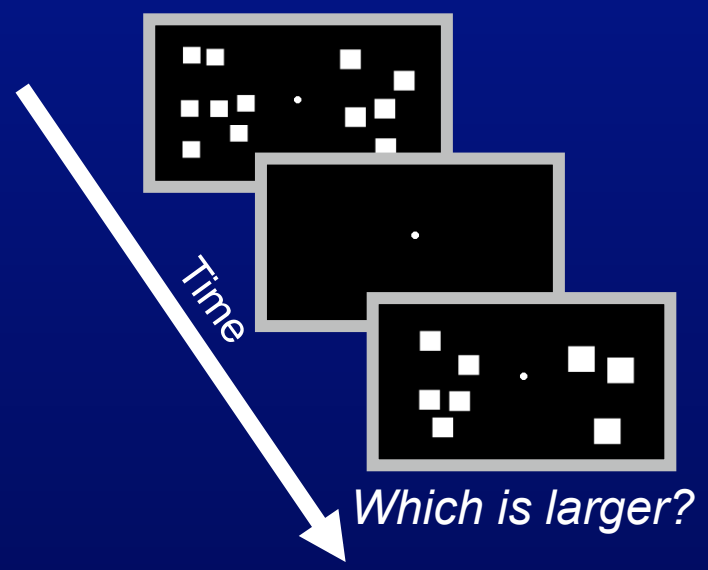
→

DEVELOPMENT

Atypical neural magnitude processing in Dyscalculia?

Atypical neural magnitude processing in Dyscalculia?

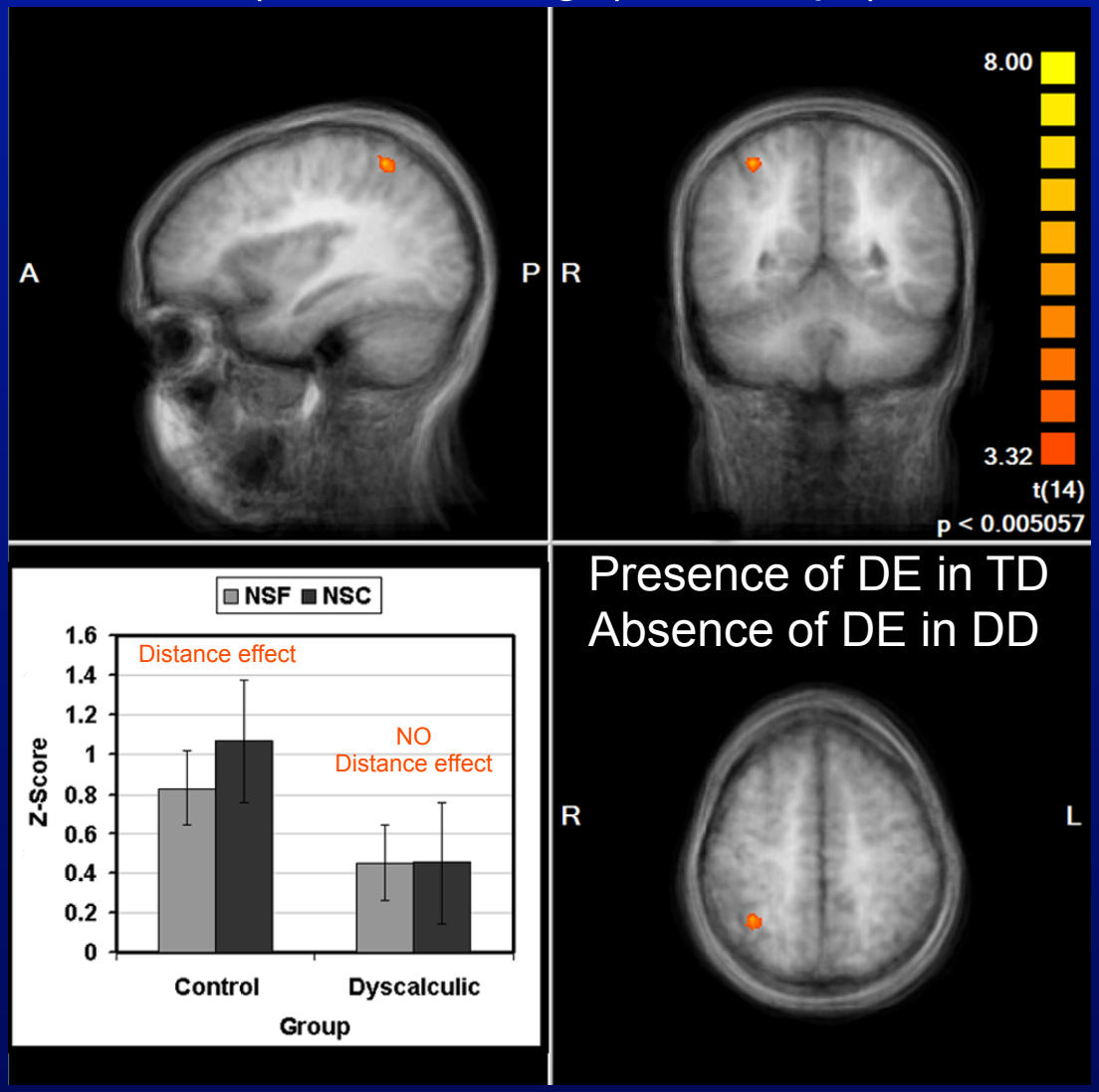
- Eight, 12-year olds with Developmental Dyscalulia (DD)
  - Specifically impaired on tests of calculation (< 1.5 Std)
- Eight, typically developing 12-year olds
- Non-symbolic number comparison



Price, Holloway, Rasanen, Versterinen & Ansari (2007)

Atypical neural magnitude processing in Dyscalculia?

Distance (Small vs. large) X Group (TD vs. DD)



Price, Holloway, Rasanen, Versterinen & Ansari (2007)

Mathematics Anxiety

'We hate math,' say 4 in 10 — a majority of Americans

WASHINGTON — People in this country have a love-hate relationship with math, a favorite school subject for some but just a bad memory for many others, especially women.

In an AP-AOL News poll as students head back to school, almost four in 10 adults surveyed said they hated math in school, a widespread disdain that complicates efforts today

Mathematics Anxiety

"Math exams terrify me. My palms get sweaty, I breathe too fast, and often I can't even make my eyes focus on the paper. It's worse if I look around, because I'd see everybody else working, and know that I'm the only one who can't do it."

Mathematics Anxiety

- **Symptoms?**
- At what level does MA affect math?
- Ashcraft and colleagues:
  - When engaged in mathematical problem solving, highly math anxious individuals suffer from intrusive thoughts and ruminations

Mathematics Anxiety

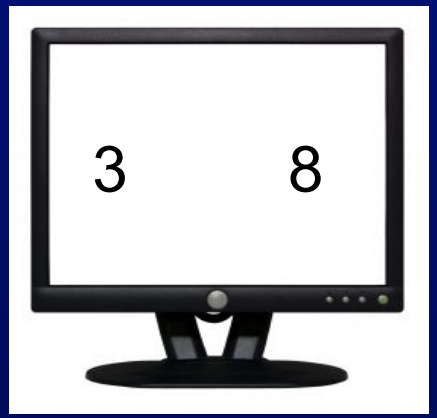
- **Current focus:**
  - **High level math**
  - **Complex calculations that require working memory**

What about low-level, basic number processing in Mathematics Anxiety?

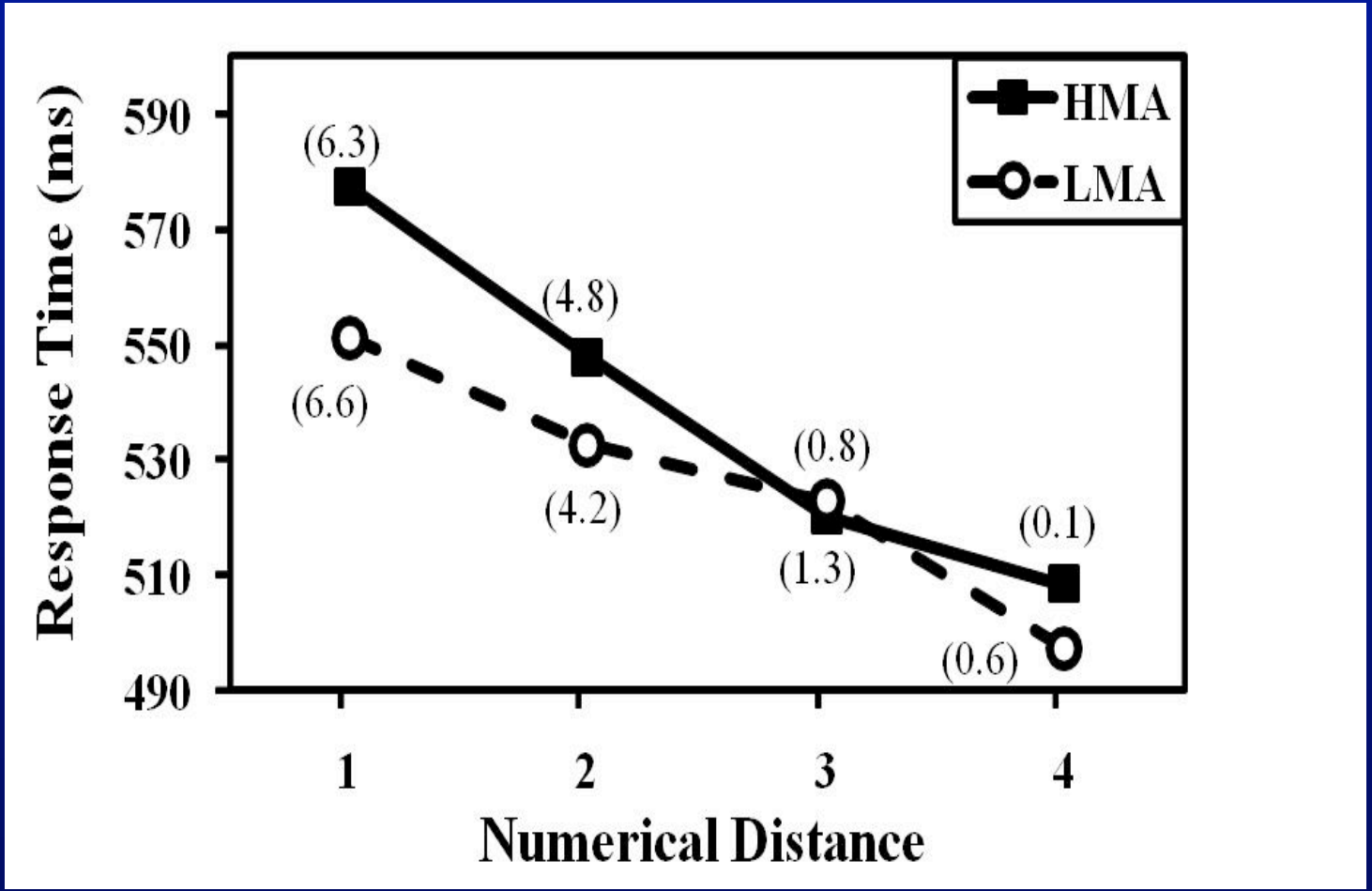
Mathematics Anxiety

Differences in numerical distance effect?

- Tested:
  - 24 Low Math Anxious Students (LMA)
  - 24 High Math Anxious Students (HMA)
  - University Undergraduates
  - Based on Short Math Anxiety Rating Scale
- Symbolic number comparison task



Mathematics Anxiety



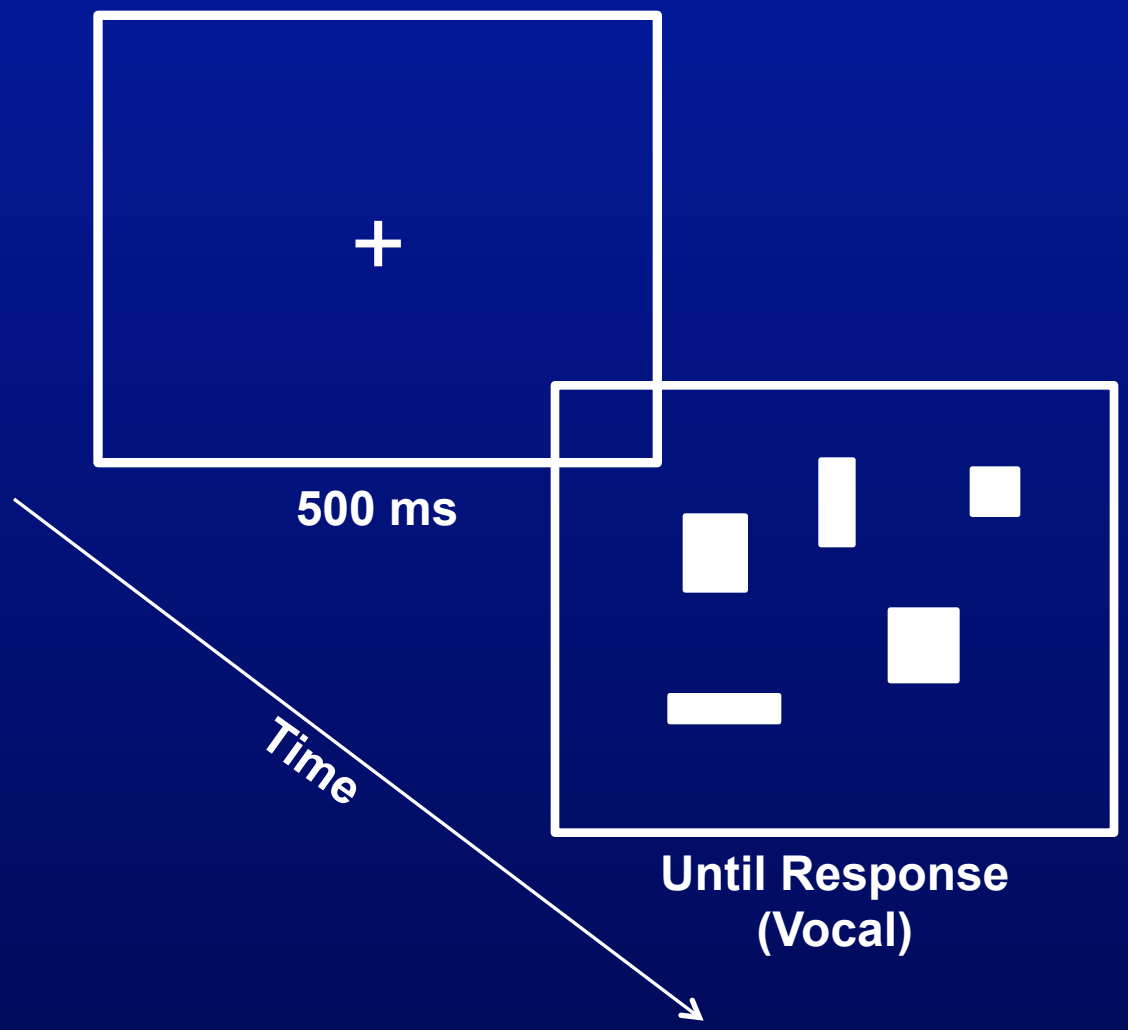
Maloney, Ansari & Fugelsang (2011)

Mathematics Anxiety

- Another example:
- Counting
- Fundamental, basic skill

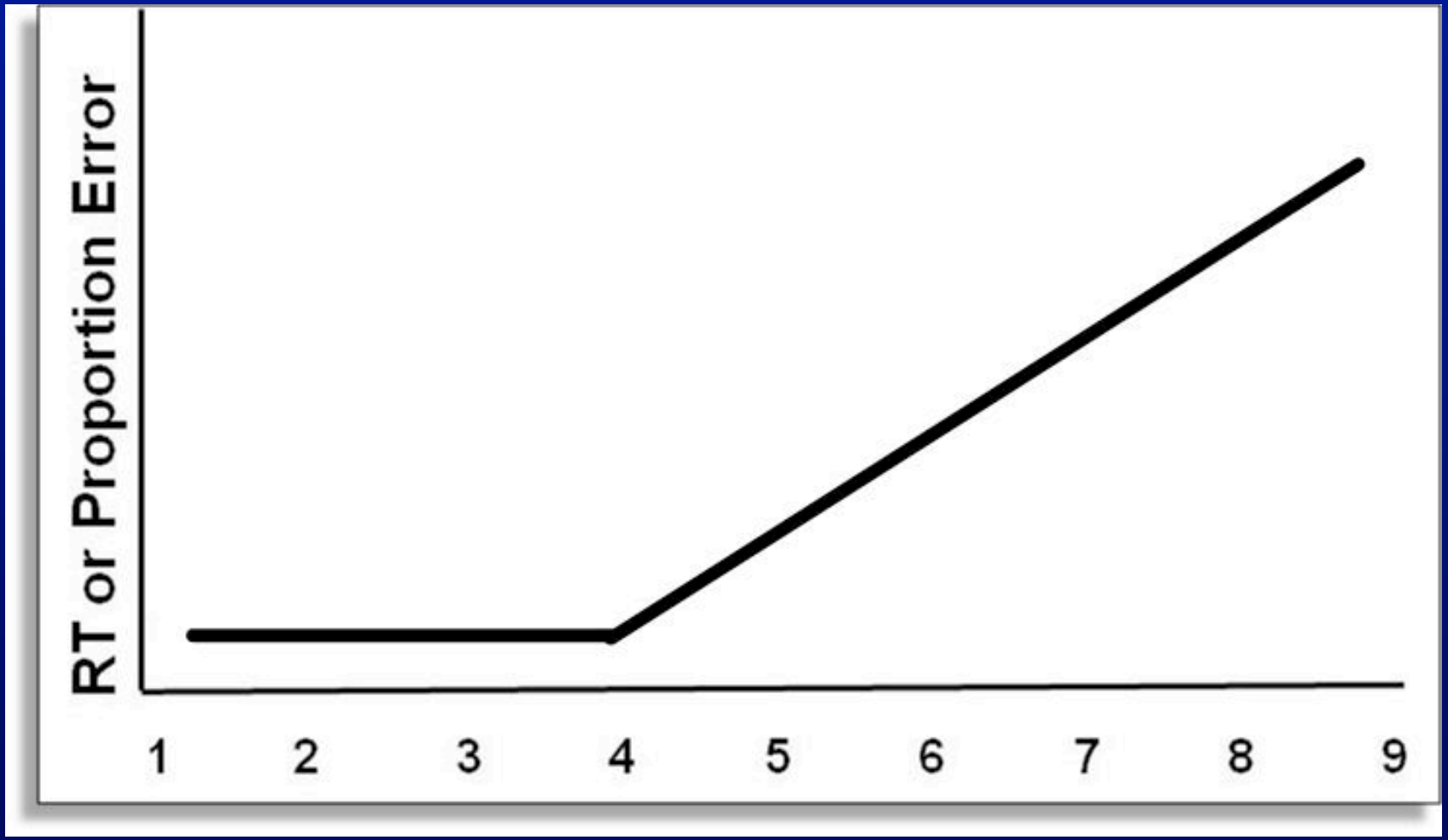
Maloney, Risko, Ansari & Fugelsang (2010)

Mathematics Anxiety

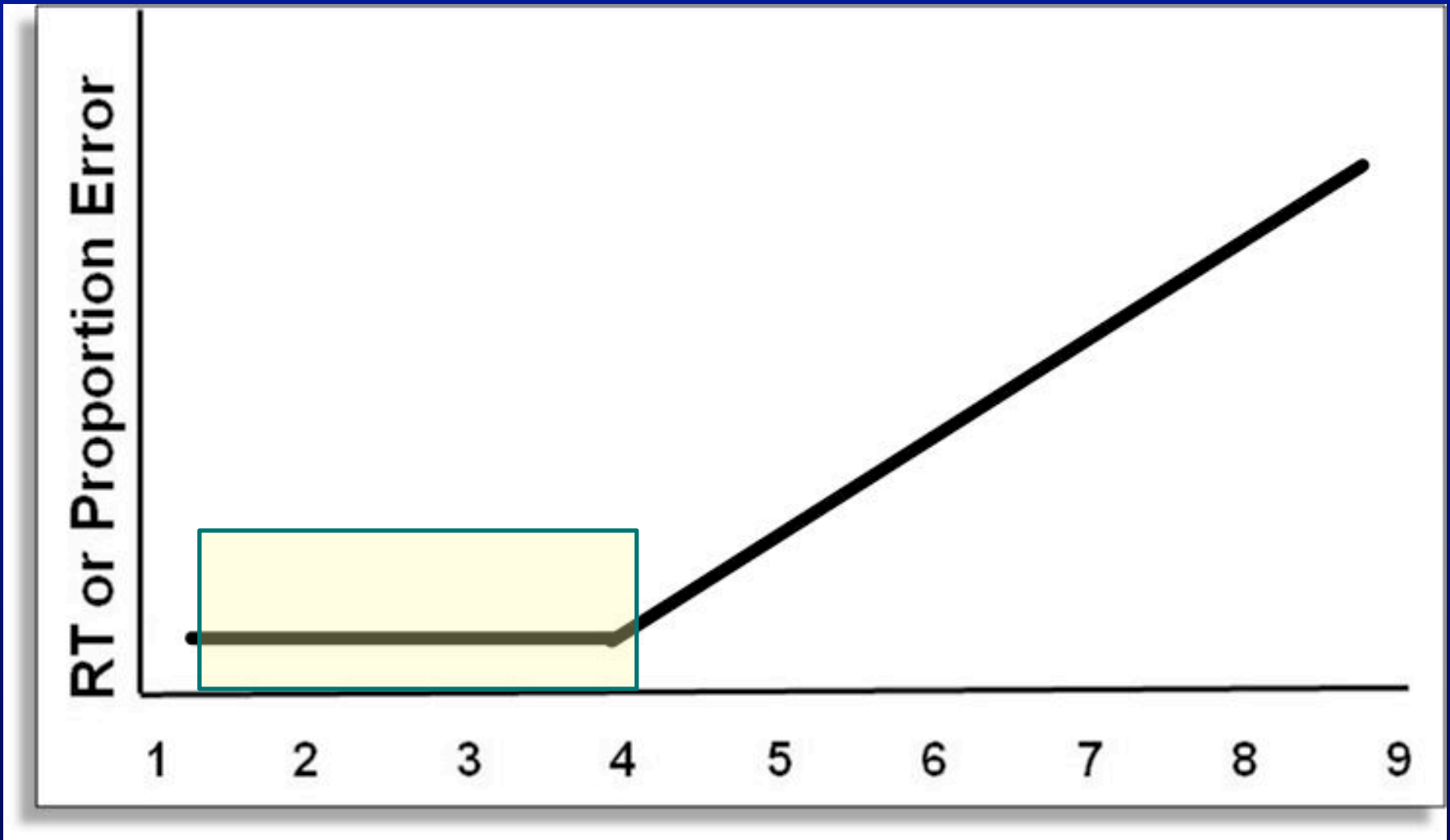


Mathematics Anxiety

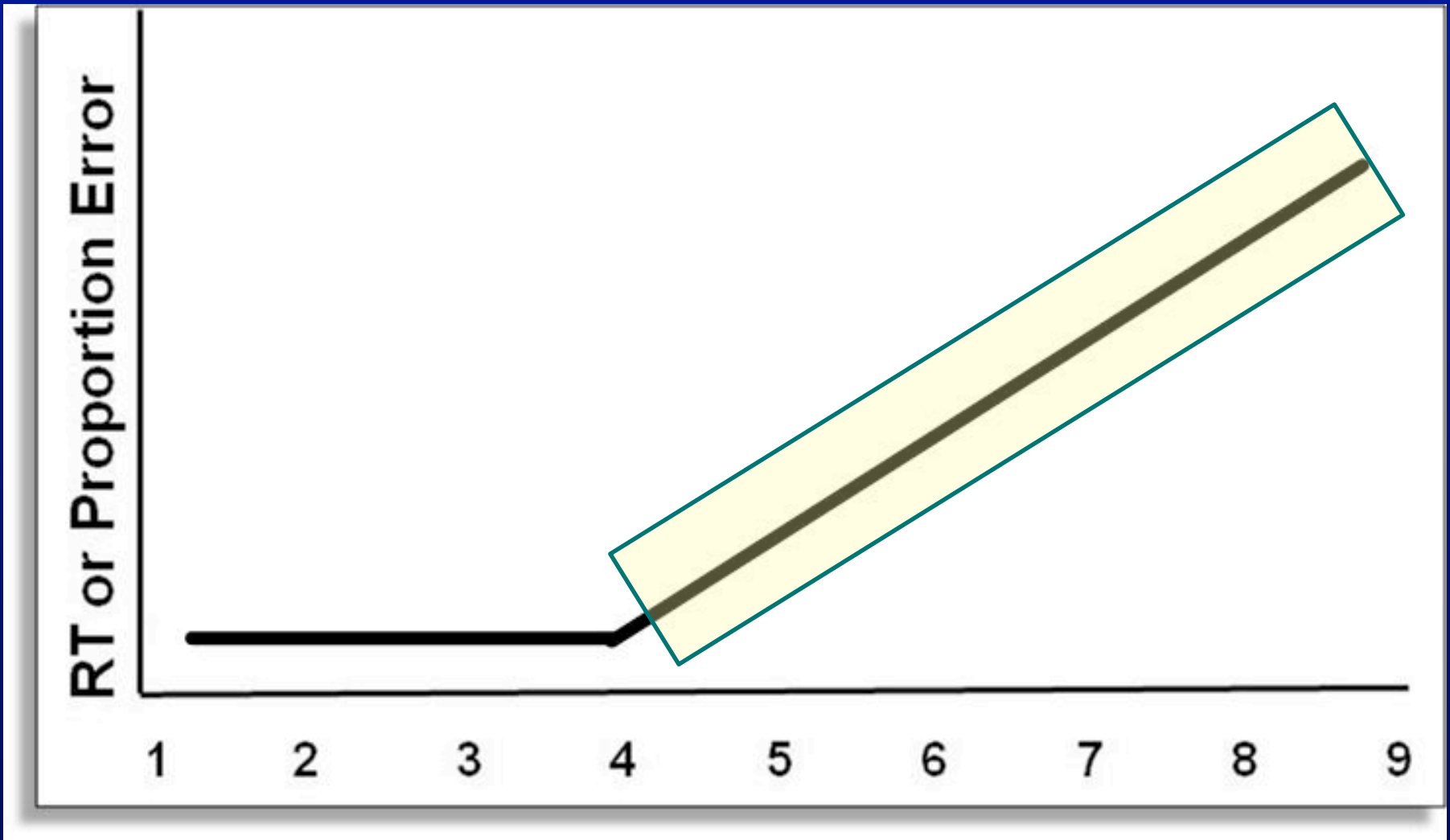
- What one typically finds:



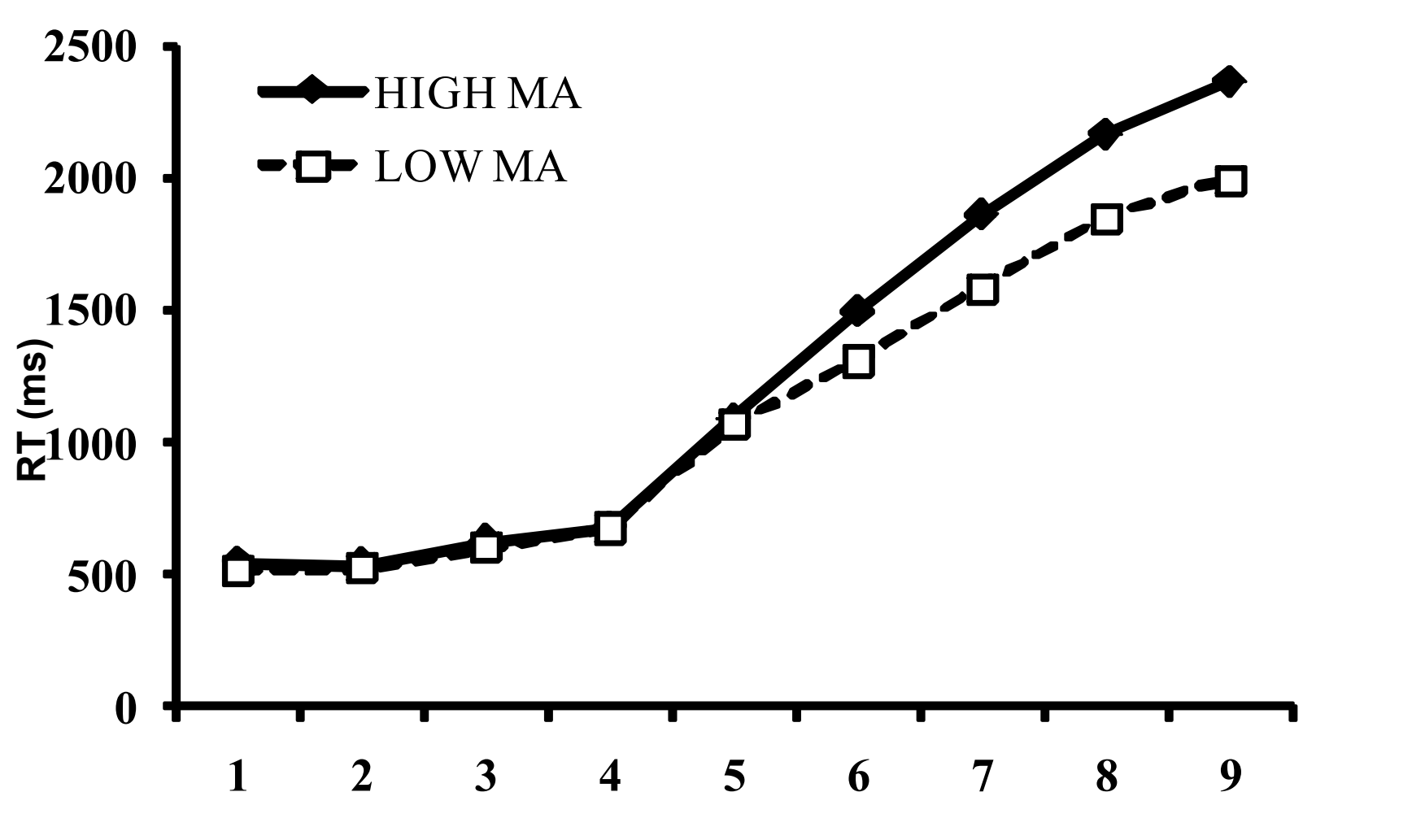
Mathematics Anxiety



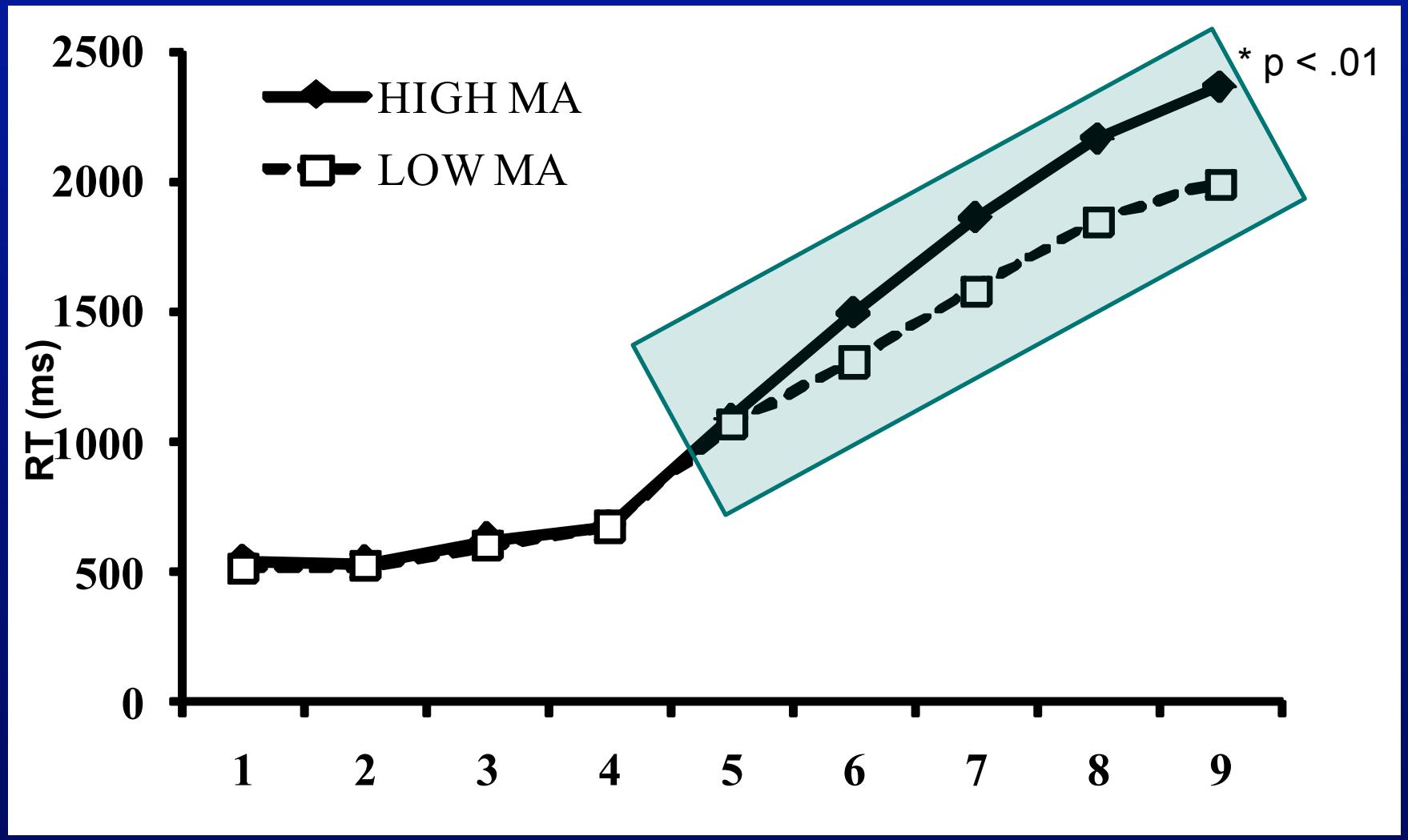
Mathematics Anxiety



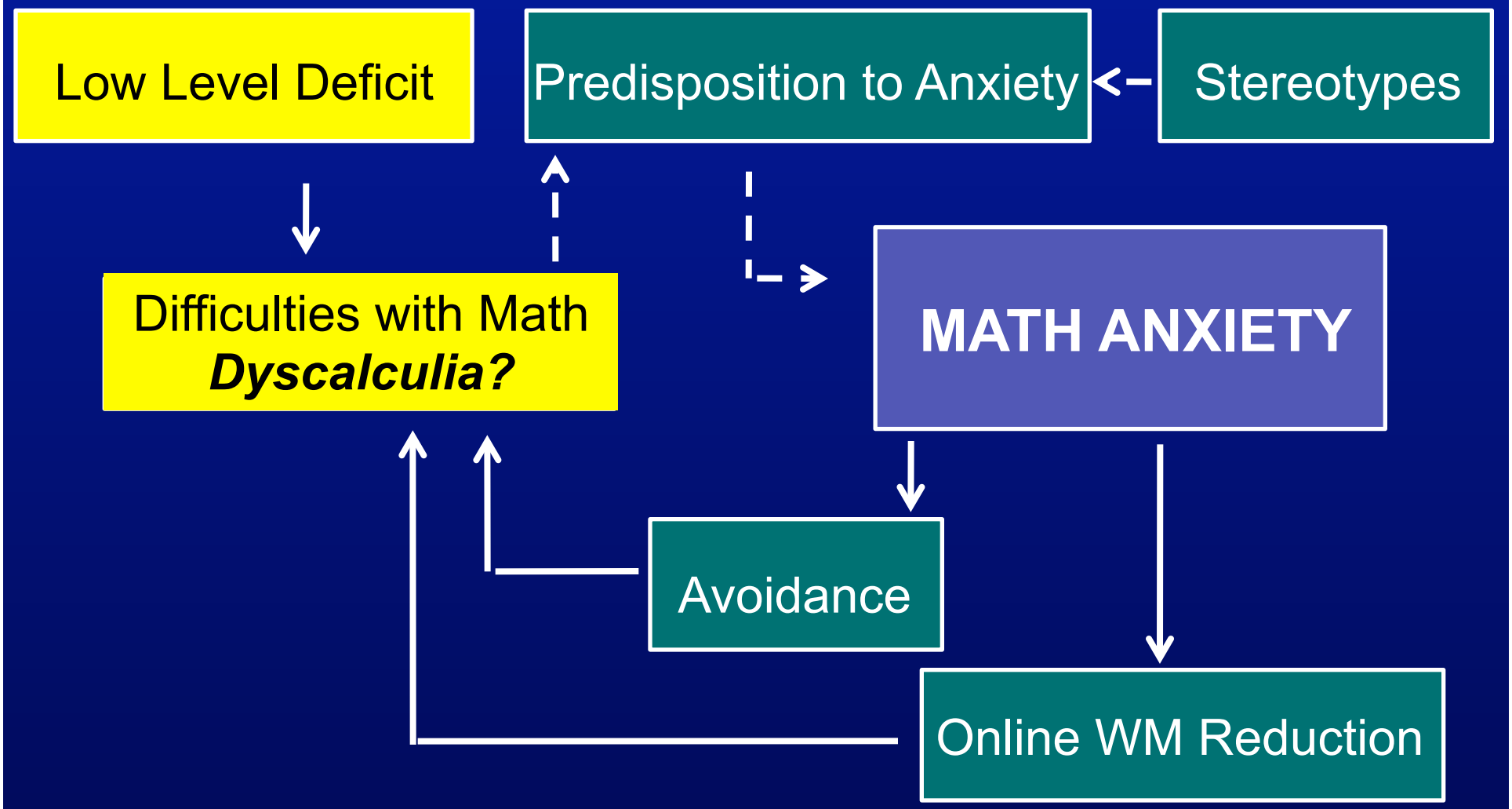
Mathematics Anxiety



Mathematics Anxiety



Mathematics Anxiety



Summary and Conclusions

- Basic numerical magnitude processing
- Foundational
- Related to math achievement
- Atypical in Dyscalculia
- Atypical in Mathematics Anxiety

Implications

- Early Diagnosis
  - Can serve as a processing measure
  - Current math assessments focus on arithmetic
- Remediation focusing on strengthening:
  - Magnitude processing
  - Symbol – quantity mapping
  - Strengthening abstract understanding of quantity

Thank you for your attention!