Testing theories of developmental dyscalculia

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Developmental dyscalculia (DD)

- Affects about **6%** of children/adults.
- Usually defined as a **selective weakness of mathematics**.
  - Intelligence, reading and motivation to learn is **normal**
  - Access to appropriate educational provision is **normal**.

- There is **no** generally accepted **functional definition** of DD.
  - Single, multiple or heterogenous problem?
  - Several potential representational problems
  - Are there different subtypes of DD?

- **Current research** focuses on trying to understand the **functional basis** (causes) of DD.

Review in Szucs & Goswami, 2013; *Trends in Neuroscience and Education*

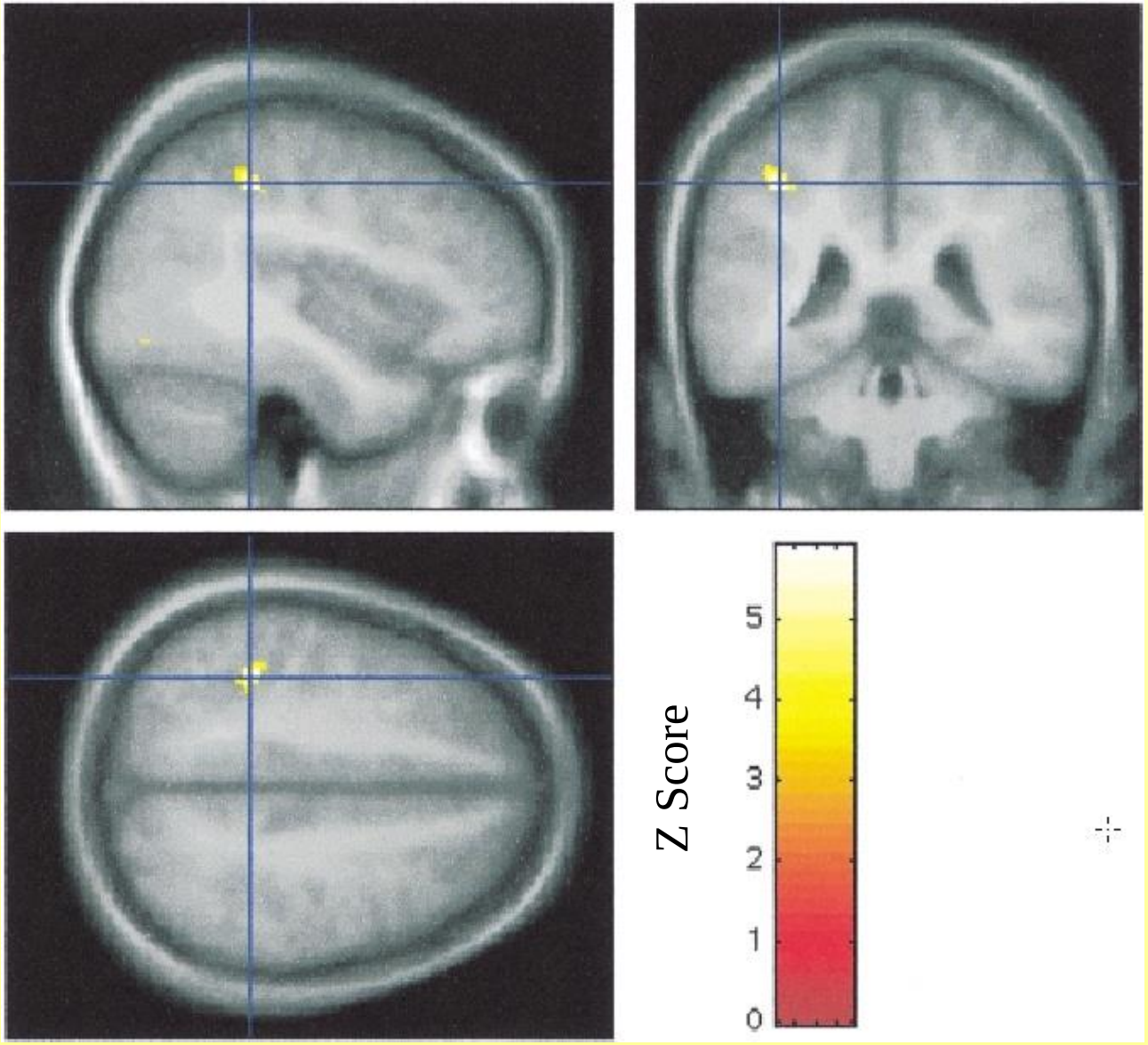
One view is that DD is related to the domain specific impairment of the Simple number processing ability (number sense) of the brain

Reduced gray matter volume in the IPS; intra-parietal sulcus.

Brain activity in this area has been shown to correlate with performance on **simple number comparison. >**

Can DD be related to impaired ability in simple number processing in the IPS?

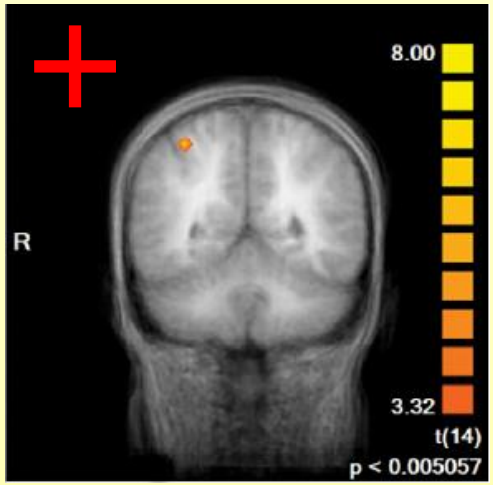
(here: low birth-weight) children who showed **deficits in solving numerical operations)**



Isaacs et al. 2001, *Brain*

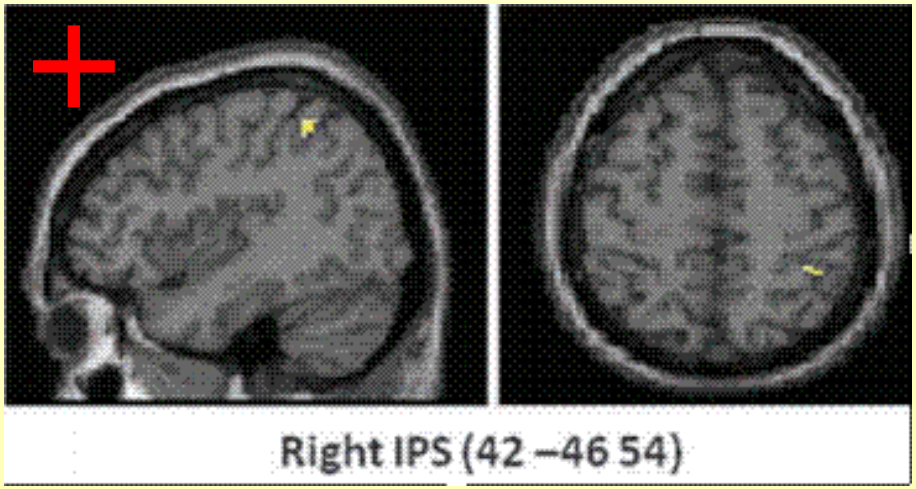
Functional MRI data about the distance effect (functional marker)

Price et al. 2007



Accuracy DE differs

Mussolin et al. 2010



Accuracy and RT **DE is NOT different**

Kucian et al. 2006: **no difference** between DD and controls

Kovas et al. 2009: **no difference**, **no ratio effect** in IPS

Kucian et al. 2011: **no difference** in IPS

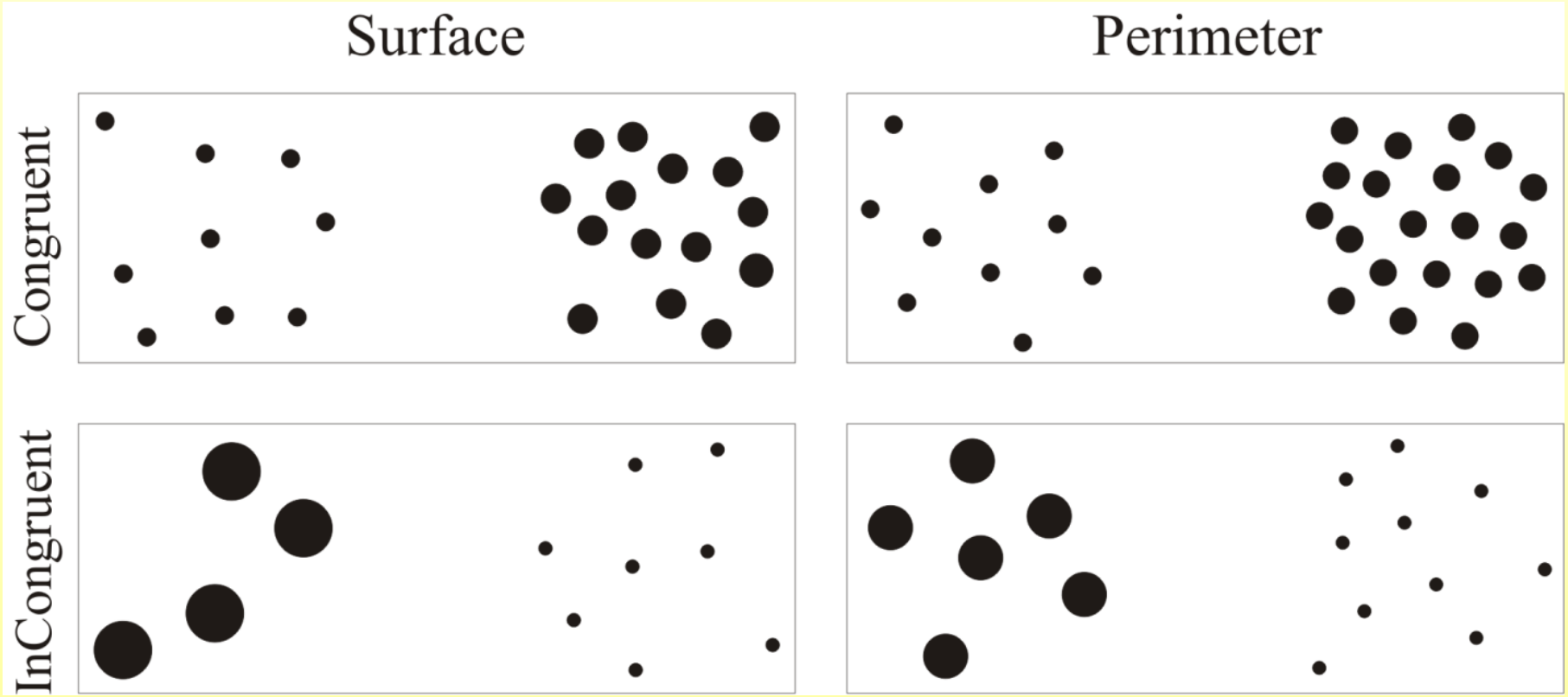
Davis et al. 2009: **no IPS difference** in *approximate* calculation

Structural: Left / Right / Right + other regions

> If there is IPS difference - what does it mean?

Reviewed in Szűcs et al. 2013; *Cortex*; In Press

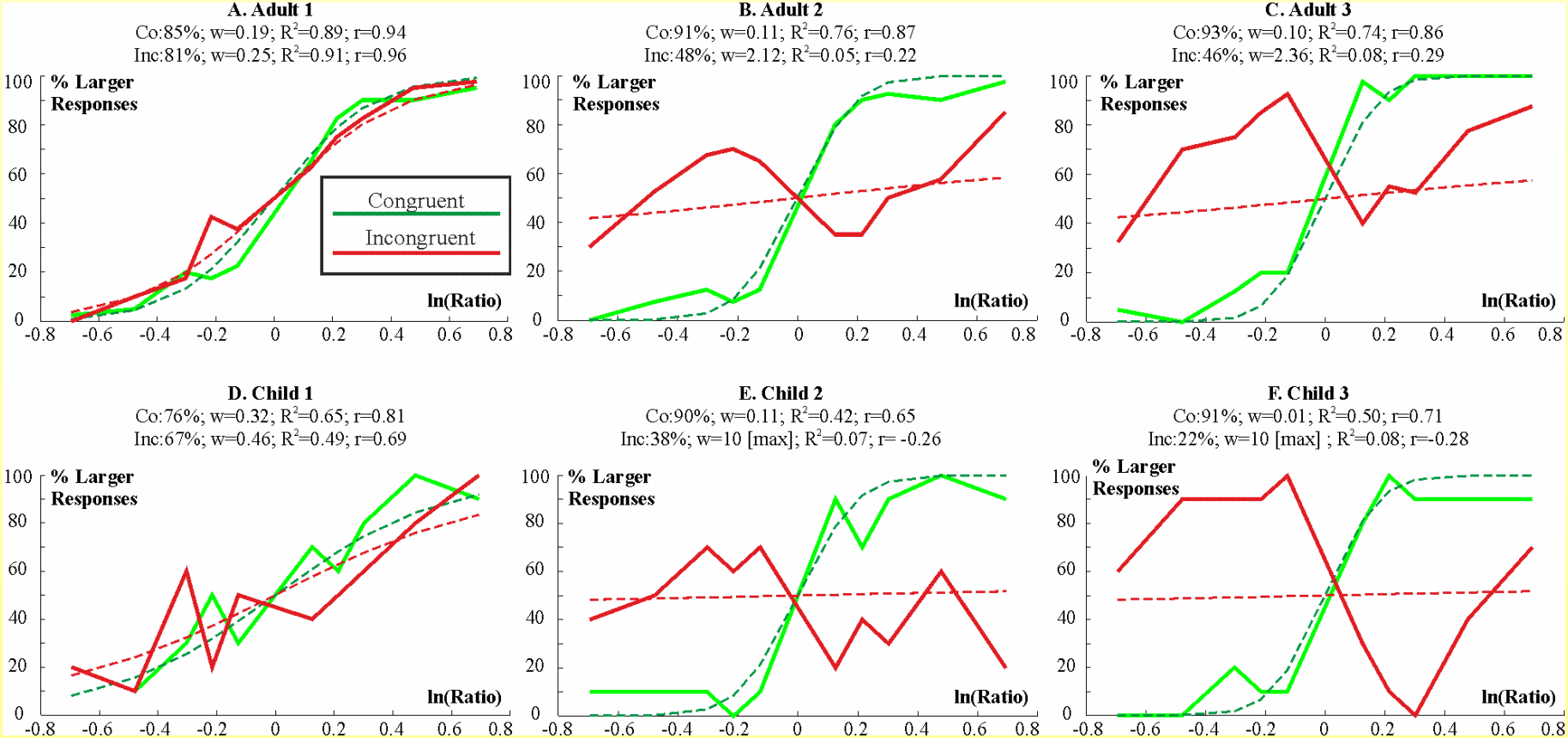
Non-symbolic dot comparison tasks: are they valid measures?



Task: Compare which side has more dots

Soltész, Szűcs & Szűcs, 2010; *Behav Brain Funct*

Are non-symbolic decision tasks valid measures at all?

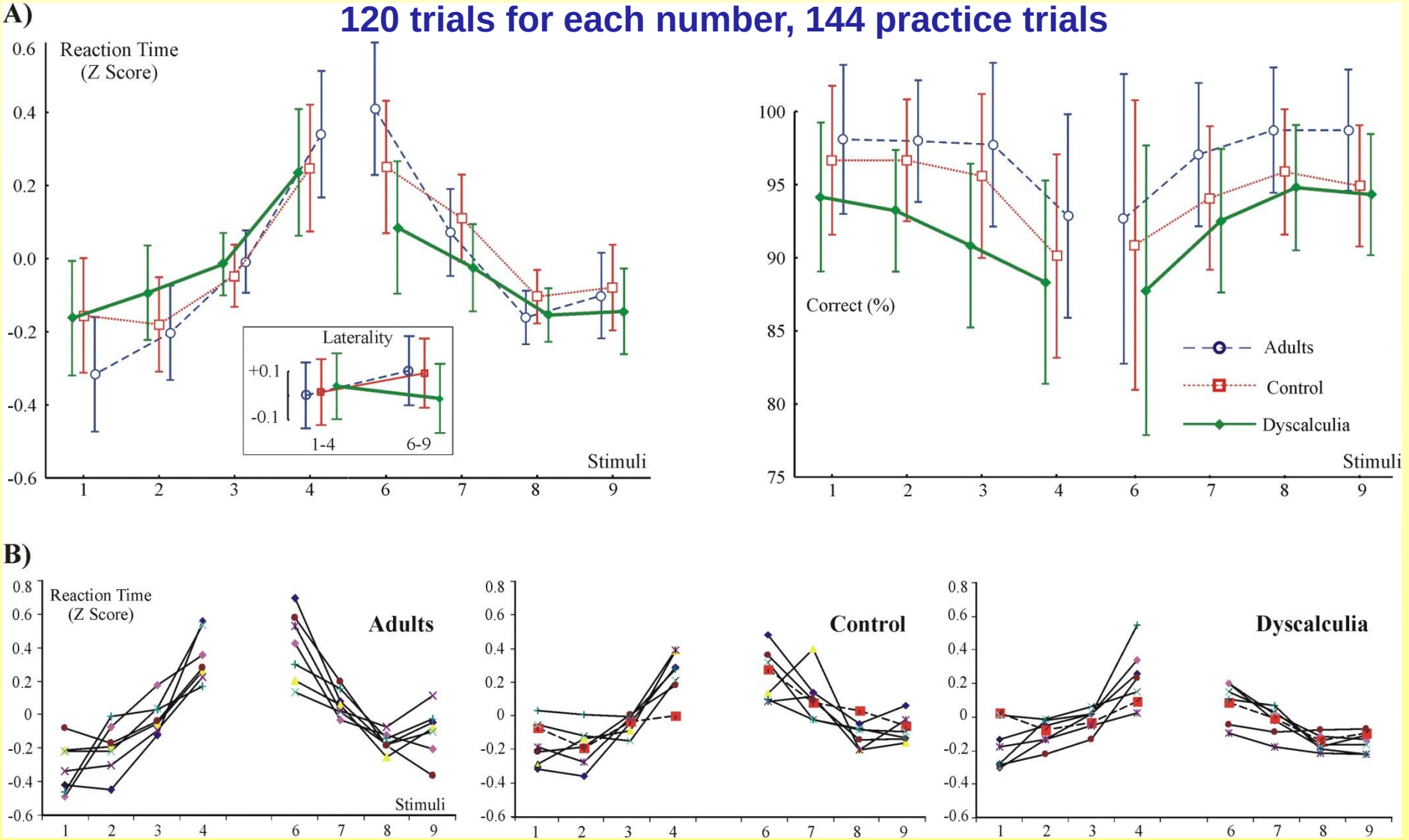


Szucs, …, Gebuis et al 2013; Frontiers in Psych. 4:444

Behavioural and EEG distance effect in Developmental Dyscalculia

Symbolic number comparison; compare to 5 N=7, all girls

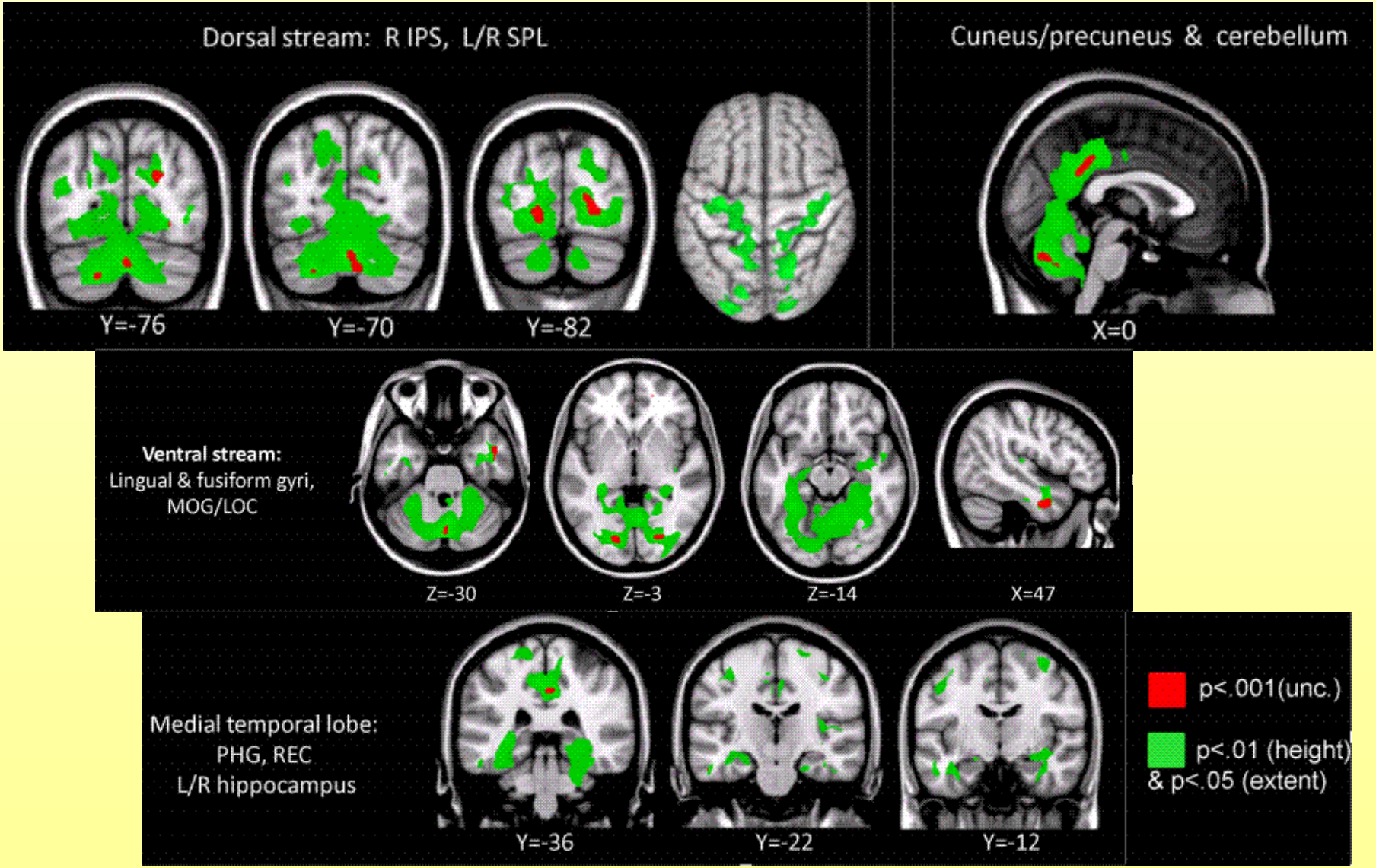
120 trials for each number, 144 practice trials



Soltész, Szűcs et al. 2007 Neuroscience Letters

Structural MRI data in DD: extended brain differences rel. to controls

Rykhlevskaia et al. 2009; reduced gray matter + white matter



Reviewed in Szűcs et al. 2013; *Cortex*; In Press

Developmental dyscalculia (DD)

- It is highly likely that DD relates to weaknesses of **<u>various</u>**

cognitive functions implemented by the extended brain network underlying mathematics:

  - Memory
  - Attention
  - Cognitive control
  - Inhibition of unwanted (mental) acts

- E.g. solving the following equation requires **careful planning** even for adults; minor mistakes lead to radically different results: **((3 + 4) + (1 - 2)) / 2 * 3**

- **Our projects** examine how the above cognitive functions
  - Relate to DD
  - And to math expertise in children in general

Szűcs et al. 2013; *Cortex*; In Press

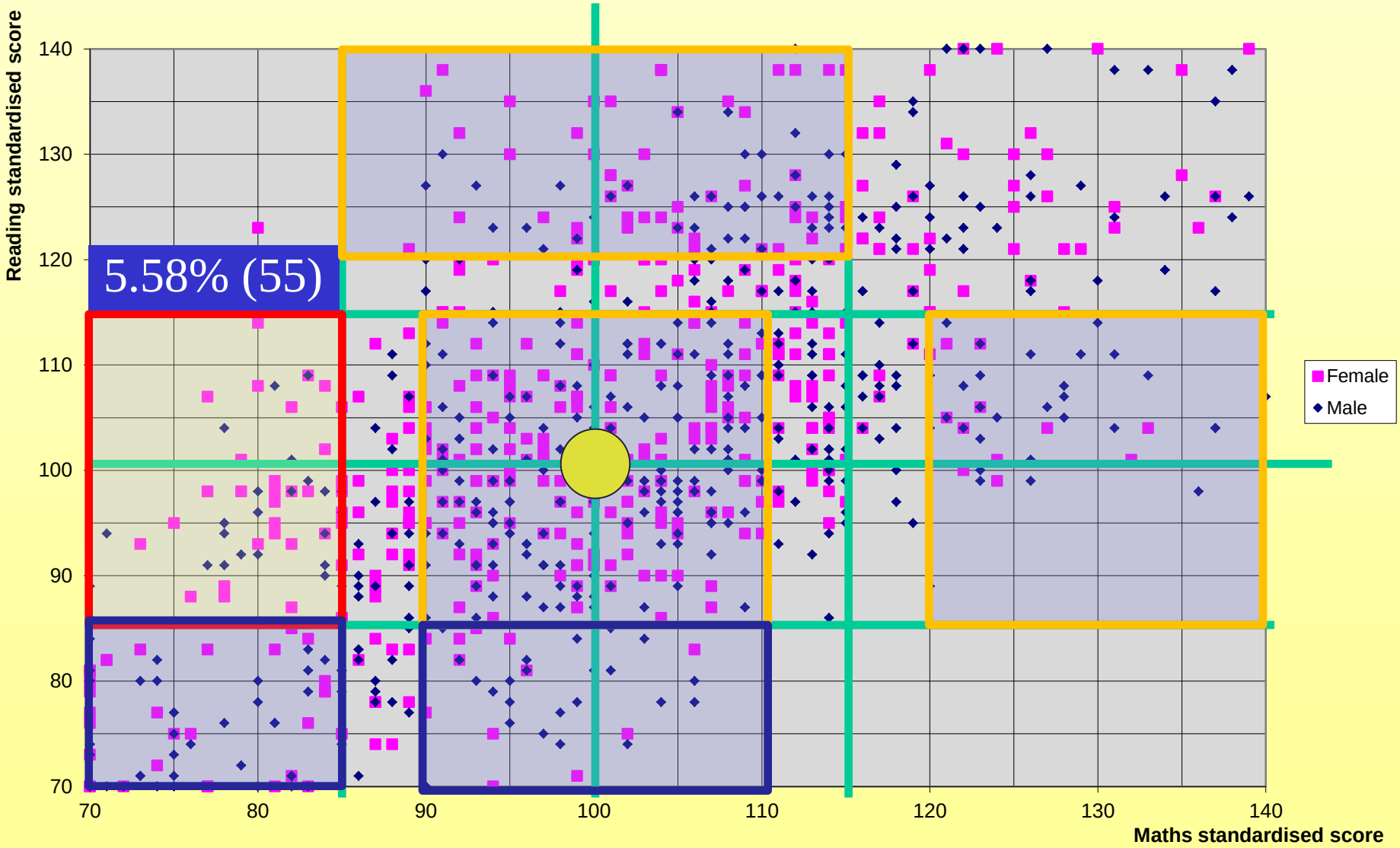
Large study on DD; Study phases

- **1,004** Year 3 and Year 4 children (526 boys and 478 girls) from 22 schools in Cambridgeshire, Hertfordshire and Essex in UK

- Phase 1 – group screening tests
  - Mathematics and reading: MALT + HGRT: UK standardized
  - Groups of interest selected for individual assessment based on their performance in both domains
- Phase 2: N=**115** – stadardized test-based individual assessment
  - Mathematics; reading: WIAT-II:
    - Numerical Operations, Word Reading & Pseudoword Decoding
  - IQ: WISC-III, Raven's Matrices ; WM: AWMA
  - Socioeconomis status; ADHD: Barkeley scales
- Phase 3 – custom tasks + experimental tasks
  - Measuring automatic access to numerical information and inhibition
- Phase 4: EEG and MRI

Szűcs et al. 2013; *Cortex*; In Press

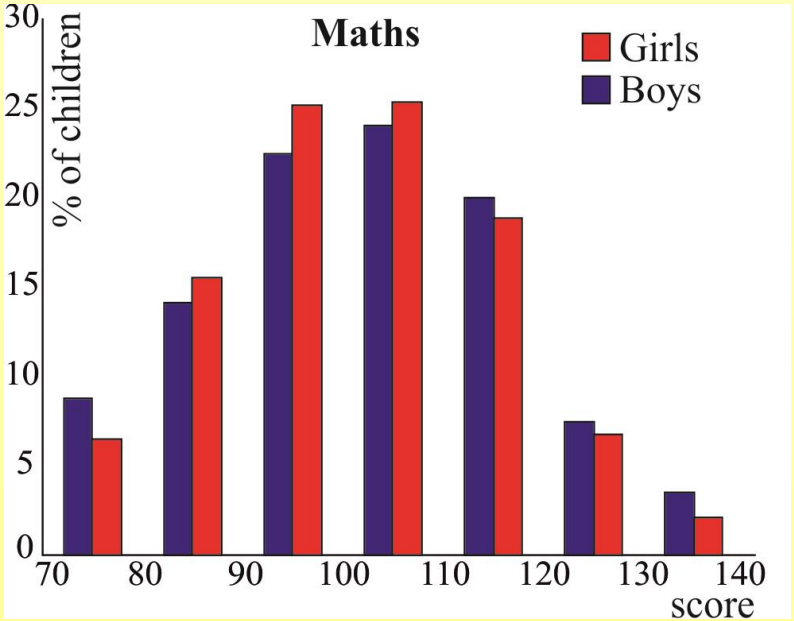
Distribution of math and reading scores:
1004 nine-year-old children (East of England, UK)

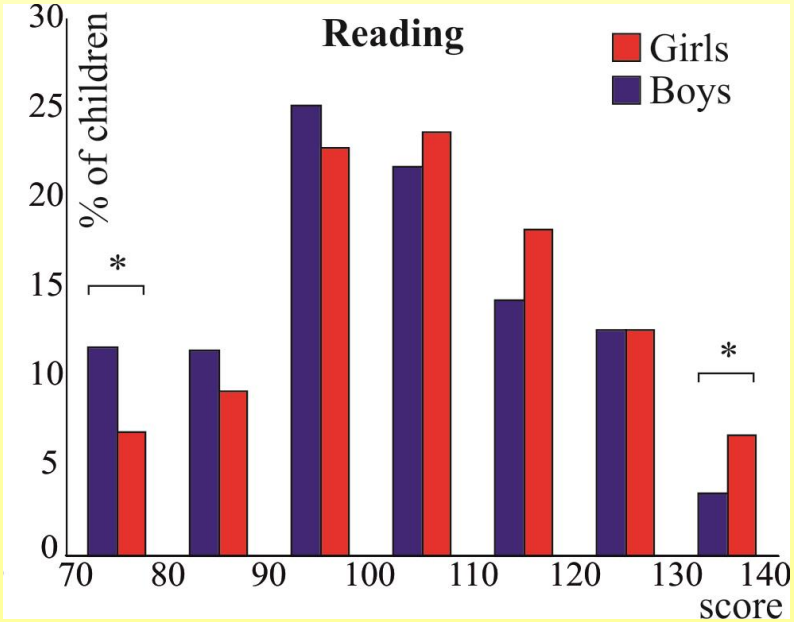


Devine, … Szűcs et al.; 2013; *Learning and Instruction*

Group test results

Mathematics scores were positively correlated with reading scores (r = .626, p < 0.001) and this correlation remained when controlling for gender (r = .632, p < 0.001).



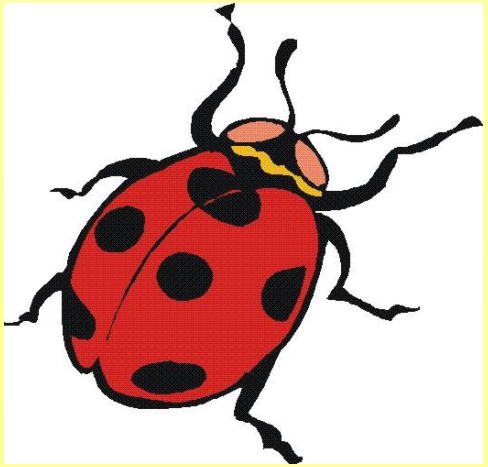


Maths and reading performance normally distributed (p>.1 for both)

Devine, Soltész, Nobes, Goswami, Szucs (2013) Learning and Instruction

Phase 3: Experimental investigations

- Speed of general cognitive functioning
- Spatial skills
- Behavioural control functions
- Attention
- **Memory**: visual/verbal STM/WM
- **Inhibition** of unwanted mental and motor acts
- Simple number processing
- Arithmetic
- Number knowledge



Respond RIGHT

Szűcs D et al. 2009.

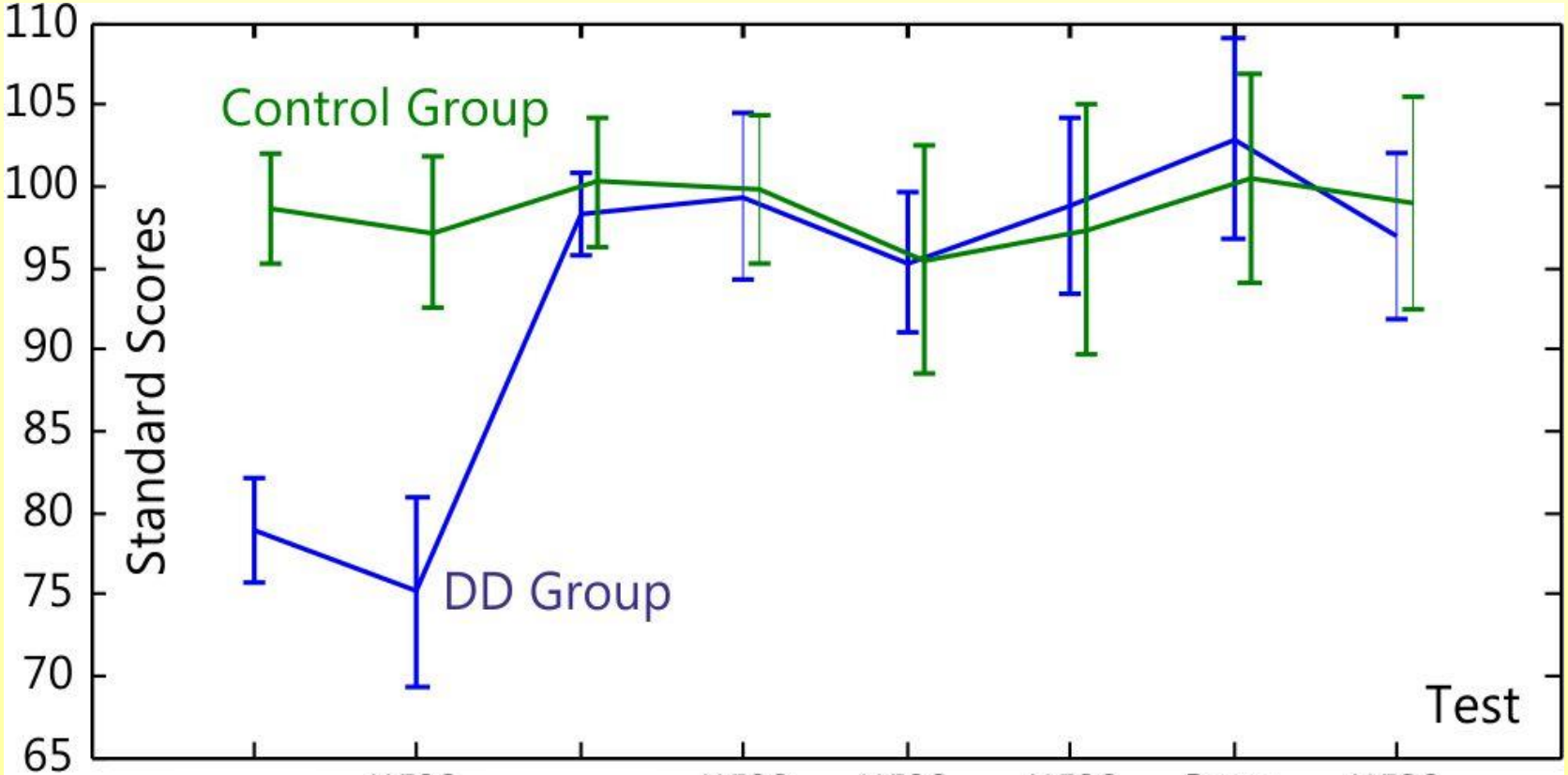
Journal of Cognitive Neuroscience.

Bryce, Szucs et al. 2011;
NeuroImage

Szűcs et al. 2013; *Cortex*; In Press

DD vs. Control sample: 12 vs. 12 children

(Age: 110 vs. 109 months; p=0.5)



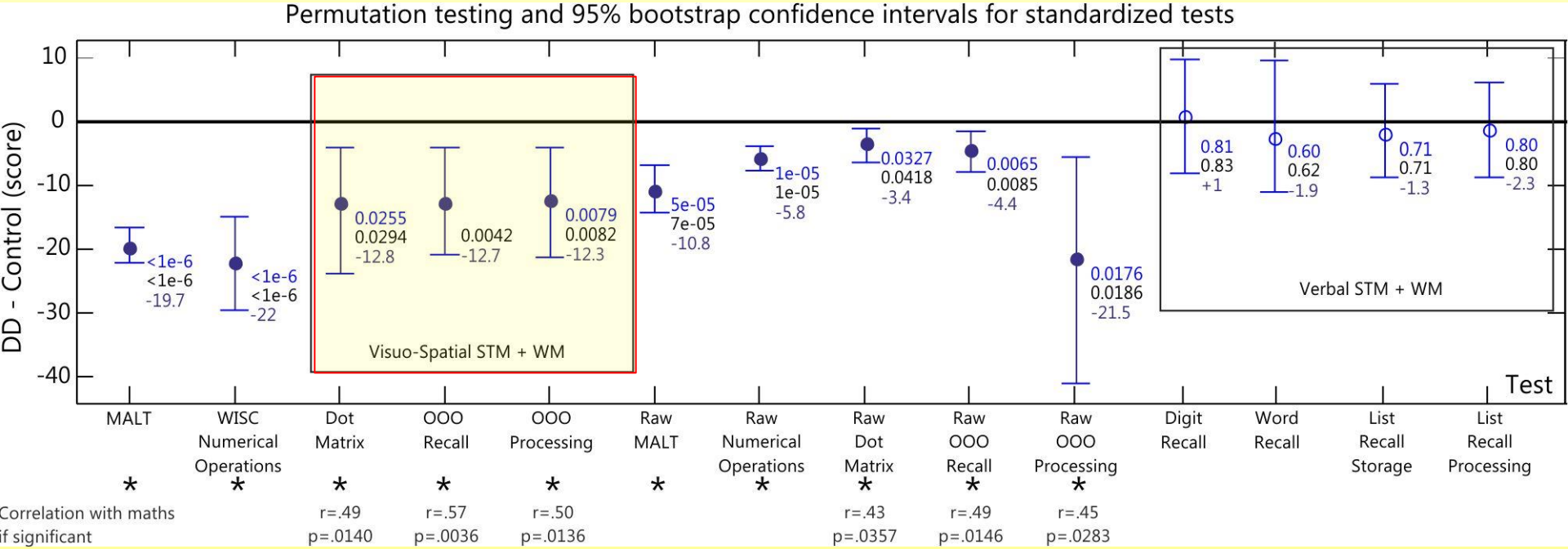
	Math	WISC Numerical Operations	Reading	WISC vocabulary	WISC Word reading	WISC Pseudo Word reading	Raven	WISC block design
Permut.p =	<1e-6	<1e-6	0.42	0.84	0.94	0.54	0.31	0.42
T-test p =	<1e-6	<1e-6	0.88	0.62	0.96	0.73	0.54	0.11
DD group:	78.9	75.2	98.3	9.3	95.3	99.8	102.9	6.9
Control:	98.6	97.2	100.3	9.8	95.5	97.3	100.4	8.9

Szűcs et al. 2013; *Cortex*; In Press

DD children performed worse than control children in

- **visual STM**
- **visual WM**
- **inhibition = weak interference suppression in Stroop tasks**

Permutation statistics: 1 million random re-groupings into 2 groups of N=12
Bootstrap: 1 million bootstrap samples with replacement



Szűcs et al. 2013; *Cortex*; In Press

Reasoning test

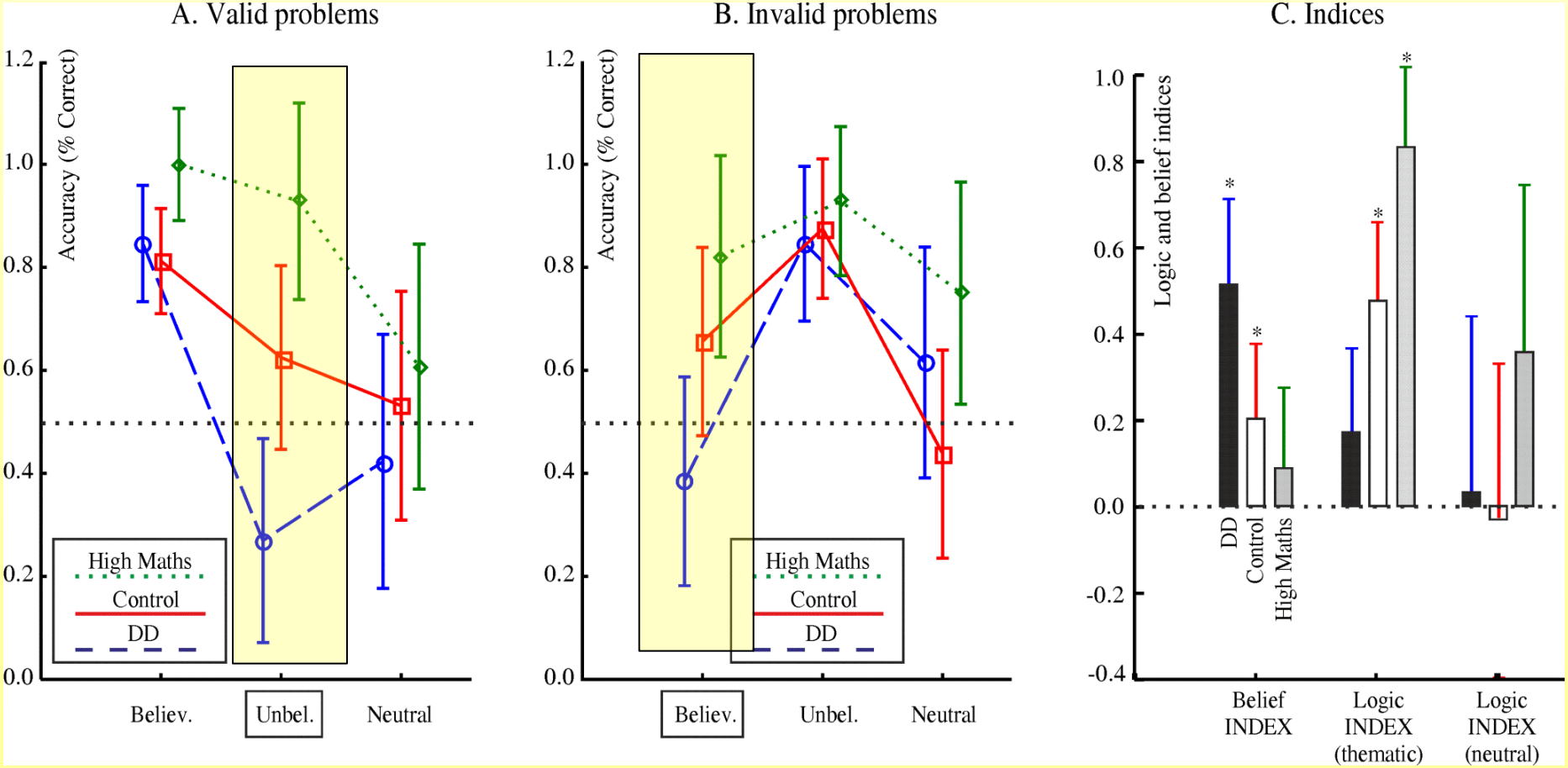
16 transitive inference problems with the following structures:

1. A>B, B>C A>C? (**valid**, easy structure)
2. A>B, C>A C>B? (**valid**, difficult structure)
3. A>B, B>C C>A? (**invalid**, easy structure)
4. A>B, C>A B>C? (**invalid**, difficult structure)

- 4 with **believable** conclusions (e.g., elephants are bigger than mice)
- 4 with **unbelievable** conclusions (e.g., rabbits are stronger than gorillas)
- 8 with **neutral** conclusions:
  - 4 **visual-spatial (**e.g., the panda is behind the giraffe)
  - 4 **non-visual** (e.g., Sarah is older than Anne)

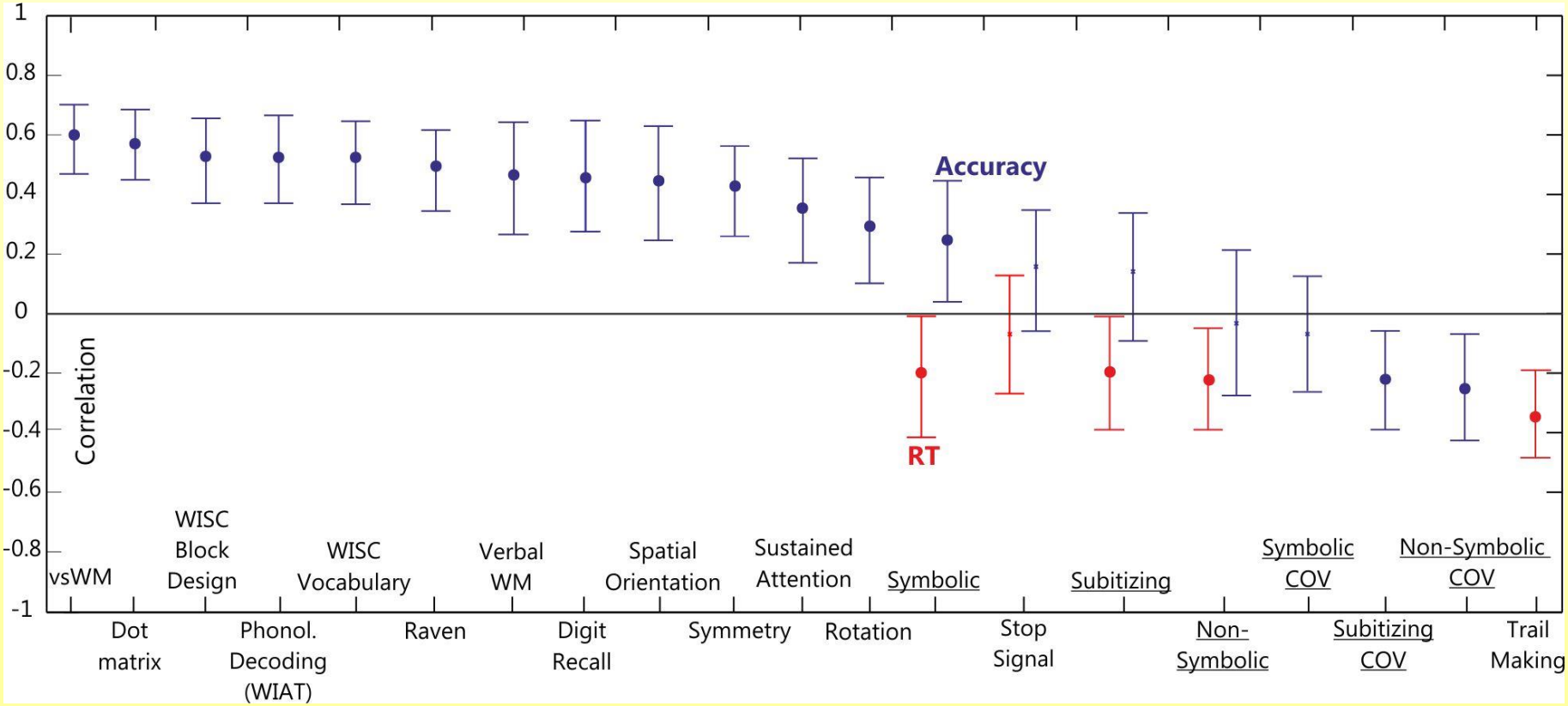
Morsanyi,…, Szucs, 2013; Developmental Science

Results



Morsanyi,…, Szucs, 2013; Developmental Science

Modelling numerical competence (N=98; 9-year-olds)



Szucs et al. Developmental Science, 2013

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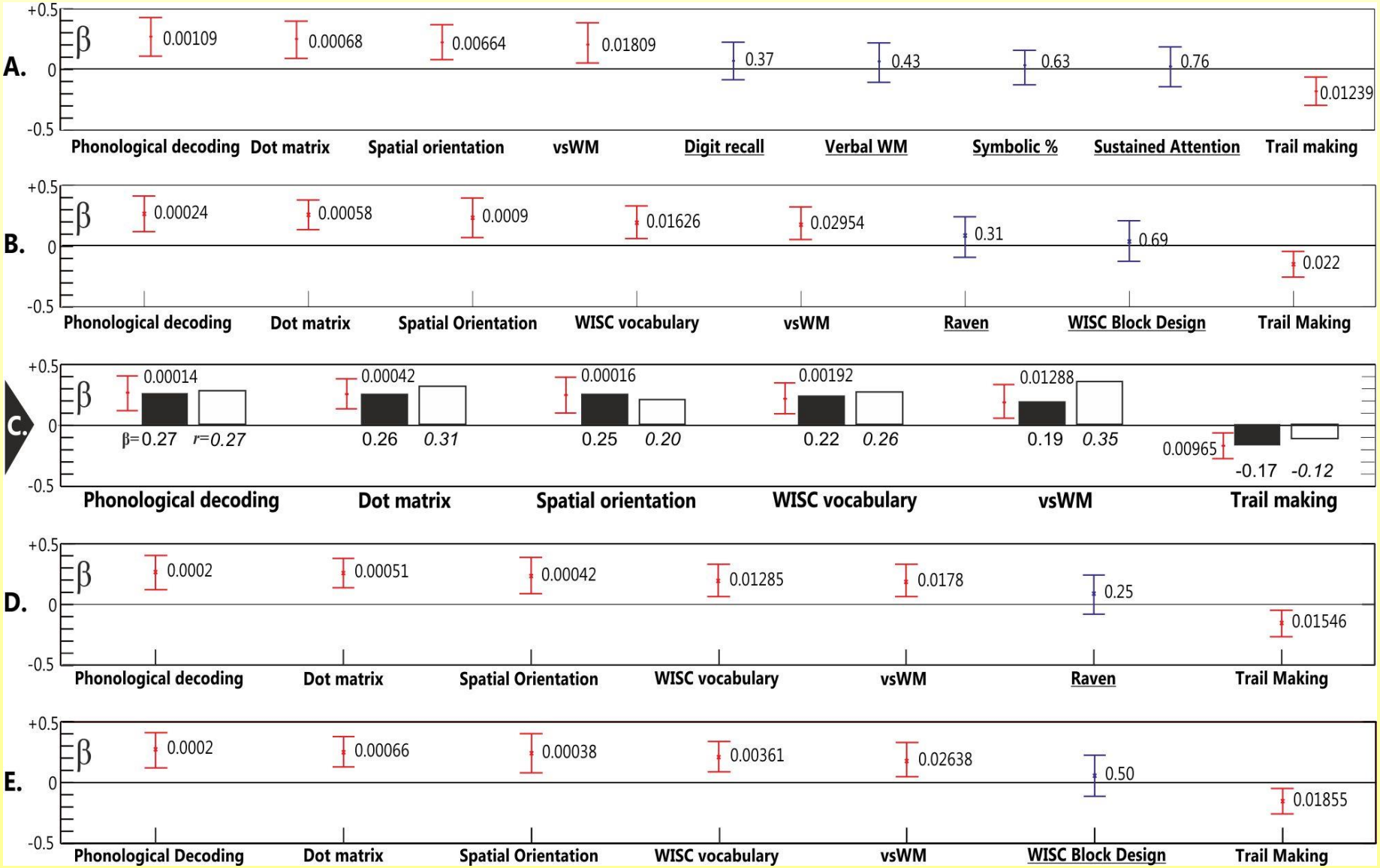

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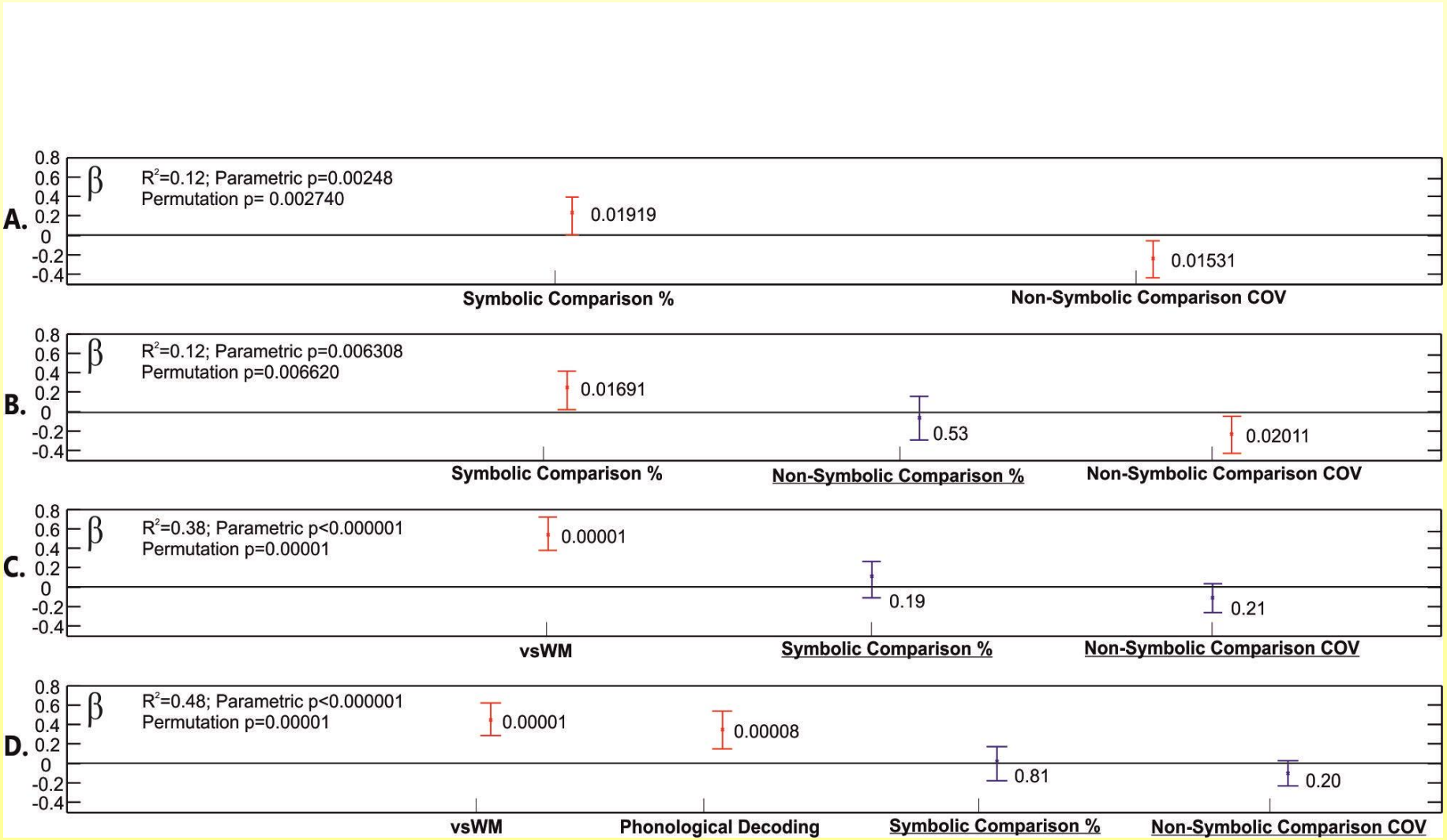

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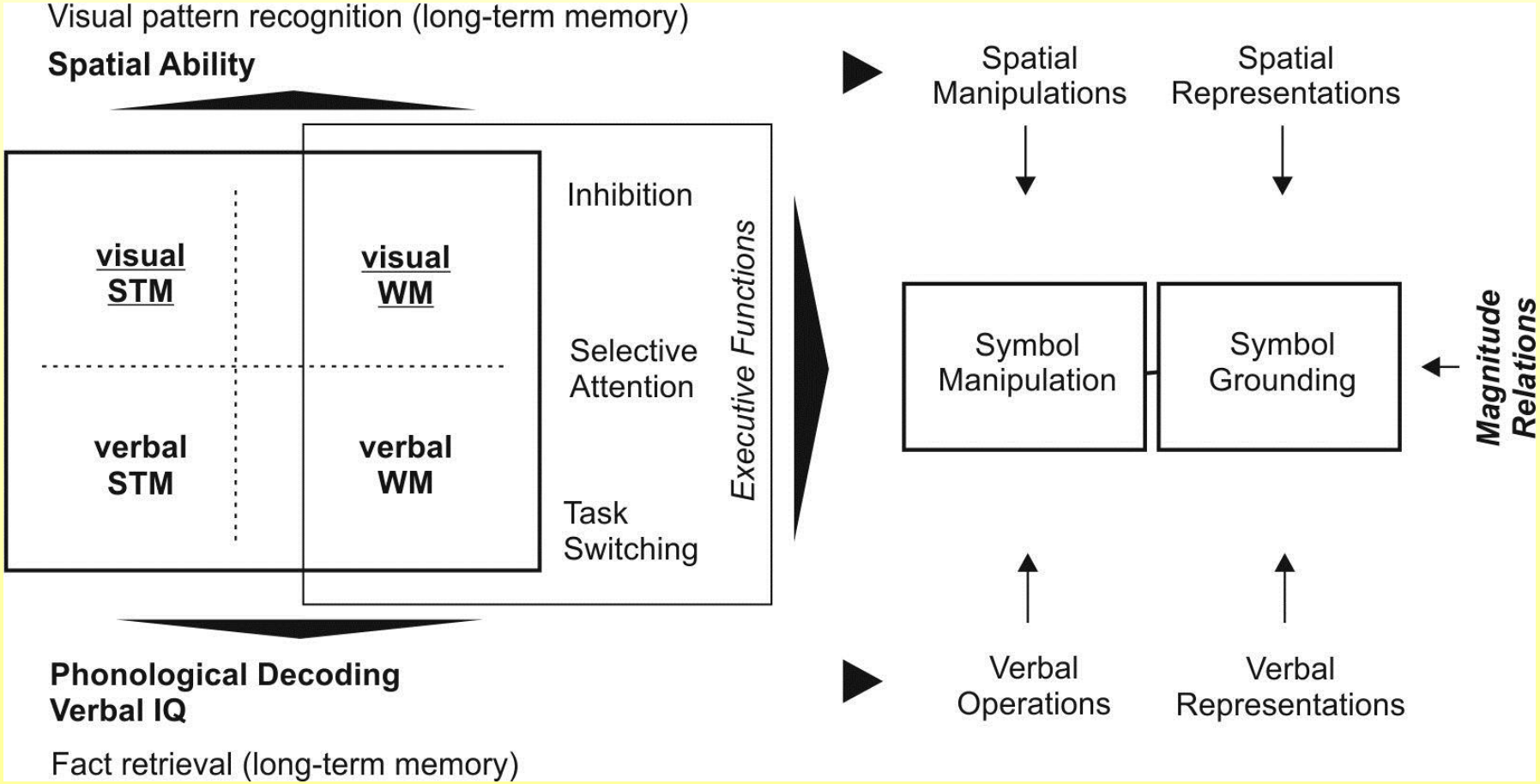
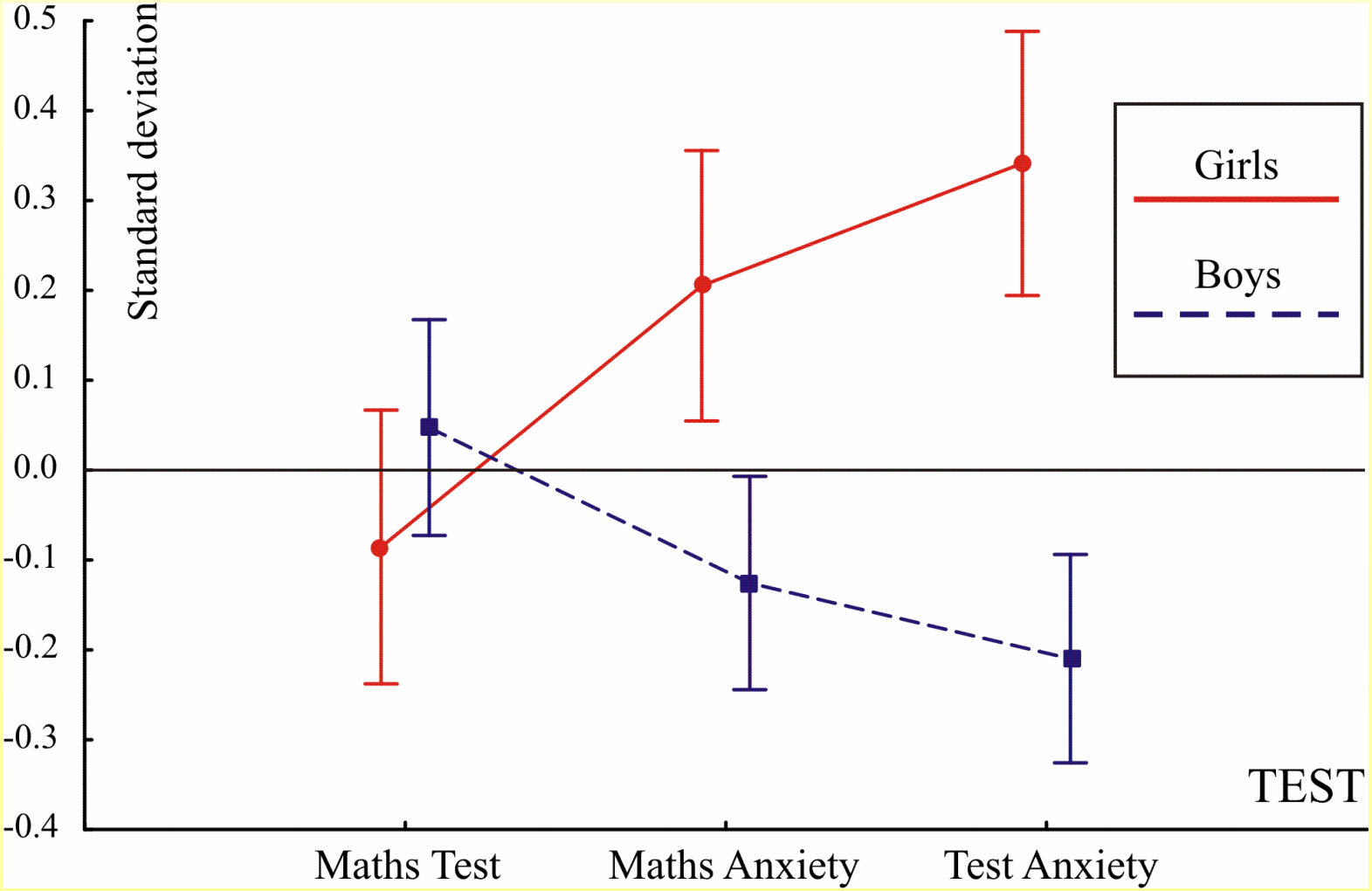


Szucs et al. Developmental Science, 2013

Emotional factors: Mathematics anxiety

433 children in the UK



Devine,…Szucs et al. 2012. Behavioural and Brain functions

CONCLUSIONS

Cognitive structure related to math in **9-year-old children**:

1. The most robust impairment in DD is that of **visuo-spatial short-term memory and working memory**

2. **Inhibition** function seems impaired as well

3. **Logical reasoning skills** are also impaired in DD and strongly relate to mathematical ability (when problems are visualizable).

4. **Educational implications:**

- **Interventions** to improve mathematical skill may want to focus on enhancing abilities in the above domains / anxiety
- However, further research is needed to establish the **efficiency** of such interventions.
- **Cross-cultural validity?**

Review in Szucs & Goswami, 2013; *Trends in Neuroscience and Education*

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