

## Testing theories of developmental dyscalculia

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with

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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.

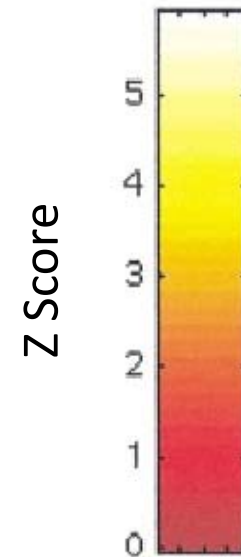
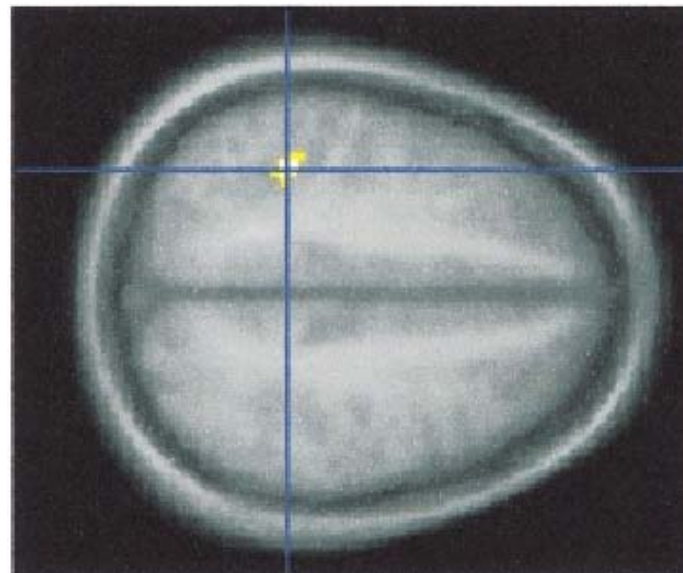
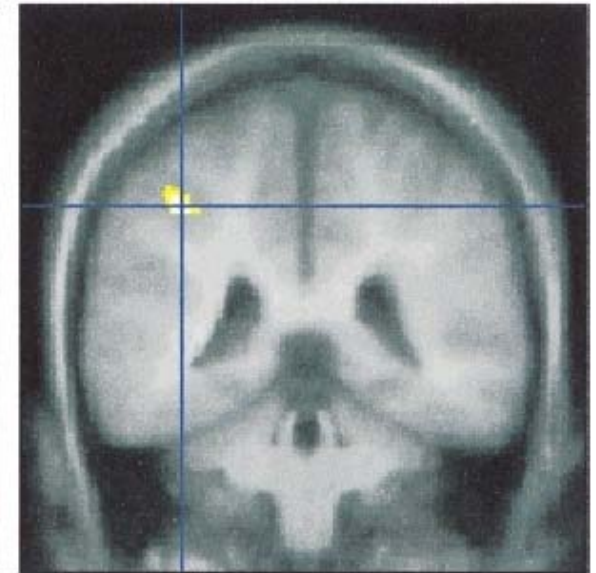
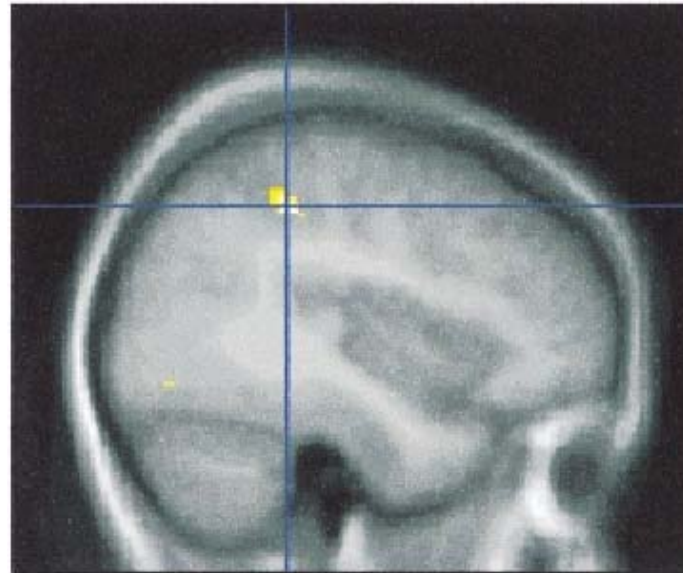
One view is that DD is related to the domain specific impairment of the **Simple number processing** ability (**number sense**) of the brain

**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**. >

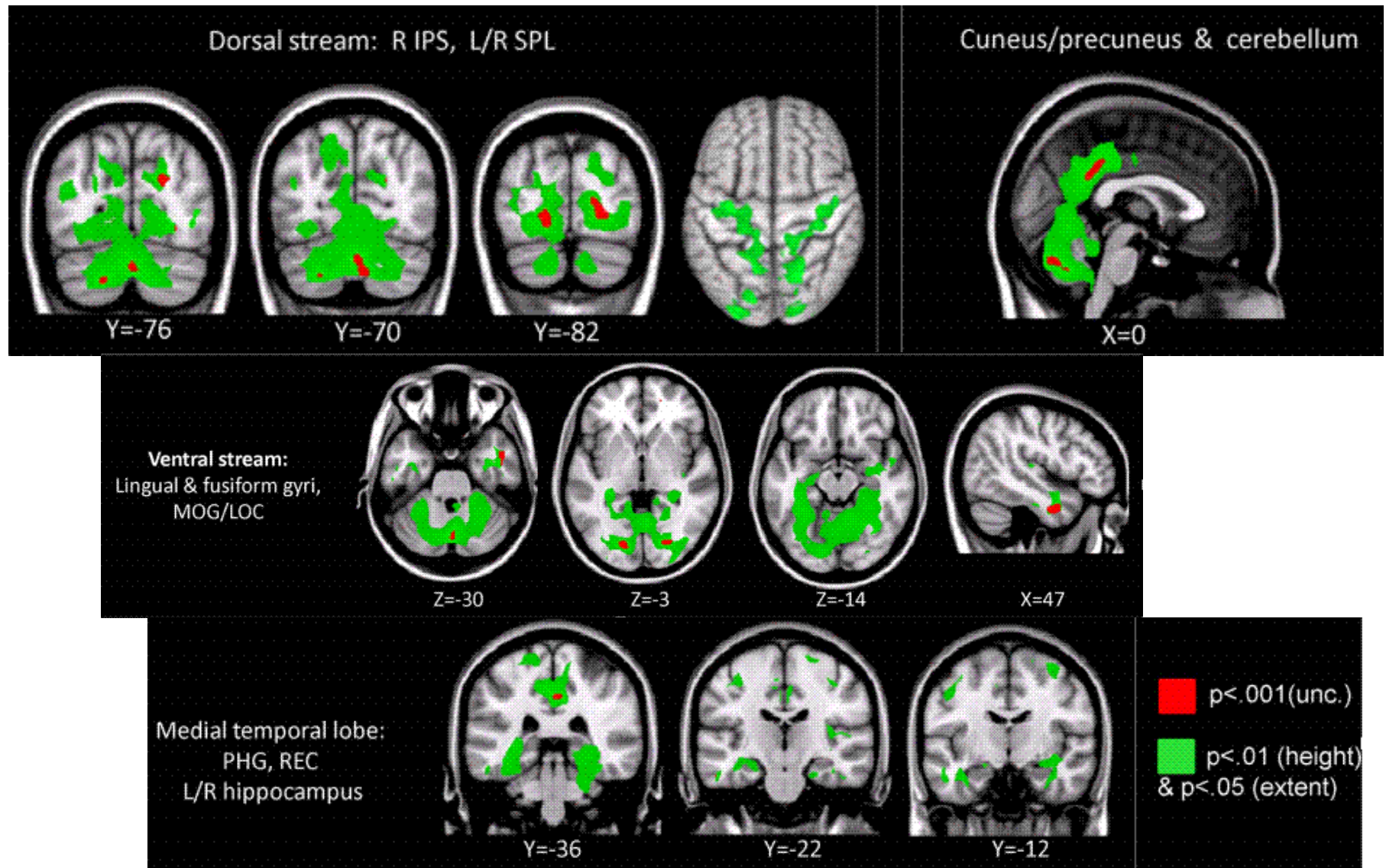
**Can DD be related to impaired ability in simple number processing in the IPS?**

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



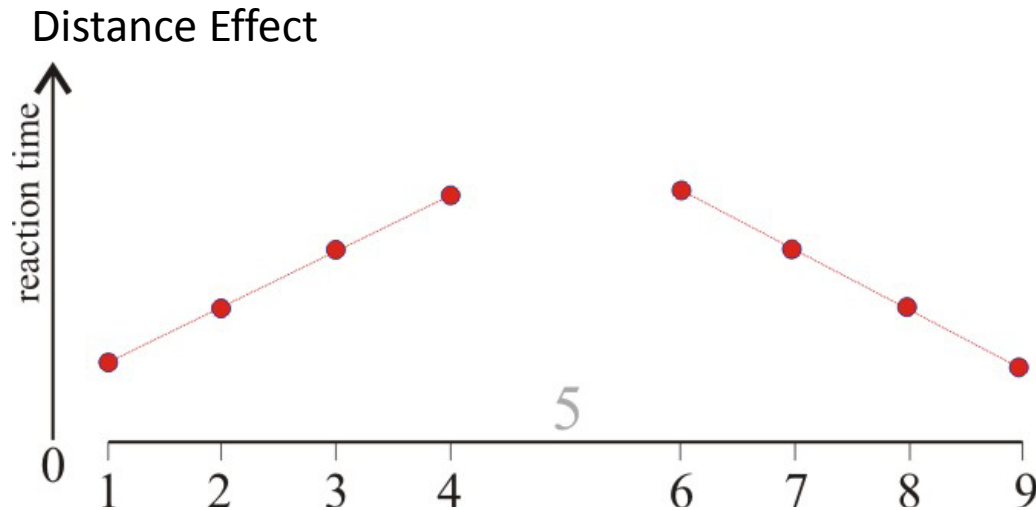
Structural MRI data in DD: **extended brain differences** rel. to controls

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

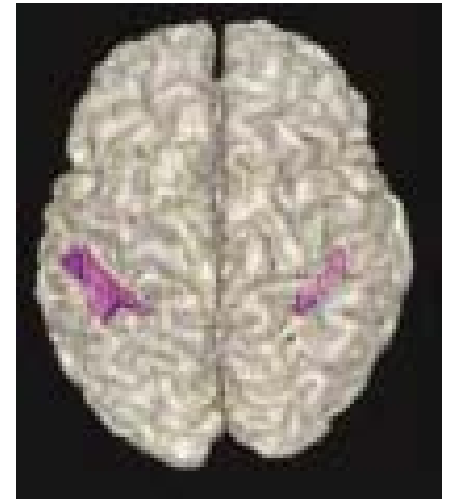
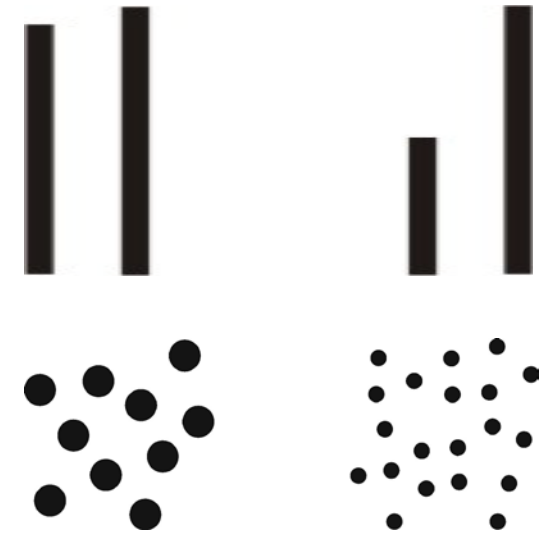
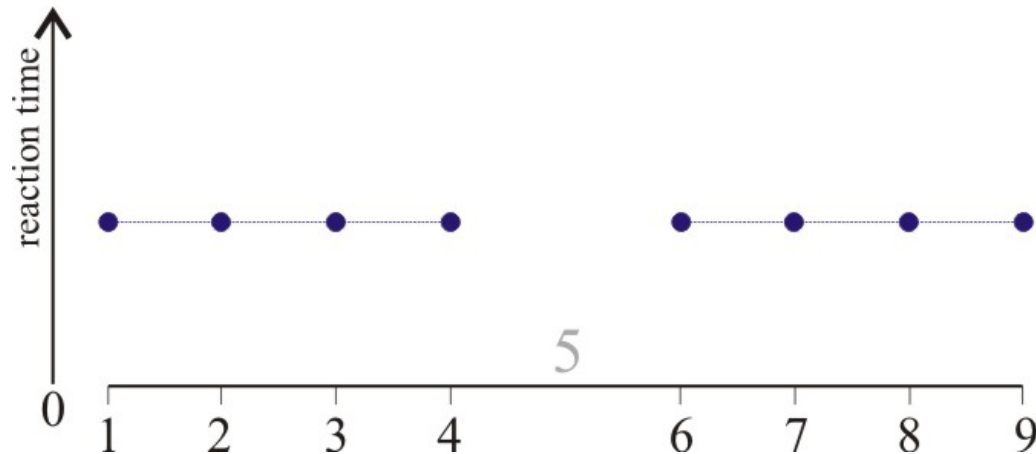


Reviewed in Szűcs et al. 2013; *Cortex*; In Press

# Simple number processing (e.g. number comparison) may rely on a Number sense OR Magnitude representation in the Intraparietal Sulcus (IPS)



Moyer and Landauer, 1967, Nature

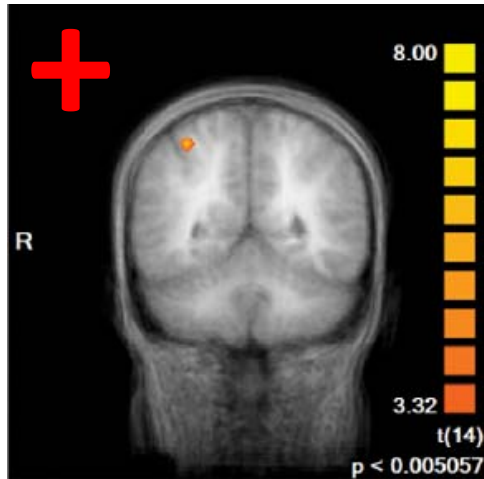


Pinel et al, 2004, Neuron



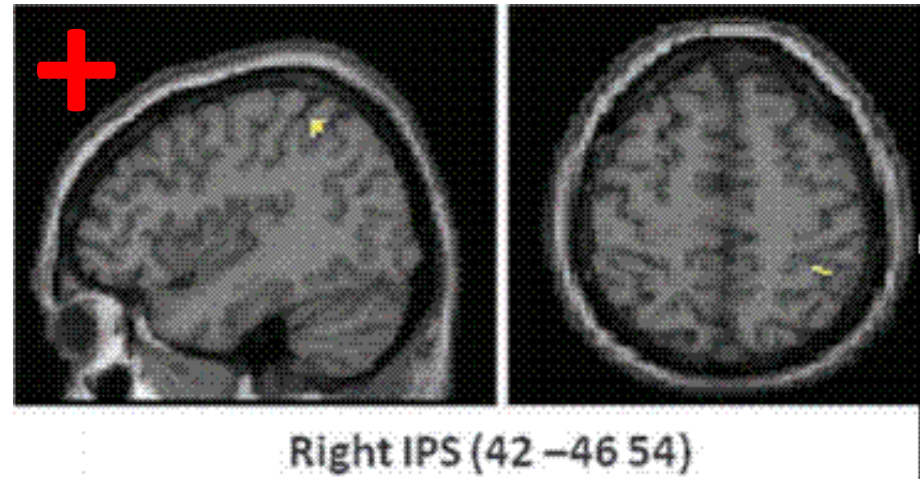
However, functional MRI data about the distance effect  
(functional marker of number sense) is weak

Price et al. 2007



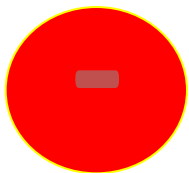
Accuracy DE differs

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?**

# Developmental dyscalculia (DD)

- It is highly likely that DD relates to weaknesses of various 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:  $( (3 + 4)^2 + (1 - 2) ) / 2 * 3$
- **Our projects** examine how the above cognitive functions
  - Relate to DD
  - And to math expertise in children in general

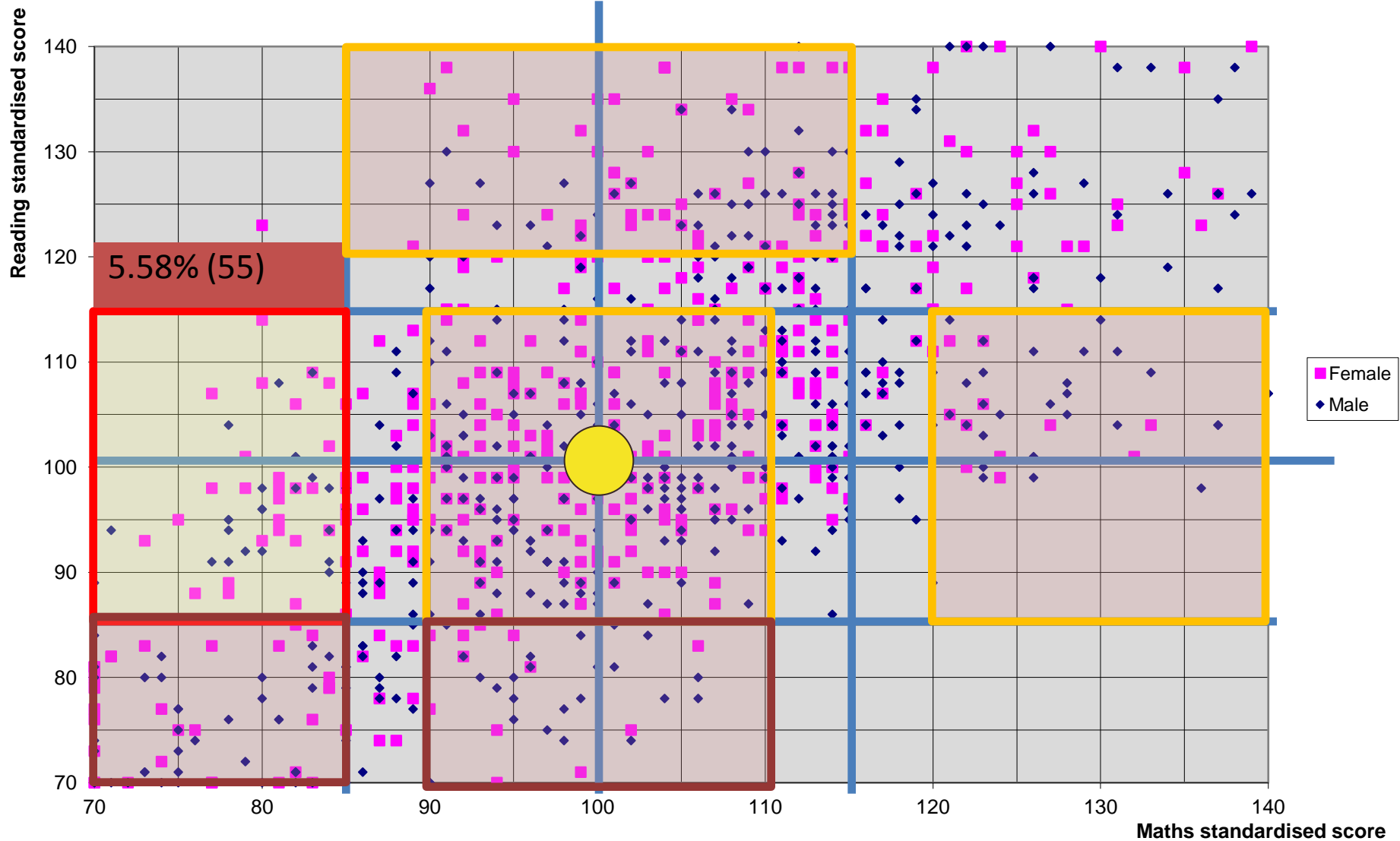
# Large study on DD; Study phases

- **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** – **standardized test-based individual assessment**
  - Mathematics; reading: WIAT-II:
    - Numerical Operations, Word Reading & Pseudoword Decoding
  - IQ: WISC-III, Raven's Matrices ; WM: AWMA
  - Socioeconomic status; ADHD: Barkeley scales
- Phase 3 – **custom tasks + experimental tasks**
  - Measuring automatic access to numerical information and inhibition
- Phase 4: **EEG and MRI**



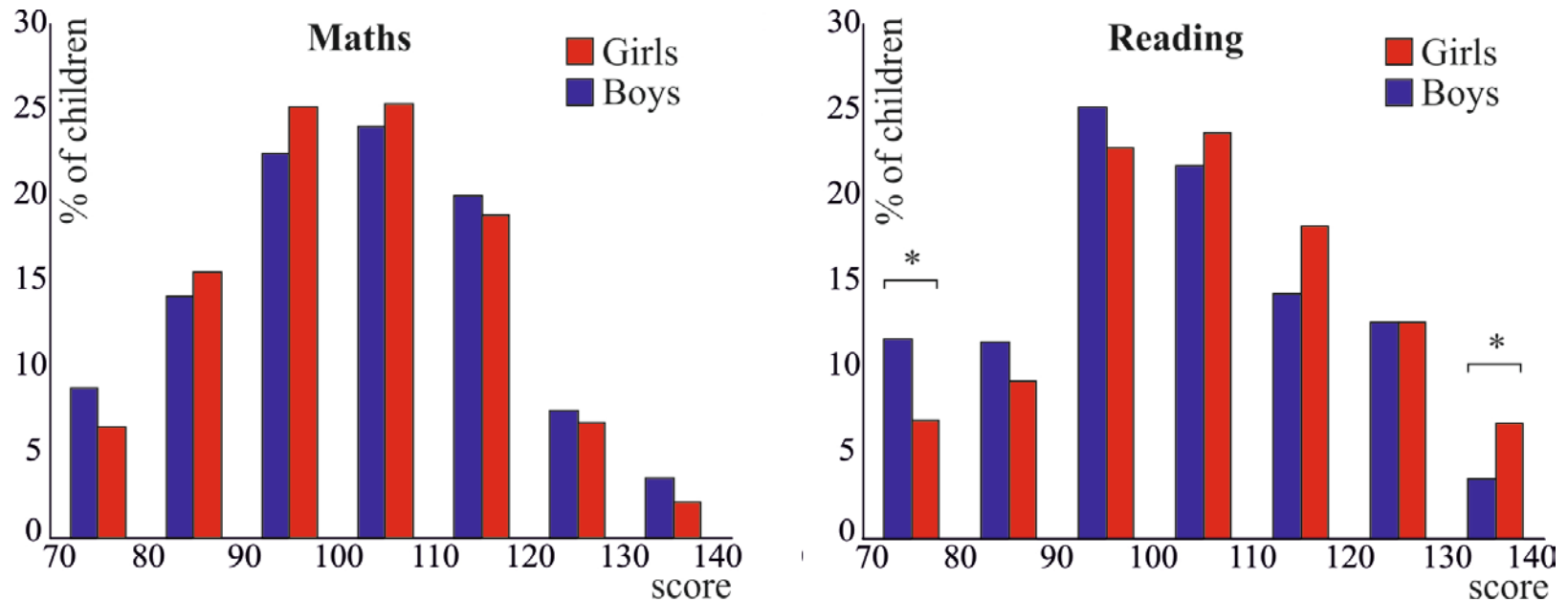
# Group test results

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



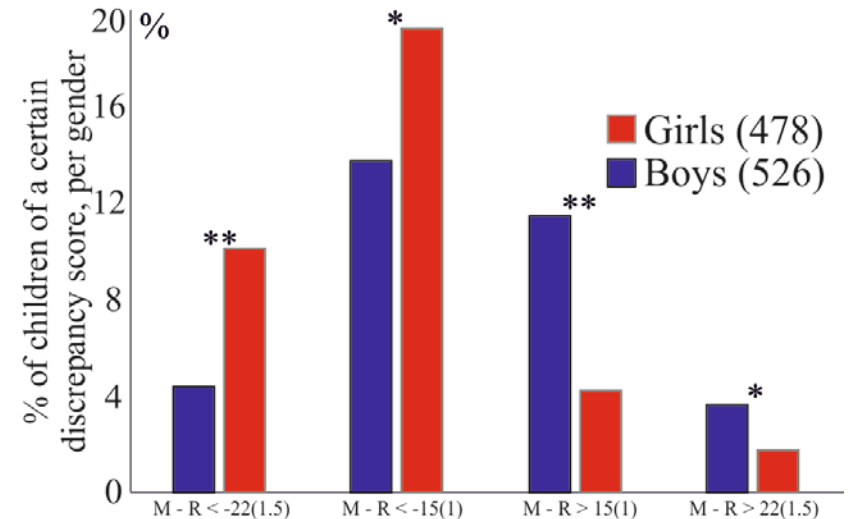
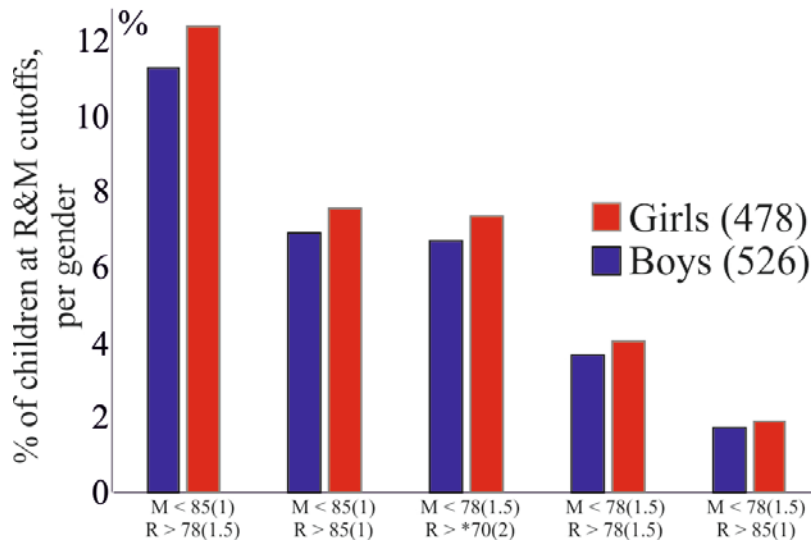
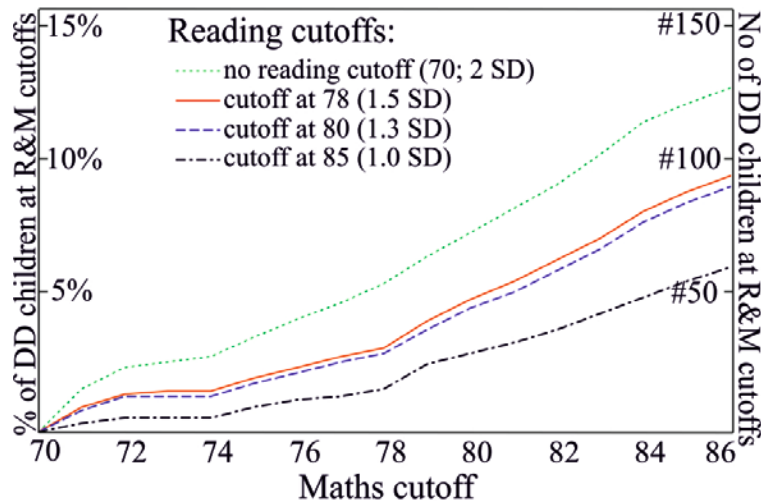
# Group test results

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



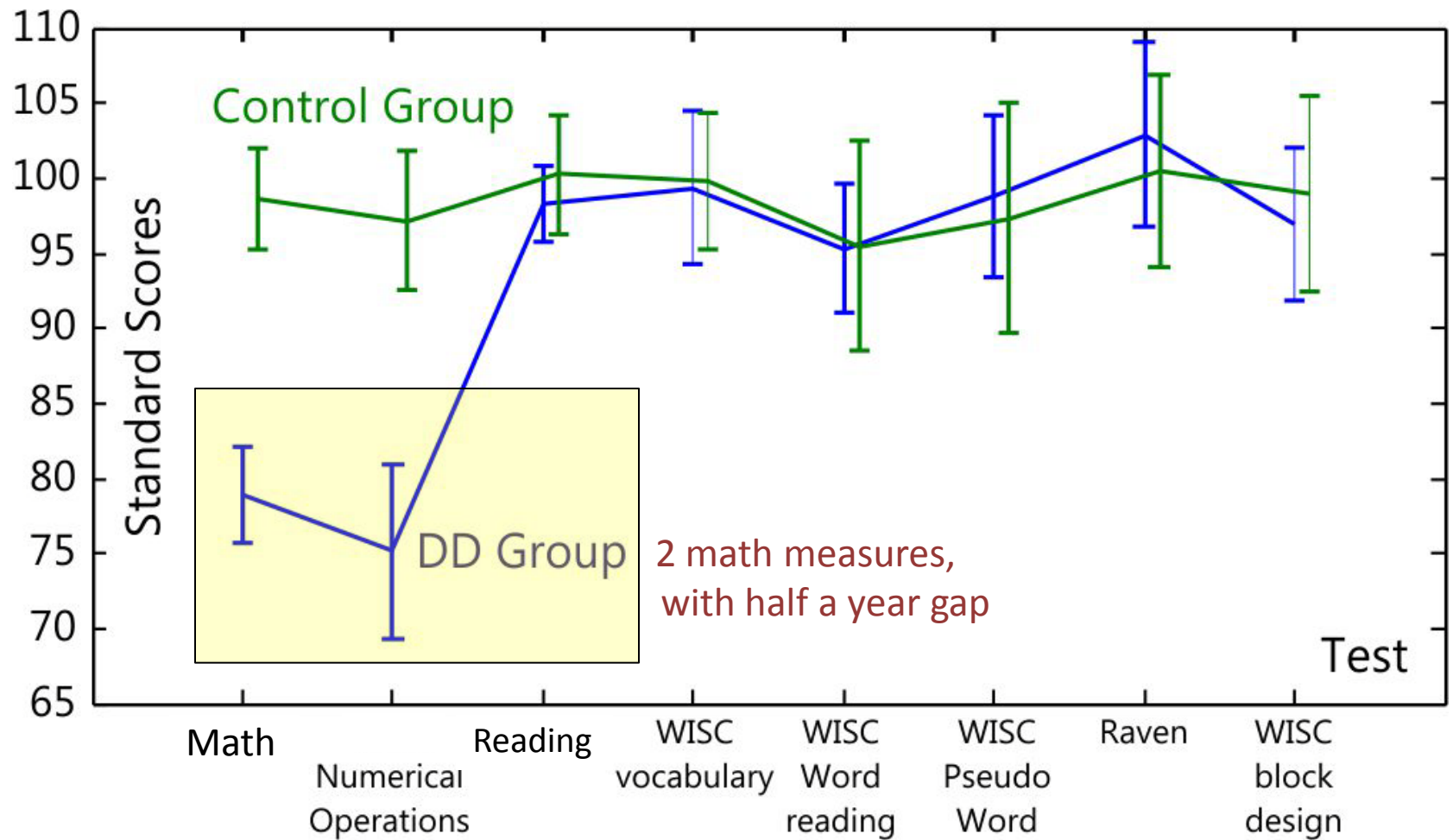
Maths and reading performance normally distributed ( $p > .1$  for both)

# Prevalence and gender ratio of DD



# DD vs. Control sample: 12 vs. 12 children

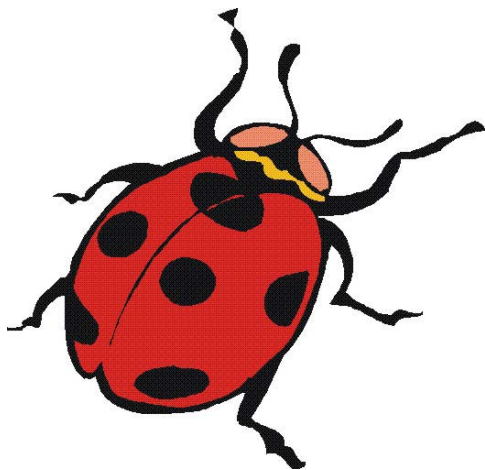
(Age: 110 vs. 109 months;  $p=0.5$ )



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	93.3	95.3	99.8	102.9	6.9
Control:	98.6	97.2	100.3	98.8	95.5	97.3	100.4	8.9

# 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

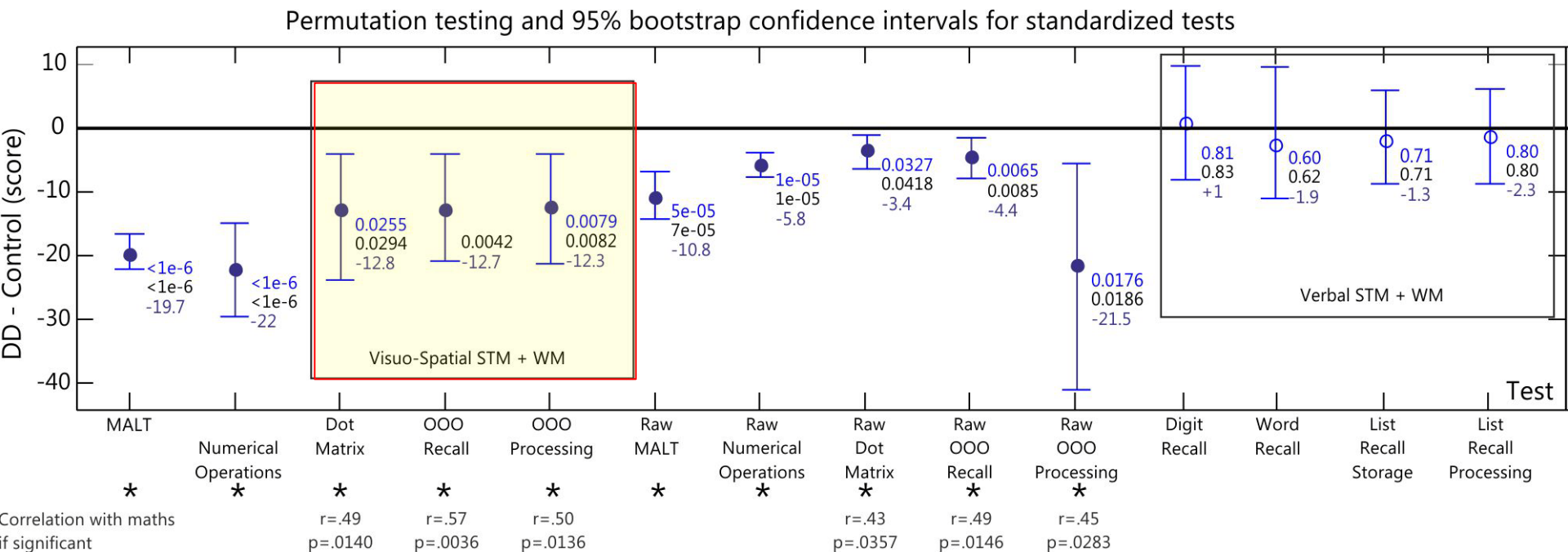
# DD children performed worse than control children in

- visual STM
- visual WM
- inhibition = weak interference suppression in Stroop tasks
- (number sense did not discriminate DD)

## Slower performance on mental rotation and trail making tasks

Permutation statistics: 1 million random re-groupings into 2 groups of N=12

Bootstrap: 1 million bootstrap samples with replacement





# Conclusions

1. Prevalence and gender ratio of DD depends on diagnosis criteria.
2. The most robust impairment in DD is that of **visuo-spatial short-term memory and working memory**
3. **Inhibition** function seems impaired as well

Thank you!



Denes Szucs



Fruzsina Soltesz



Swiya Nath



Florence Gabriel



Francesca Hill



Kinga Morsanyi



Jan Zirk



Alison Nobes