Numeracy development and disorders

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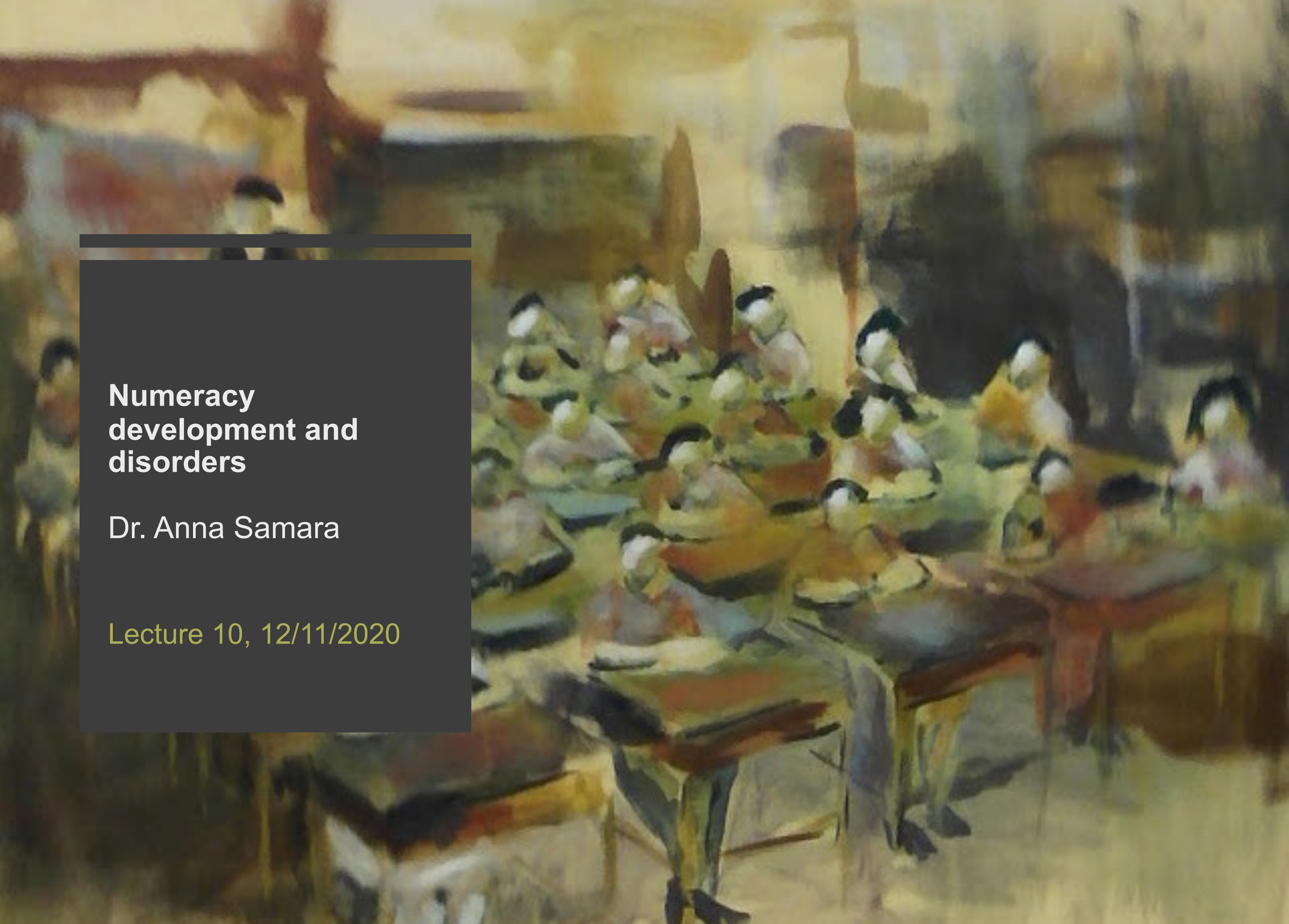
Lecture 10, 12/11/2020



School Room, 2012. Mark Wickline

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Today's lecture

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

Learning outcomes

1. Describe key areas of numerical difficulty for children diagnosed with developmental dyscalculia
2. Describe and evaluate evidence for theories of developmental dyscalculia
3. Describe methods used to study children's and adults' numerical and arithmetic skills

Atypical number development

- More direct evidence into capacities that are key (foundational) for learning arithmetic from studies of atypical numerical development
- "Mathematics Learning Disability", "Specific Arithmetic Difficulties", "Mathematics Disorder", "Arithmetic Deficit", "Developmental dyscalculia"
- Methodological considerations (Mazzocco, 2007)
  - Difficulty: poor achievement deriving from various causes, with no presumed biological basis
  - Disorder: biologically based disorder

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Atypical number development

- ‘Mathematics is a complex subject, involving verbal, space and quantity skills
- Exogenous factors: Poor/inappropriate teaching, missing lessons, behavioral problems, attentional problems, and language-related impairments including dyslexia
- Anxiety about numbers and mathematics
  - Failing to understand one concept results in failure to understand concepts that build on it

Developmental dyscalculia

- Discrepancy approach taken by DSM:
  - *Mathematical ability, as measured by […] standardized tests, is substantially below that expected given the person's chronological age, measured intelligence, and age- appropriate education'*
  - Standardized achievement tests, however, are diverse; furthermore, many also tap on nonnumerical skills (increased Type I error)
- Definition taken here: Difficulties with numbers (can be) highly selective; normal/superior IQ does not protect against them; 6 –7% prevalence (Butterworth, 2005; Shalev, 2007)

Congenital deficit

- Approximately 1 in 2 siblings of dyscalculics are also dyscalculic (5 to 10 times greater risk than controls) (Shalev et al., 2001)
- If a twin is dyscalculic, 58% of monozygotic co-twins and 39% of dizygotic co-twins are also dyscalculic (Alarcon et al. 1997)
  - a third of the variance seems to be specific to mathematical ability, though not exclusively numerical ability (Kovas, Harlaar, Petrill, & Plomin, 2006)

Areas of difficulty

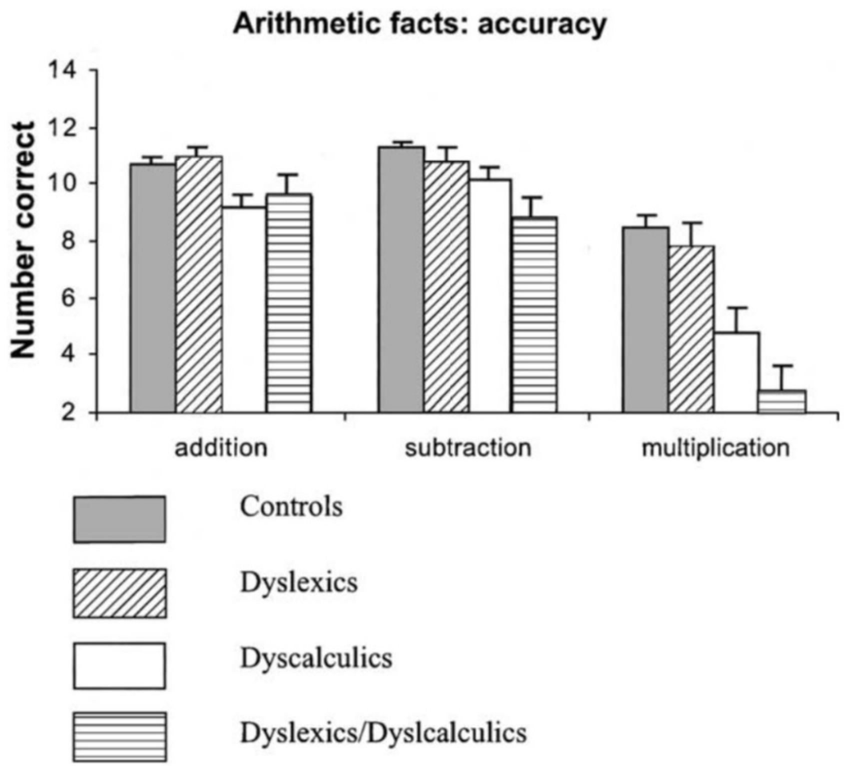

Fig. 1. Mental arithmetic: mean number (SE) of correct responses for each operation.

- Most generally agreed difficulty: learning and remembering arithmetic facts
- Landerl, Bevan, & Butterworth (2004)
- 9-year-old DDs (n=10) and 18 matched controls

Domain-general difficulties as the cause?

- Conceivably, domain-general **memory difficulties** would affect the ability to executive complex calculation procedures (e.g., storing info in WM to apply procedures such as borrowing) as well as memorized arithmetic facts (2x1; 2x2, 2x3 etc. – stored in long-term memory)
- Note that memory (e.g. WM) is not unitary (Baddeley, 1998)

1. Central Executive for high level monitoring and control
2. Phonological loop (ST storage/maintenance of verbal info)
3. Visuo-spatial sketchpad (ST storage/maintenance of visuo-spatial information

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Domain-general difficulties as the cause?

- Working memory (Geary et al. 1993)
  - No difference between children with arithmetic difficulties and controls in three measures (e.g. FW/BW digit span, word span) and no correlation between any of the measures and arithmetic ability (Temple & Sherwood, 2002)
- Semantic memory (Geary et al., 2000, 2001)
  - Little empirical evidence for a non-numerical semantic deficit in dyscalculic children
  - Patient IH (Cappelletti et al. 2001) with semantic dementia affecting semantic knowledge over a range of living and man-made items but not numbers

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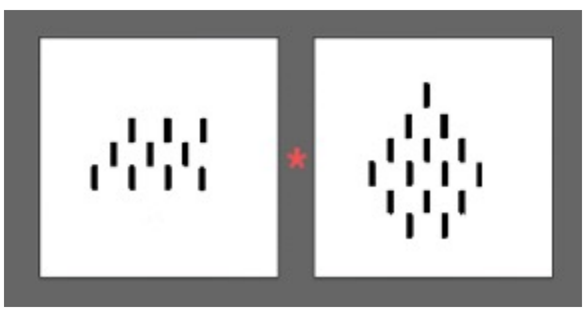
Defective mapping hypothesis

- Dealing with numbers includes transcoding between spoken number words (hearing three), written number words (seeing ‘three’) and Arabic numerals (e.g., 3)
- Intact numerical representations but deficit in linking numerosities with the symbolic meaning of their expression
  - Impairments expected when task involves relating a symbol to its quantitative meaning (e.g., comparing Arabic digits)
  - NOT when no symbolic processing is involved (e.g., dot comparison task)

Evidence for defective mapping hypothesis?

- **Rouselle & Noel (2007)**

1. Arabic digit comparison task
2. Physical size comparison task
3. Collection comparison task (non-symbolic)



Low perceptual control conditon
numerosity and other perceptual cues (e.g., density) available for comparison

High perceptual control condition
numerosity as the only available cue for comparison

Rousselle & Noel (2007)

Table 4
Mean reaction times and accuracy data by task and achievement group

Group	Physical comparison		Arabic number		Collection[a] Density	Collection[a] Surface	Congruity effect[b]
RTs							
MD	771 ms (104)	*	1156 ms (157)	***	809 ms (104)	976 ms (155)	88 ms (104)
NA	721 ms (120)		970 ms (151)		759 ms (94)	936 ms (144)	82 ms (60)
Accuracy							
MD	11.73/12 (.36)	ns	11.01/12 (.56)	**	11.62/12 (.61)	11.10/12 (.91)	.71 (.89)
NA	11.87/12 (.27)		11.38/12 (.49)		11.78/12 (.33)	11.47/12 (.86)	.69 (.76)

Note: Standard deviations are shown in parentheses. MD = mathematics difficulties; NA = normal achievement. See Appendix D for an exhaustive presentation of RTs and accuracy data in each task and in each experimental condition.

[a] Only data of the ratio-set are reported.

[b] Difference between data in the congruent and incongruent conditions.

- As predicted by defective mapping theory differences in symbolic comparison only
- But criterion used for identifying DD is the lowest 15% of the sample

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Defective number module hypothesis

- **Deficit in processing *exact numerosities (i.e. exact 'fiveness')*** *{Butterworth, 1999}*
  - Defective number module analogous to the core PA deficit seen in dyslexia
  - Predicts impairments in tasks requiring (symbolic, non-symbolic) numerical magnitude processing and representation but intact ability to represent approximate numerosities
  - Deficits prevent DDs from understanding number concepts and, in turn, learning numerical information

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Summary: Underlying causes of DD

- Most evidence suggests domain-specific deficit in accessing magnitudes, or in the magnitudes per se (exact in nature)
- Domain-general deficit(s) e.g. in memory (but note other possibilities too; e.g., impairments in executive function, speed of processing, language (see Donlan, Bishop & Hitch, 1998; Donlan, Cowan, Newton & Lloyd, 2007))

Core & recommended reading

- Iuculano, T., Tang, J., Hall, C.W., Butterworth, B. (2008). Core information processing deficits in developmental dyscalculia and low numeracy. *Developmental Science, 11(5)*, 669-680.
- Landerl, Bevan, & Butterworth (2004). Developmental dyscalculia and basic numerical capacities: A study of 8–9 year old students. *Cognition, 93*, 99-125
- Rousselle & Noel (2007). Basic numerical skills in children with mathematics learning disabilities: A comparison of symbolic vs non-symbolic number magnitude processing. *Cognition, 102*, 361-395.

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