Dyscalculia and related disorders

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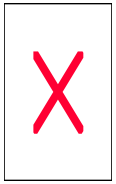


Plan

- Definition & criteria
- Characteristics
  - Prevalence & associations
  - Persistence of the problem
  - Genetic contribution
- Explanatory models
  - General cognitive factors
  - Specifically numeric factors
- Neurobiological bases
- Conclusion

Definition & criteria

- *Developmental dyscalculia is a specific learning difficulty manifested by failure to achieve adequate proficiency in arithmetic despite normal intelligence, scholastic opportunities, emotional stability, and sufficient motivation.*
- *These difficulties do not result from a sensorial deficit or an acquired brain damage*
- *These difficulties interfere significantly with daily life and/or school success*

Characteristics

- Writing & reading numbers
  - Reading: *85* => *eighty-two* (Paul; Temple, 1989)
  - Writing: *fifty thousand ninety* => *50,90* (CM, Sullivan, & al., 1996)
- « visual-spatial dyscalculia »
  - Errors in counting random patterns of dots, problems in left-right orientation (< >, + -), mastery of the positional system of the Arabic notation (11 - 14), geometry (Spiers, 1987)
- Arithmetical facts : 3+6; 9-2; 4x6; 12:3
  - longer RTs, immature strategies (e.g., counting on fingers), less retrieval from long-term memory, more errors (counting & retrieval)
- Calculation procedures
  - Mastery of the procedures required to solve multi-digit written calculation: carrying, borrowing ... (SW, Temple, 1991)

- *Nathalie*
  - *33 y.o. woman, normal intelligence, normal reading & writing*
  - *Simple 1-digit additions : 15% errors*
    - *1+4=4 , 3+5=9*
  - *Simple 1-digit multiplications: : 39% errors*
    - *5x5=35; 7x4=21, 0x5=5*
  - *Divisions: impossible*
  - *Counts on her fingers*
  - ⇒ *major difficulties with dealing with her money, shopping, comparing prices*
  - ⇒ *did not obtain her certificate of primary school*

Prevalence & associations

- Prevalence: from 3.6% to 6.5%
  - 3029 children from Israel, 10 y.o.
  - score < two grade below mean & IQ > 80
  - 6.5% of dyscalculics (Gross-Tsur, Manor & Shalev, 1996)
- Associations
  - with reading disability in 36% to 64% of the cases (Lewis & al. 94; Gross-Tsur & al., 96)
  - With ADHD in 26% (in Gross-Tsur & al. 96)
- Sex ratio: 1.1:1 girls:boys

A persistent problem

- 3 year follow-up of 123 dyscalculic children
- 47% persistent dyscalculia (score < pc 5)
- 95% poor learning in math (score < 25 pc)

- Persistent vs. Non-persistent DC
  - More attention problems
  - More anxiety problems
  - similar performance IQ (100.4 vs. 104.2)
  - equivalent verbal IQ if arith subtest is excluded
  - 46% vs 28% of siblings received arithmetic tutorials

Shalev, Manor et al. (1998), J. Pediatr.

A persistent problem

- 6 years follow-up
  - Among the 104 DC children
    - 40 % : score < pc 5 standardised test
    - 95% : score < pc 25
  - The profile changes
    - Difficulties in counting, difficulties in doing simple computations
    - Deficits in the retrieval of simple arithmetical facts from memory
    - Errors in complex (written) calculation
    - Difficulties to handle and understand fractions, decimals

Shalev & al. (2005). Dvptal Med & Child Neurolol

Genetic contribution: family studies

- 31 families of persistent DC (over 3years)
- 149 family members tested for DC
- DC criteria:
  - poor performance in arithmetic (<pc25),
  - IQ > 85,
  - significant ≠ between math and IQ (> 1 SD)

⇒ half of the family members are DC
⇒ 10 x more than in the general population

	% of DC
mothers	67
fathers	41
siblings	53

Shalev et al. (2001)., J. Learning Dis.

Genetic contribution: twin studies

- Dyscalculic twins
  - 58% of monozygotic co-twins are DC
  - 39% of dizygotic co-twins are DC
  - Concordance rate is even higher when considering dyscalculic children with not reading difficulties
    - .73 vs .56 (mono and dizy)
    - .85 vs. .46 (mono and dizy; no reading diff)

Alarcon & al. (1997), J. Learn. Disabilities

Genetic contribution: genetic syndromes

- Turner syndrome (Royet & al., 94; Temple & al., 1998; Bruandet & al., 2004)
- Williams syndrome (Paterson & all, 1999)
- Fragile-X syndrome (Hagerman & al., 1992)
- 22q11 (Simon, 2005)

Explanatory models

- General cognitive factors
  - poor intelligence ?
  - poor inhibition capacities ?
  - poor long-term memory abilities ?
  - poor short-term memory
  - poor finger gnosia

poor intelligence ?

- No problem of intelligence is one of the criteria of the DSM
- Gross-Tsur & al. (96)
  - IQ of DC: 98.2
  - Performance IQ: 102.4
  - Verbal IQ (no arith): 94.8
- 3 years later: persistent vs. non-persistent DC
  - Similar performance IQ
  - Similar verbal IQ (no arith)

poor inhibition capacities ?

The presentation of a problem activates many responses

4 x 6 = 18, 24, 28, 30

=> difficulty to inhibit the wrong responses associated with the problem ?

- **Math disabled**: 10 y.o., n=20; <pc15 math; >pc50 reading
- **Controls**: 10 y.o., n=20; >pc 50 math & reading

- Inhibition of external distractors
  - Flankers letters:
- Inhibition of a dominant response
  - Stroop colour
- Suppression of irrelevant information
  - Intrusion in a listening span

Congruent - Incongruent

DDDDDDD GGGDGGG

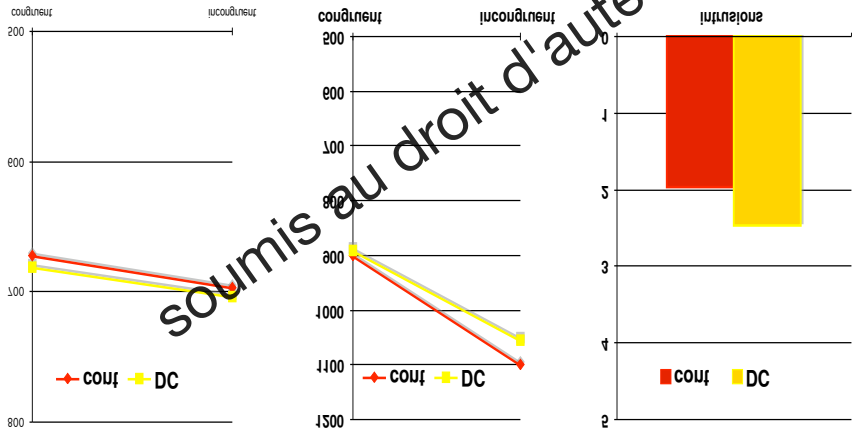
red **blue**

The crone if for the **king**.
Horses live in **nests**.
Wrong answer: crone - nests

Censabella & Noël, 2005 (JLD) & 2007 (Child Neuropsy)

Censabella & Noël

Controls vs. DC: no difference

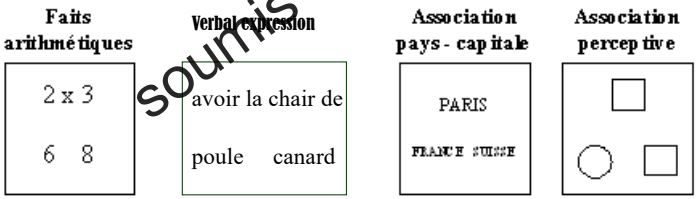


Flankers lettres Color Stroop Listening span

poor long-term memory abilities ?

– Difficulties to store in long-term memory the association between a problem (4 x 6) and the answer (24)

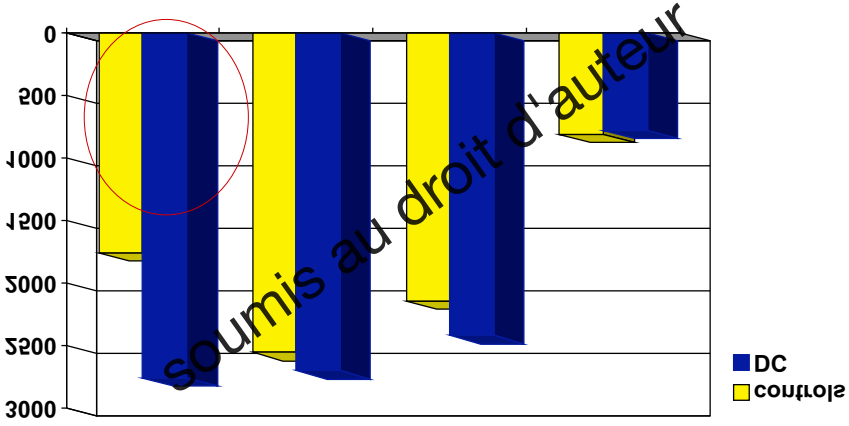
- Associate a multiplication to its product
- Associate a verbal expression with its ending word
- Associate a capital with its country
- Associate a form to another similar form (speed of processing, of selecting an answer, no retrieval from LTM)



Mussolin & Noël

- Population
  - 18 DC children (score < 10 au KRT)
  - 18 controls (score > 40 au KRT)
  - No reading problems (tests L3 et LUM)
  - IQ > 85
  - Two groups paired on age, sex, IQ and education

Mussolin & Noël



=> Specific difficulties in accessing AF from LTM

poor short-term memory ?

- Weak central executive capacities in MD (e.g., backward digit span)
  - Siegel & Ryan (1989)
  - mcLean & Hitch (1999)
  - Passolunghi & Siegel (2001; 2004)
- In normal population,
  - CE capacities are correlated with calculation strategies:
    - poor capacities => less mature strategies, e.g., more finger counting (Geary & al. , 2004; Noël & al., 2004)
- Results are contradictory for the 2 others components (phonological loop and visual-spatial sketchpad)

poor finger gnosia ?

- Fingers are used to count and to touch the counted objects
- Fingers can be used to access the magnitude of number words
  - » *Which is bigger, three or five ?*
  - » => recites the number names, raises one finger more each time, compares the collections of fingers
- Fingers are used to calculate: add - subtract
- Finger agnosia may be associated with dyscalculia after brain damage (Gerstmann syndrome)
- Finger gnosia predicts math skills in unselected samples
  - When tested at 6 y.o. it predicts math skills 1 and 3 years later (Fayol & al., 98; Noël, 2005)
  - The predictive power is better for finger gnosia than for processing speed or intelligence
  - Finger gnosia better predicts math skills than reading skills

Explanatory models
general cognitive factors?

- poor intelligence ?
- poor inhibition capacities ?
- poor long-term memory abilities ?
- poor short-term memory
- poor finger gnosia

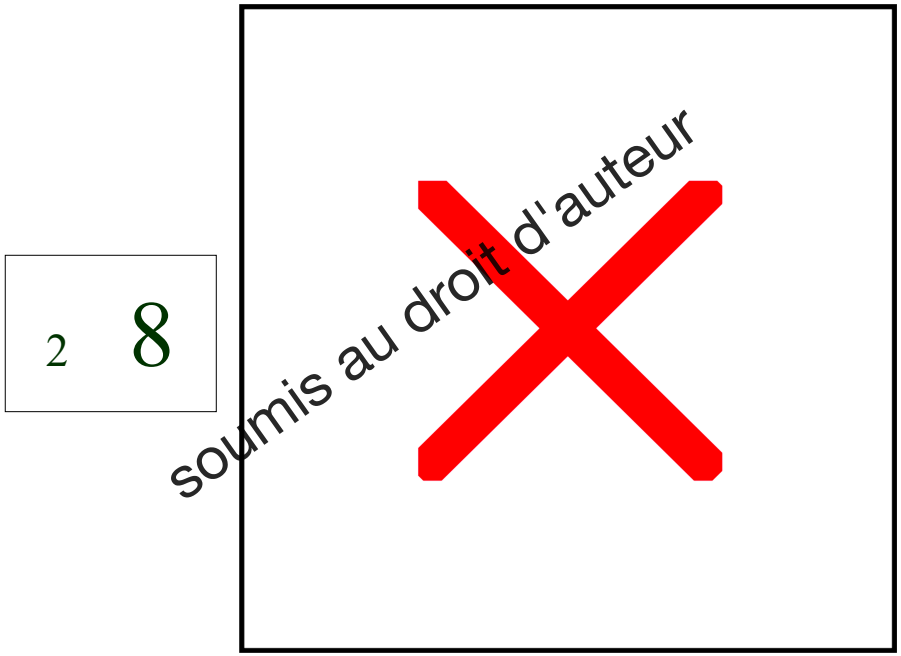
Explanatory models

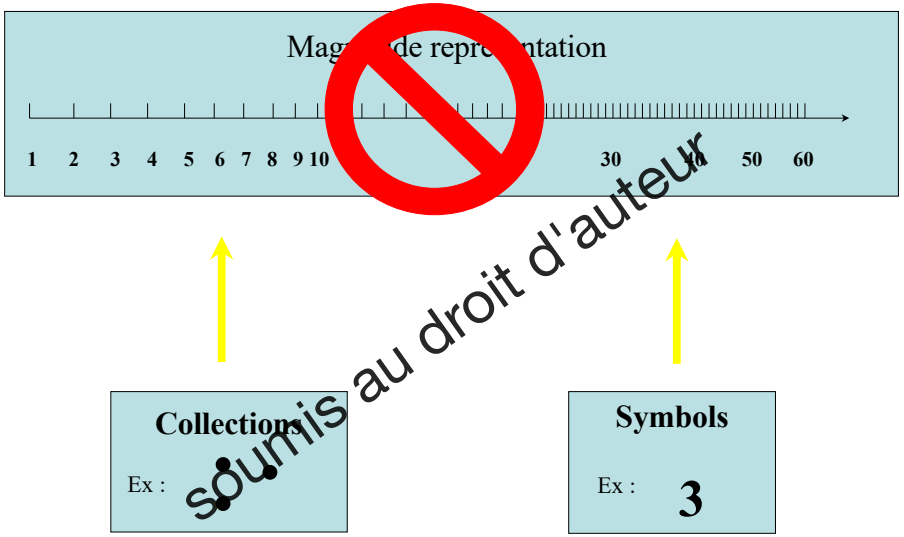
- A specifically numerical disorder ?
  - A deficit in the number sense ?
  - A deficit in accessing number sense from symbols

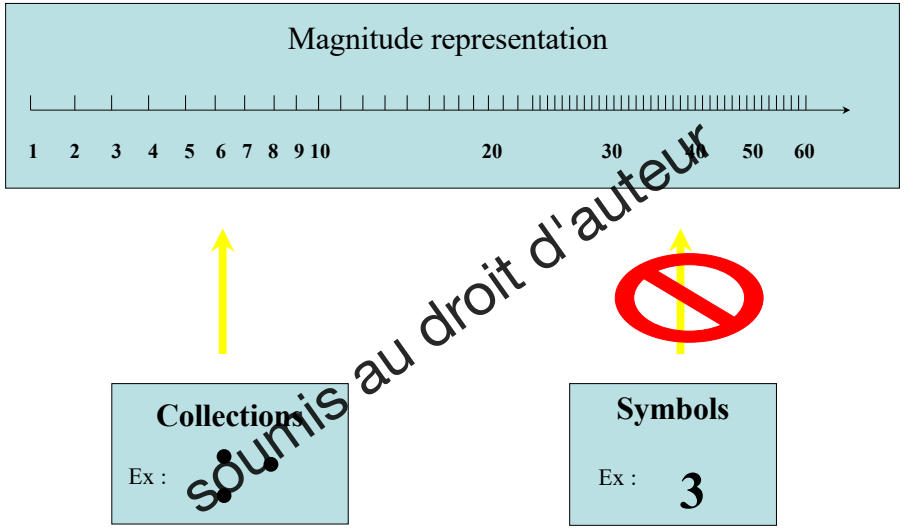
A deficit in the number sense ?

- Dyscalculia might be due to a number blindness, a deficit in the number sense, the ability to represent and process numerical magnitude (Butterworth, 1999)

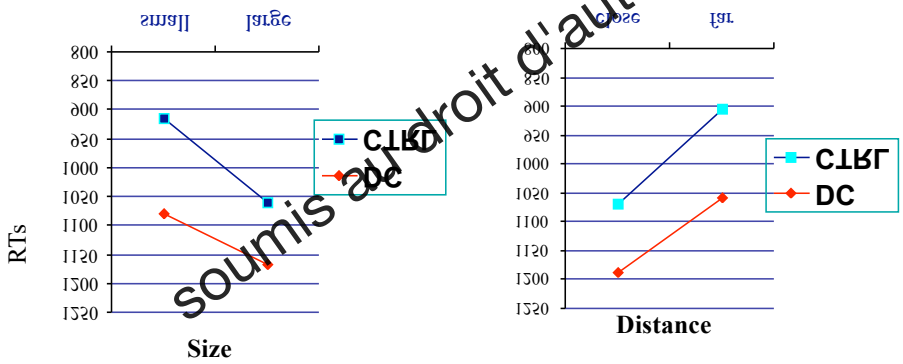
  - Dyscalculics are slower to count, to read Arabic numbers and to compare the magnitude of 2 Arabic digits (Landerl & al., 2004)



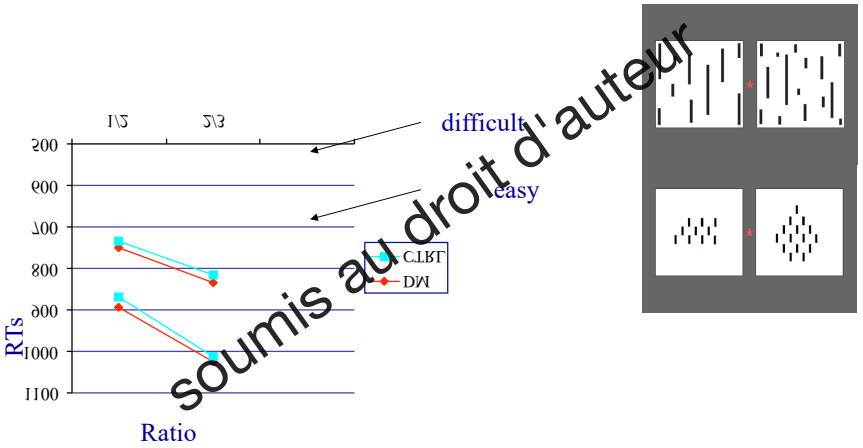




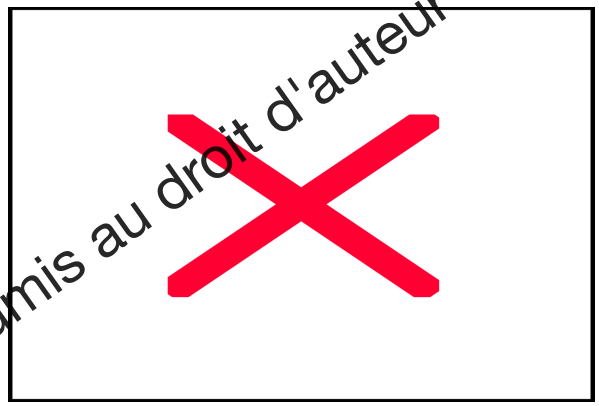
Comparison of Arabic digits



Comparison of collections

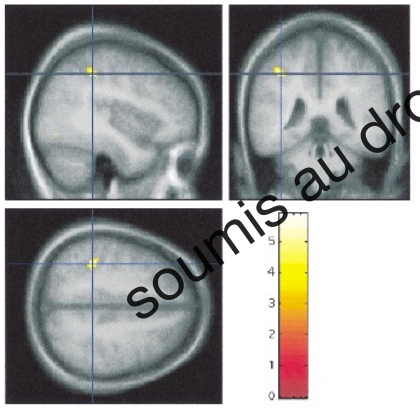


=> A deficit in accessing the magnitude representation from symbols, rather than a deficit in the magnitude representation itself



Neuroanatomical bases

- Isaacs & al. (2001)
  - Born pre-term teenagers
  - Low or normal performance in math relative to what is expected on the basis of their intelligence
  - MRI: one brain region shows difference



- Lower grey matter density in the left intraparietal sulcus of teenagers poor in math
- Bilateral IPS is typically activated in all numerical tasks by normal adults

conclusion

- As frequent as dyslexia
- Persistent problem
- Genetic contribution
- General cognitive factors?
  - Not a problem of inhibition nor of accessing information from long-term memory
  - Poor short-term memory (central executive) and poor finger gnosia are risk factors
- Numerical factors
  - Maybe not a default in the number sense
  - problem in accessing magnitude representation from symbols
  - Fingers might play a role in this connection: analogical representation, serial order, typical configurations that act as first symbols ?

conclusion

- Prevention is possible
  - Pre-school
    - Finger gnosia
    - Working memory capacities
    - Basic numerical skills
- Remediation is necessary
  - To alleviate (but not solve) the problems
  - Allow these individuals to play their role in the economical society

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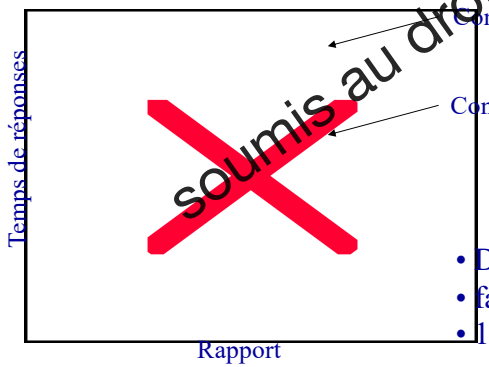
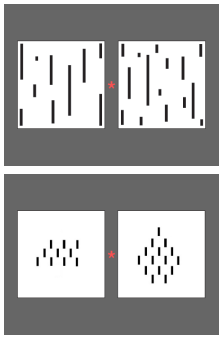
- Sandrine Mejias
- And Xavier Seron and Mauro Pesenti and ...

Comparaison de collections

Facile		Difficile	
1/2	2/3	1/2	2/3
6-12	6-9	6-12	6-9
8-16	10-15	8-16	10-15
14-28	16-24	14-28	16-24





- DC = CTRL
- facile < difficile
- 1/2 < 2/3