Working memory capacities and learning mathematics

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A frequent difficulty : arithmetics

- In simple arithmetic, children with mathematical disability (MD)
  - produce more errors,
  - are slower,
  - use less mature strategies than controls
    - E.g. they use counting (3+5=4,5,6,7,8) when the others retrieve the answer from LTM

Fleischner et al., 82; Geary et al., 87, Geary et al. 90,

Geary's hypothesis

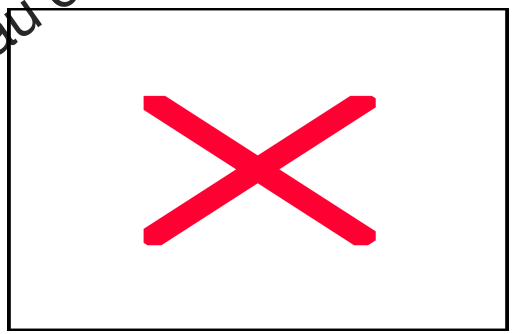
- Low WM capacities in MD children would prevent them to form AF, i.e., an association in LTM between the problem and the answer
- Condition for forming an AF: co-activation of both representations in WM
- Conditions of this co-activation
  - Addition strategy
    - 5+3=1,2,3,4,5,6,7,8
    - 5+3=6,7,8
  - WM capacities

Plan of the presentation

- Weaker WM capacities in MD
- Poor WM is associated with immature addition strategies
- Poor WM is associated with less elaborated counting string
- Weak WM capacities may lead to some arithmetical disabilities

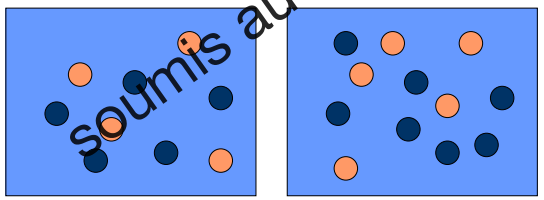
WM capacities in MD

- Lower forward digit span
  - Geary, Brown & Samaranayake (1991)
  - Hitch & McAuley (1991)



WM capacities in MD

- Weaker central executive capacities
  - Siegel & Ryan (1989)
    - counting span <
    - listening span =

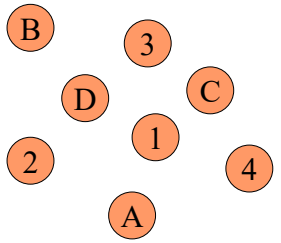


/ four five /

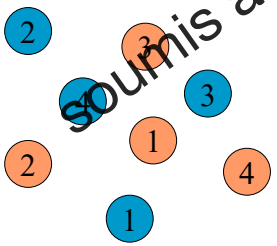
/ four / / five /

Studies controlling for reading disabilities

- Mc Lean & Hitch (1999)
  - 8-9 y.o. children: MD and controls
  - PL
    - Forward digit span: MD < controls
    - Non-word repetition: no ≠
  - VSSP
    - Corsi: MD < controls
    - Matrices: no ≠
  - CE
    - trials tests: MD < controls
    - Missing items: MD < controls

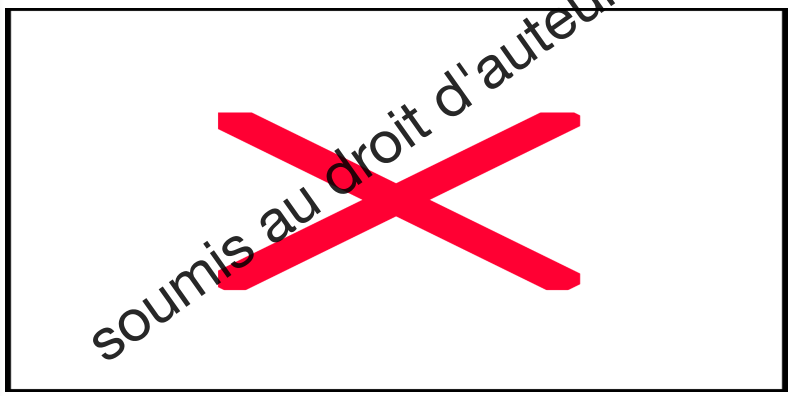


Trial tests



Missing item

2+3 = 4+? =?



Noël & Verstraete

First conclusion

- Poorer WM abilities are seen in (some) MD children (even when no reading difficulties)
  - Phonological loop
  - Visuo-spatial sketchpad
  - Central executive

WM in learning to add ?

Goal:

- Evaluate the predicting power of WM capacities (PL & CE) on addition learning
- Compare the predicting power of WM and processing speed

Noël, Seron & Trovarelly (2004)

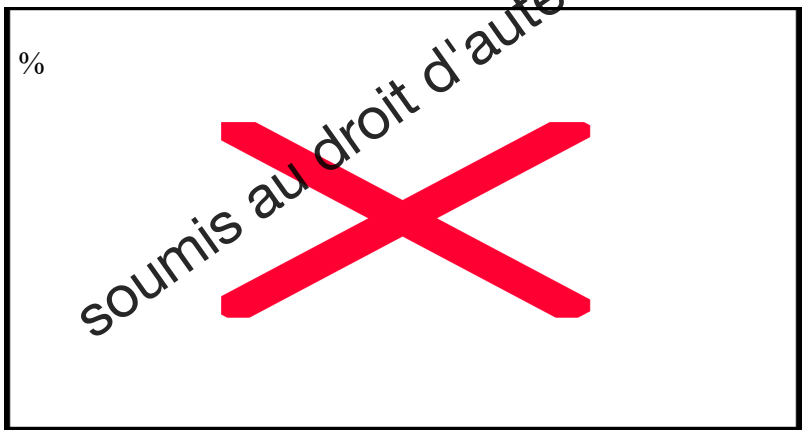
- population: 25 first-grade children (6;7 y.o.)
- November: cognitive predictors
  - PL: digit span, short-word span, long-word span, non-word repetition
  - CE: listening span
  - Processing speed: code subtest (WISC)
- March: calculation
  - 40 one-digit additions
    - algorithm :
      - Counting all: 2 + 8 = 1,2,3,4,5,6,7,8,9,10
      - Counting on: 2 + 8 = 3,4,5,6,7,8,9,10
      - Counting min: 2 + 8 = 9,10
      - Retrieval: 2 + 8 = 10
    - support : finger - verbal - mental

Results

- the general processing speed measure had no significant predicting power

: p=.05:; p=.025: **, p<.01: ***

Subgroups with low vs. high PL capacities



interpretation

- Weak WM capacities => less accurate
  - => monitoring the counting string (cfr adult studies: Healy & Nairne, 85; Logie & Baddeley, 87):
  - => monitoring the number of counting steps
- Weak WM capacities => concrete support needed to monitor the counting steps
  - => finger counting
- Weak WM capacities => less mature counting strategies
  - Why ? Immature counting string ?

WM in learning to count ?

- PL capacities have been shown to predict vocabulary acquisition
- What about the number words ?
- Particularities
  - Number words must be recited in a specific order
  - The counting string needs to be elaborated
    - *Unbreakable list*
    - *Breakable chain (start counting from n≠1)*
      - *Numerable chain (counts number words)*
      - *Bidirectional chain (recite in both directions)*

Predictions

- Phonological loop capacities are related to
  - Development of the number vocabulary
  - Development of the counting string (order)
- Central executive capacities are related to
  - The level of elaboration of the counting string
  - Ability to use counting to solve additions

Method

- Population
  - 38 4 y.o. & 42 5 y.o.
- Evaluation of
  - Counting level
  - Calculation abilities
  - WM capacities
  - Vocabulary
  - Non-verbal reasoning

Numerical measures

- Counting measures
  - Count as far as you can
  - Number fluency
  - Number decision task (*Monday four twoty)*
- Level of elaboration of the counting string
  - Counting from /up to a number
  - Counting x steps from a given number
  - Counting backwards
- Calculation
  - simple additions with the first addend drawn as a collection of items

WM measures

- Storage capacities
  - 2 short word span, nonword repetition
  - Corsi span
- Decay sensitivity
  - Nonword repetition after 5 and 10 s.
- Processing capacities
  - Short-word span in the reverse order
  - Short-word span with a categorical restitution (animals/food)

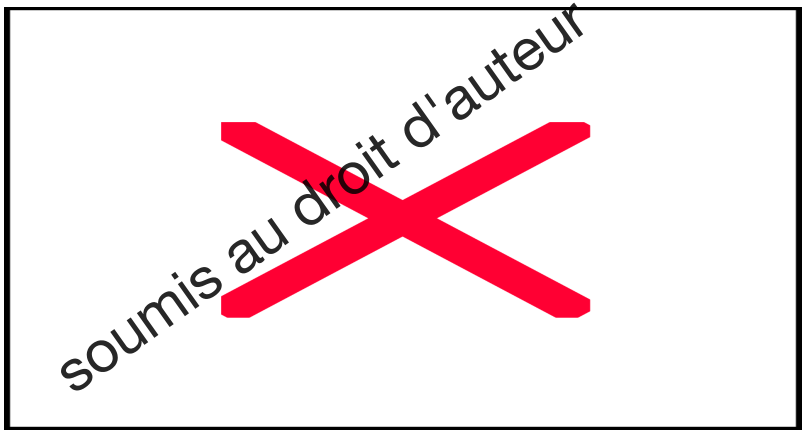
Plus

- Vocabulary: Picture naming test
- Non-verbal reasoning test: Raven colour matrices

Results

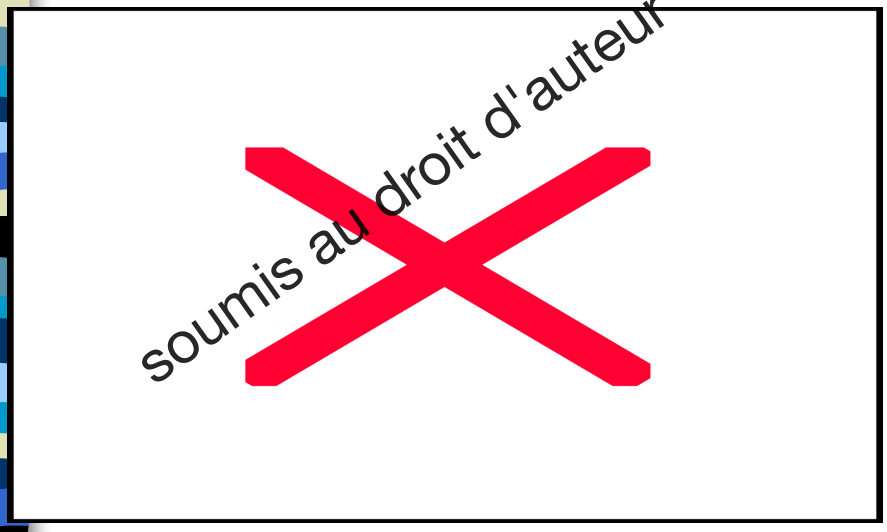
- Split of the population in two subgroups
  - Those with lower memory spans than expected for their age
  - Those with higher memory spans than expected for their age
- No significant differences when groups are based on the VSSP measure
- Significant differences when groups are based on the PL or the CE measures

Phonological loop

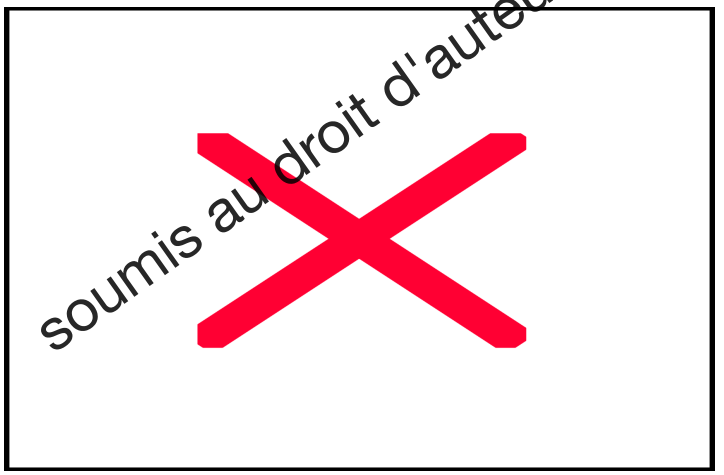


≠ for the level of elaboration and the vocabulary

Processing cost



Storage & processing



Low WM: a way to MD ?

- Weak WM capacities =>
  - Smaller number vocabulary
  - Less extended number string
  - Lower level of elaboration of the counting string
  - Less mature counting strategies in addition
  - Weaker abilities to monitor counting for calculation
  - More calculation errors
  - Use of external support
  - Poor conditions for establishing an association in LTM between a problem and the correct answer

A take-home message for policy-makers ?

- Although MD is diagnosed after at least one year of schooling, math development starts well before formal teaching of math
- Children at risk of MD could be detected in kindergarten
- preventive education programs should be introduced for those children
- But
  - Preliminary data
  - Longitudinal studies are needed
  - Considering several factors: numerical module, SES, familial comorbidity …

Thanks for your attention

WM in learning to add ?

- Geary: AF needs the coactivation of the problem & the answer in WM
- Couting speed

  5+3=4,5,6,7,8

  5+3=4...5...6...7...8
- Couting strategy

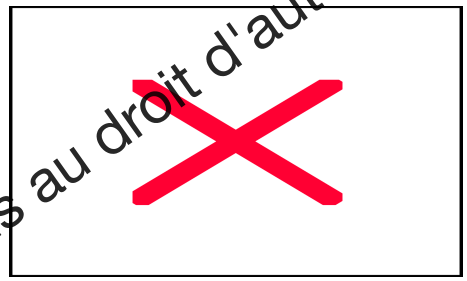
  5+3=1,2,3,4,5,6,7,8

  5+3=6,7,8
- WM capacities

- The repeated use of counting to solve a problem does not lead to the constitution of an AF (problem-answer in LTM)
  - Thevenot, Barrouillet & Fayol (2001)
    - Add: 39/16 /55=sum?/ 16 (= n1 or n2 ?)
    - Compare: 39/16/25 = between 39&16 ?/16
    - Better recognition of 16 after compare than add

Bull & Johnston (1997)

- 69 children (7 y.o.)



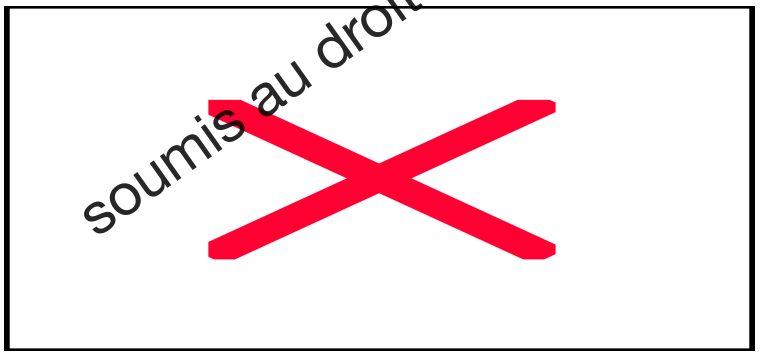
- Global correlation (WM-math) = .50
- Correlation after controling for reading = .25
- But dyslexia is often associated with dyscalculia

Hecht, Torgesen et al. (2001)

- Follow-up of children from kindergarten to 11 y;o;
- Kindergarten: evaluation of phonological capacities
  - Phonological memory tasks
    - Digit span, memory for sentences, listening span
  - Phonological analysis and synthesis
    - Phoneme elision, phoneme segmentation, sound categorisation, blending phonemes into words, blending phonemes into nonwords
  - Rate of access
    - Naming digits, letters
- General tests of reading and computational skills

Hecht, Torgesen et al. (2001): results

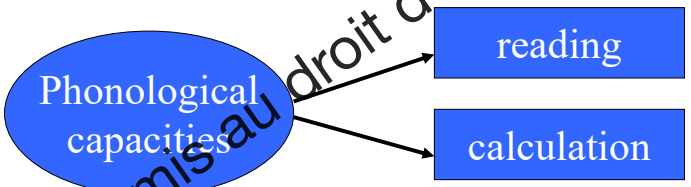
- Correlations with math performance



Role of the phonological capacities in the correlation between calculation and reading?

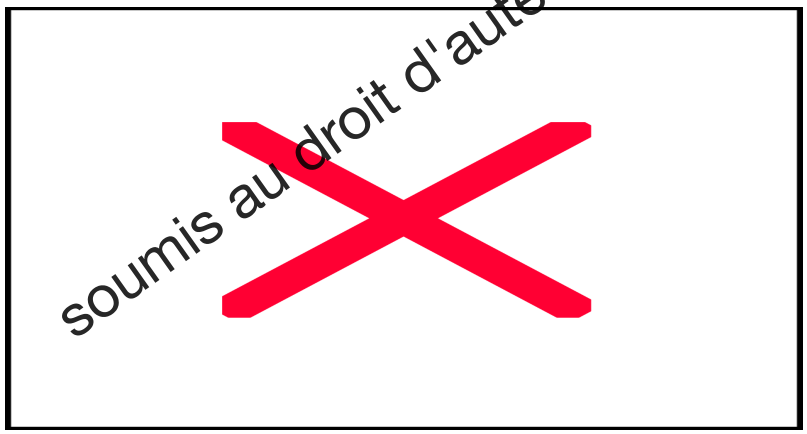
- corr (calcul - reading) .60 - .64
- corr (calcul-reading) / intelligence .41 - .54
- corr (calcul-reading) / intelligence & WM .33 - .35
- corr (calcul-reading) / intelligence & 3 phono measures .00 - .01

=> phonological capacities influence both the development in math and in reading



But by which mechanism ?

Central executive



Mean and *p* value