# When spatial difficulties affect number's representation

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## Association between spatial and numerical disabilities

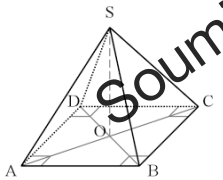
- Association between visuo-spatial abilities and math skills
  - In 400,000 high school students,
  - Spatial thinking was a better predictor of mathematics success than verbal skills.
  - Nearly all those holding a science, technology, engeneering or math PhDs were within the top 12% on spatial ability 11 years earlier (Wai, Lubinski and Benbow; 2009)
- A cognitive characteristics of children with dyscalculia
  - Low visuo-spatial short-term and working-memory (Szucs, 2013)



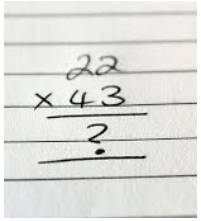


## Association between spatial and numerical disabilities

- Spatial skills are indeed necessary in math
  - For geometry
  - For understanding the place-value system of Arabic numerals
  - For dealing with multi-digit calculation in column
  - For differentiating between + and x or < and >




365
536
653

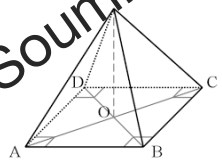


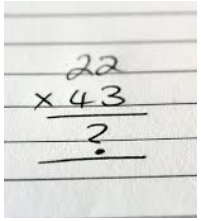





## Association between spatial and numerical disabilities

- Children with nonverbal learning deficits or visuo-sptial deficits
  - Poor performance in geometry (Mammarella et al., 2013)
  - More errors in multi-digit calculation (Venneri et al., 2003 & Mammarella et al., 2010)



# Association between spatial and numerical disabilities

- Spatial deficit leading to secondary math difficulties are called "spatial dyscalculia"
  - Violette; 10 Y;O, 4th grade; visuo-spatial deficits
    - Writing numbers under dictation:
      - Too many errors
      - Five thousand and two => 50002
      - Six thousand and forty => 600040
    - Magnitude comparison of 2 Arabic numbers
      - Confusion between < and >
      - Only 61 % C (<-2 SD)
      - E.g. 53 ... 13650:

      *« On the one hand there is 10 et 13; thus the second is bigger*
      *On the other hand there is 53 et 50 and thus the first is larger »*

    - Multi-digit calculation in column: wrong positioning
      - Align on the left rather than on the right

125
+ 3486

795
- 28



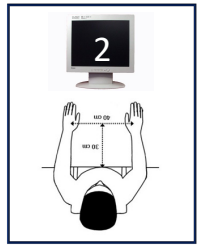


# The number magnitude representation would be coded spatially

- In number comparison:
  - A size effect:2-4 versus 6-8
  - A distance effect: 2-4 versus 2-6

  ⇒ Analog representation

- In parity judgment (and other tasks):
  - Faster answers on the
    - left side for small numbers
    - right side for large numbers








# The number magnitude representation would be coded spatially

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  - A size effect:2-4 versus 6-8

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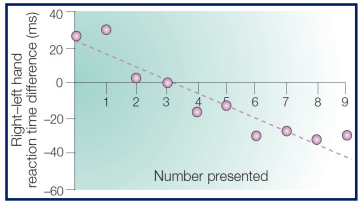
- In parity judgment
  - Faster answers on the
    - left side for small numbers
    - right side for large numbers
  - SNARC effect: spatial numerical association of response codes

  => Spatial representation

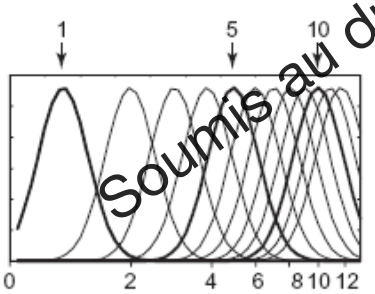







# The number magnitude representation would be coded spatially

- Idea of the mental number line



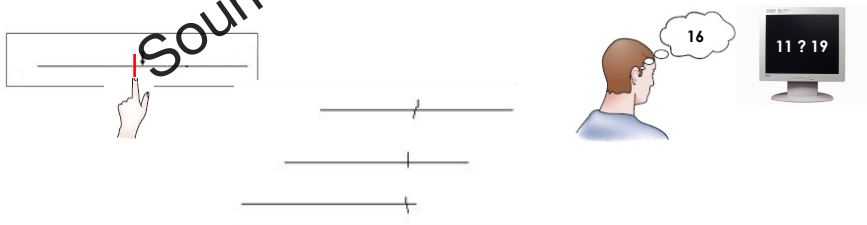

Dehaene, 1997

More precise representations of small than large numbers

Small numbers coded on the left and large numbers on the right

# The number magnitude representation would be coded spatially

- In hemineglect (e.g. Zorzi &al., 2002)
  - (often) Neglect the left portion of space
    - The left portion of a line = midpoint too much on the right
    - Midpoint of two numbers in number bisection: two verbal numbers, which one is in the middle => give too large numbers (e.g., [11-19]: answer « 16 », instead of 15)








# Hypothesis

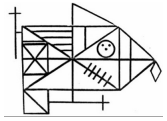
- Low visuo-spatial skills would have an impact on children's number magnitude representation
- Test this hypothesis by comparing the performance of children with typical versus low visuo-spatial skills in 3 numerical tasks
  - Number to position on a line
  - Number magnitude comparison
  - Number bisection

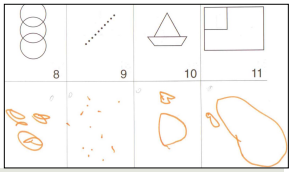




# population

- 15 children diagnosed with low visuo-spatial skills = NVLD
  - 10±2 y.o.; 6-13 y.o.
- 15 children with typical visuo-spatial skills,
  - matched on gender and age
- 7 screening tests
  - Verbal IQ:
    - Vocabulary and Similarity
  - Visuo-spatial IQ:
    - Matrix reasoning and Block design
  - Two drawing copy tests:
    - NEPSY and Rey
- The visuo-spatial questionnaire of Cornoldi







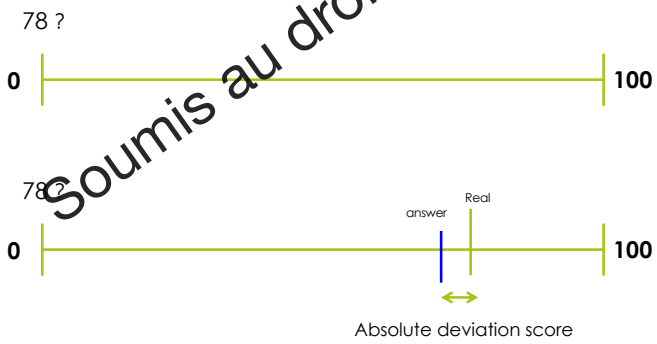



# Profile of the two groups

| | NVLD | Control | *t* |
|---|---|---|---|
| Vocabulary | 13.27 ± 3.29 | 14.13 ± 2.20 | -0.75 |
| Similarity | 13.55 ± 1.88 | 15.73 ± 1.98 | -1.71 |
| Matrix reasoning | 7.27 ± 2.93 | 12.80 ± 2.14 | -5.56** |
| Block design | 4 ± 2.49 | 13.07 ± 2.68 | -8.76** |
| NEPSY | 42.6 ± 12.59 | 59.87 ± 3.38 | -5.13** |
| Rey | 16.93 ± 2.74 | 33.33 ± 0.70 | -5.79** |
| Cornoldi | 20.7 ± 4.87 | 34.67 ± 4.48 | -7.37** |

# Task: number to position on a line

- Stimuli: 4, 8, 13, 17, 22, 26, 31, 36, 41, 45, 59, 64, 69, 74, 78, 83, 87, 92, 96

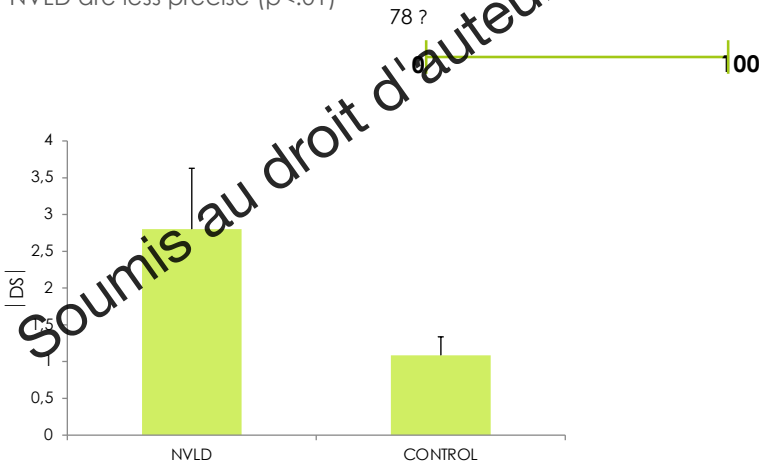







# Results: Number to position on a line

- NVLD are less precise (p<.01)



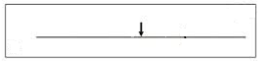





# Tasks: line and number bisection

- Line bisection
- Number bisection

18 lines of 8 or 16 cm,
In the middle, near the left / right margin



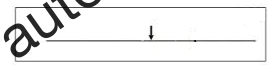

| | | Distance | |
|---|---|---|---|
| | 5 | 7 | 9 |
| Small | 9-14 | 8-15 | 9-18 |
| Medium | 29-34 | 18-25 | 18-27 |
| Large | 59-64 | 68-75 | 68-77 |

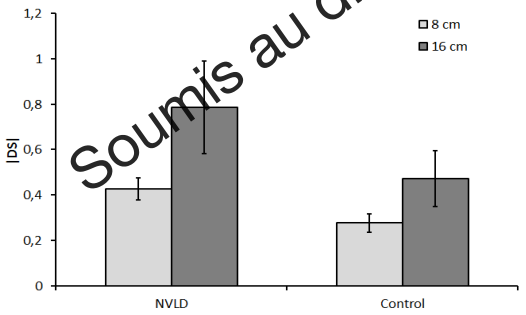




# Results: line bisection

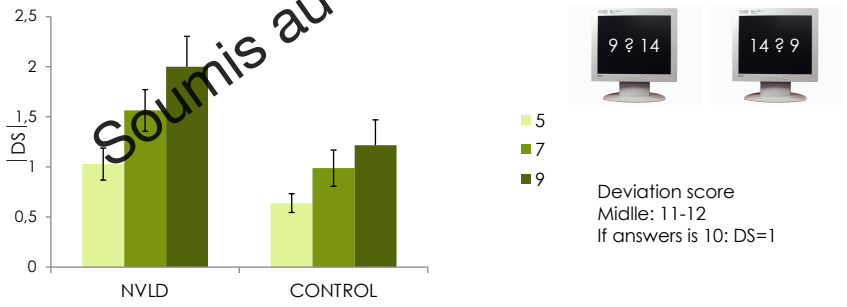
- Absolute deviation score
- Length effect, no group effect





# Results: number bisection

- 5 NVLD children excluded because too much answers outside the interval; for the others 17% of answers outside the interval (<1% for the control children)
- Distance effect (less precise if larger distance)
- NVLD are less accurate ($p<.05$)







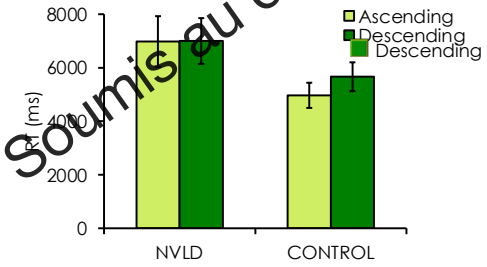
Deviation score
Midlle: 11-12
If answers is 10: DS=1





# Results: number bisection

- Order effect in controls (ascending order 9-14 is faster than descending order (14-9)
- No order effect in NVLD

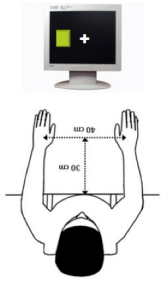







# Tasks: Simon and SNARC

## Simon task



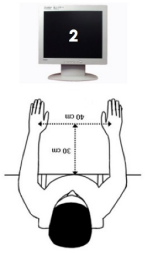
If green, press left
If red, press right

⇒ Spatial compatibility
⇒ Easier to press left when green square appears on the left rather than on the right

## Number comparison

Condition 1
If < 5, press left
If > 5, press right

Condition 2
If < 5, press right
If > 5, press left



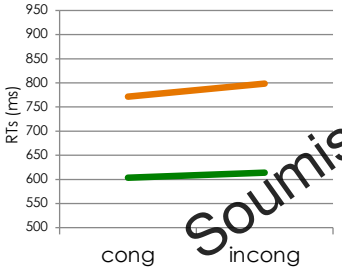

⇒ SNARC effect?
⇒ Easier to answer left for small numbers and right to large numbers ?

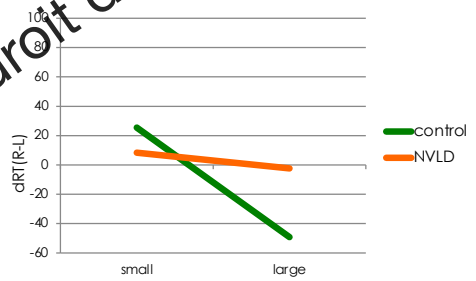




# Results: Simon and SNARC

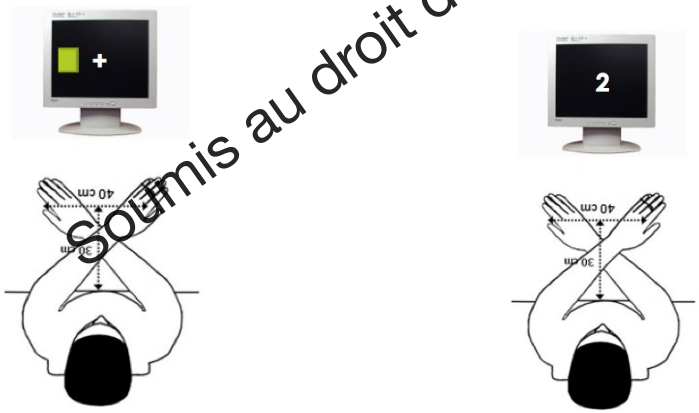
- Simon tasks
  - Congruity effect for both groups
  - NVLD slower
- SNARC
  - SNARC effect in the control ($p<.05$) but not in the NVLD group ($p>.1$)



# Tasks: Crossed hand-position

- Is it a space representation centred on the body or on the external space ?

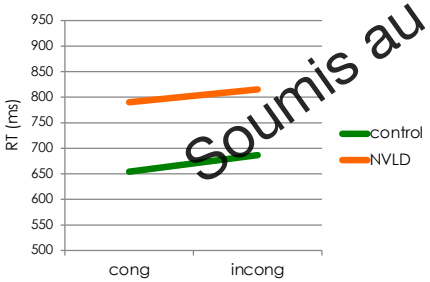


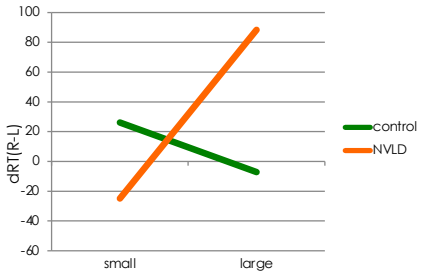





# Results: Crossed-hand position

- Simon tasks
  - Congruity effect for both groups
- SNARC
  - SNARC effect in the control (p<.05) but not in the NVLD group (reverse direction)








# Task: number comparison

- Controls were more accurate than NVLD (96% - 91%)
- Controls are faster than NVLD
- Global distance effect (faster responses if larger distance)
- Larger distance effect in NVLD than controls

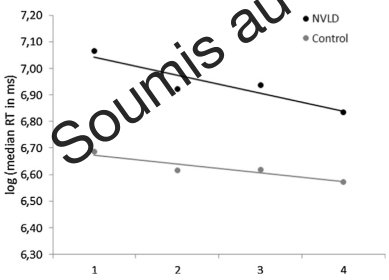


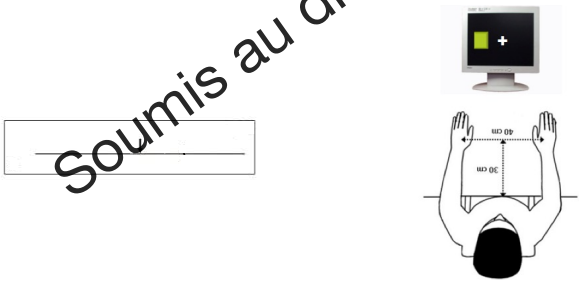

Fig. 4. Distance effect in the numerical comparison task.





# Conclusion - discussion

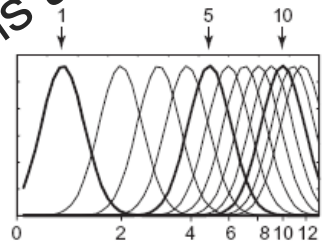
- NVLD children performed as well as controls in
  - A simple spatial task: line bisection
  - The Simon task, same spatial constructed effect independent of effectors (normal or crossed hand condition)



# Conclusion - Discussion

- NVLD children performed more poorly than controls
  - In positioning numbers on a line: less precise
  - In number bisection: less accurate, more aberrant answers,
  - In number comparison: slower, less accurate, larger distance effect,

  ⇒ **less precise number magnitude representation**



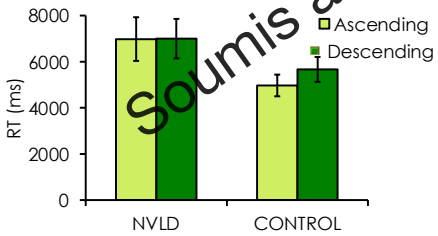




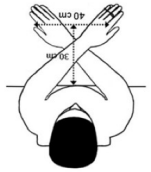

# Conclusion - Discussion

- In number bisection: no order effect
- In number comparison: no SNARC effect

**=> disturbed spatial orientation of the mental number line or less salient left-right orientation of the mental number line**












# Conclusion - Discussion

- Spatial disability would induce difficulties
  - in numerical tasks that require explicit spatial processing (e.g., placing numbers on a line),
  - In tasks that require to manipulate the number magnitude representation itself, even if the task does not require any spatial processing





# Thanks to....

**UCL (LLN)**

Virginie Crollen
Camille Vanderclausen

**ADAPT (Paris)**

Florence Allaire

FNRS

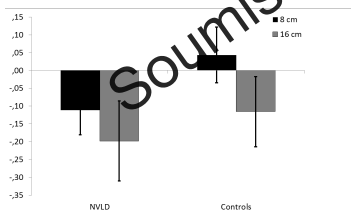


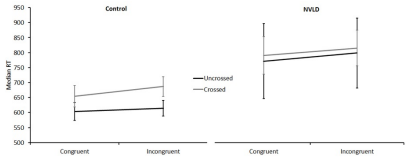
# Thanks for your attention !

## Conclusions

- Moindre précision dans les tâches spatiales & numériques

- Présence de la pseudo-négligence et de l'effet Simon



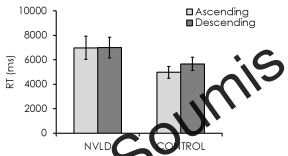


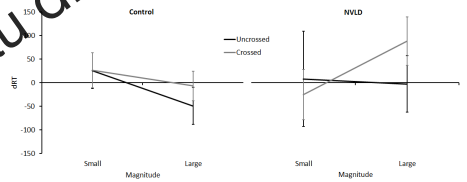





## Conclusions

- Absence de l'effet SNARC et de l'effet d'ordre




- Orientation G-D de la ligne numérique mentale moins saillante?

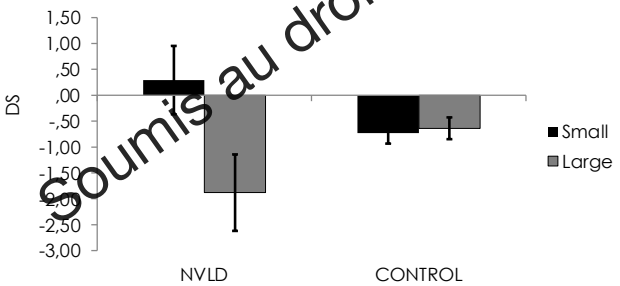






- **Placement de nombres**

- Pseudo-négligence dans les 2 groupes



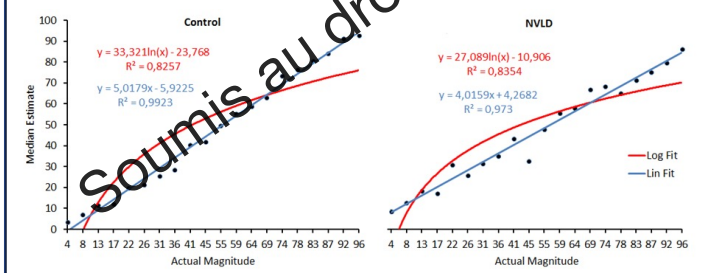






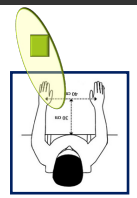

- **Placement de nombres**

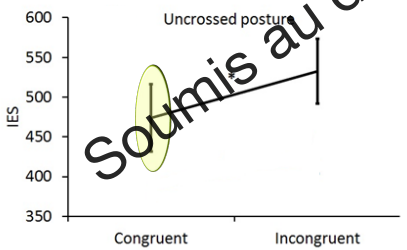
- Ligne numérique linéaire > logarithmique



# Simon tasks

Press left when green





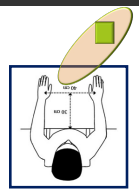

Congruent when green appears on the left or red on the right

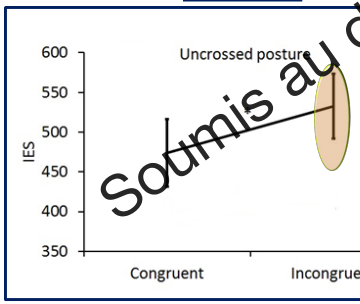




# Simon tasks

Press left when green



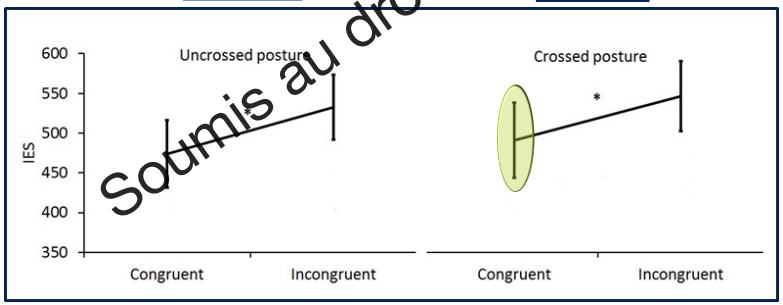



Incongruent when green appears on the right or red on the left





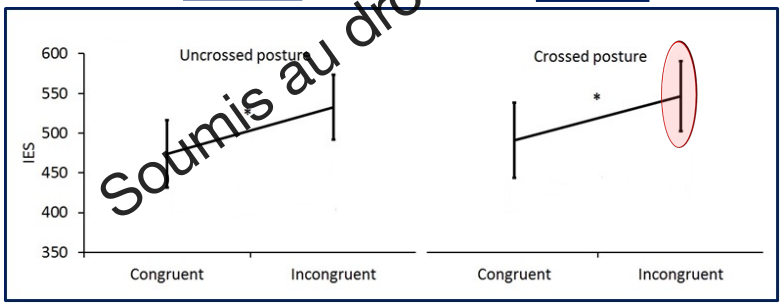




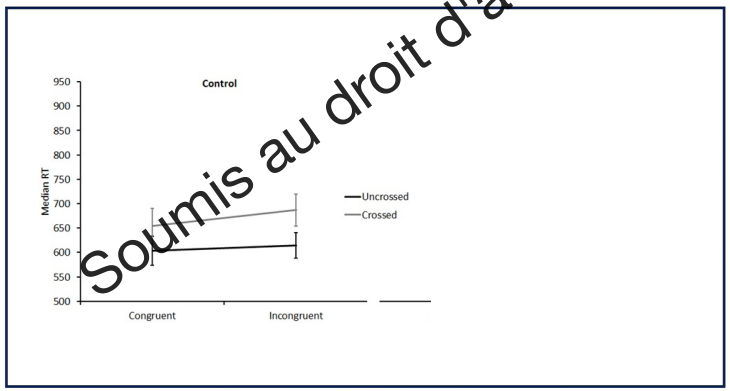






- **Tâche Simon**

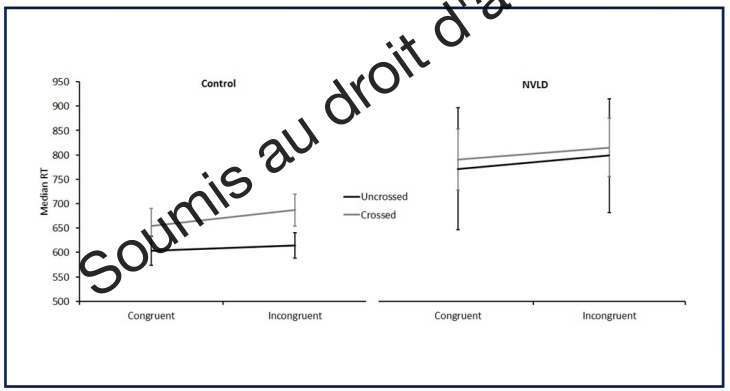







Introduction Méthode & Résultats Conclusions

- **Tâche Simon**








Introduction Méthode & Résultats Conclusions

- **Comparaison de nombres**