

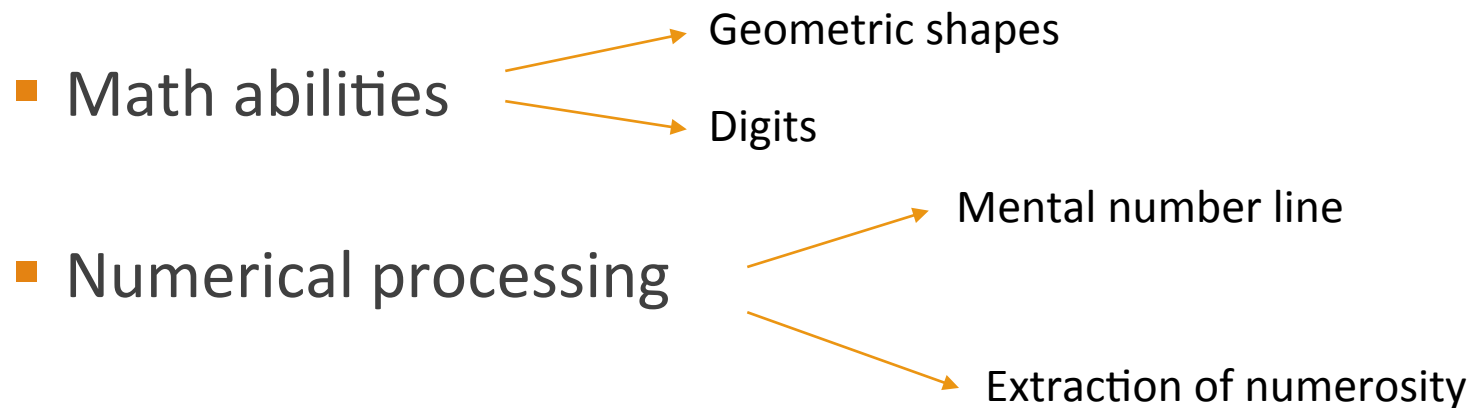
The implication of short-term memory in numerical magnitude processing: evidence from Turner syndrome

Lucie Attout, Marie-Pascale Noël, & Laurence Rousselle

The problem

2 important general factors in math achievement :

- Visuo-spatial skills



The problem



Halberda and colleagues

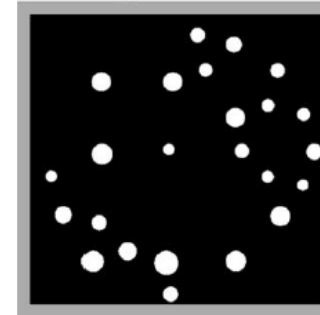
To assess magnitude representation

- Visual modality ++

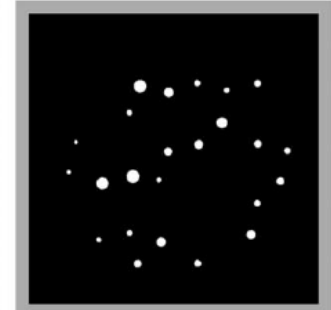
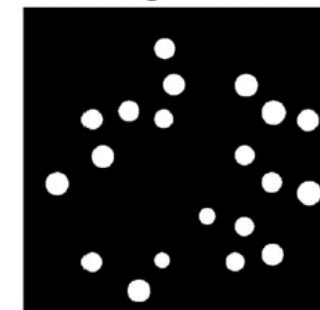
→ Requires visuo-spatial skills

→ Bidirectionnal influence

c3: congruent trial



c3: incongruent trial



Gebuis & Reynvoet (2012)

The problem

2 important general factors in math achievement :

- Visuo-spatial skills
- **STM abilities**

- Math abilities : simple calculation

- Numerical processing :

no direct evidence

Process numerosity
(Accumulator model; Gelman &
Gallistel, 1978)

Important role of WM in the
number space association (Van Dijck
& Fias, 2009; Herrera et al., 2008)

The problem

- **Visuo-spatial skills**
- **STM abilities**

→ mathematical achievement

→ numerical processing

→ Importance of these two factors when assessing basic numerical processing



The problem

Turner syndrome (female XO)

- IQ discrepancy (verbal > visuo-spatial)
- Visuo-perceptual deficit
- WM (verbal and VS) deficit
- Mathematical disabilities :
 - AF vs. procedural calculation
 - counting skills vs. subitizing
 - continuous magnitude processing (length judgment)

The present study

→ Studies on early magnitude representation have focused on the visual modality with no possibility of disentangling the influence of VS skills and STM abilities on quantification processes.

Aim : To explore the basic quantitative processes by varying STM and VS requirement in adults with Turner syndrome



Methodology

Population : 20 females with Turner syndrome (7-33 years) ($18;5 \pm 7;5$ years)
20 healthy participants matched on age, educational level, and IQ

Tasks:

- Math abilities : Fluency tasks (simple addition, subtraction, multiplication and complex calculation)

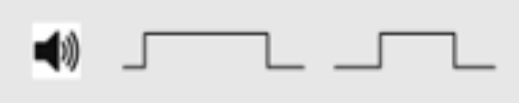

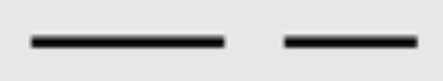


- WM components:

- Verbal WM : Catego span task
- Verbal STM : letter span task
- VS STM : // Corsi task

Methodology





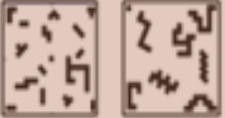
Tasks:

- Non-symbolic magnitude comparison tasks

Continuous quantities	Discrete quantities
<p data-bbox="607 879 819 922">Durations</p> 	<p data-bbox="1330 879 1787 922">Sequences of sounds</p> 
<p data-bbox="629 1098 797 1141">Lengths</p> 	<p data-bbox="1274 1098 1839 1141">Sequences of flashed dots</p>  <p data-bbox="1442 1289 1675 1332">Collections</p> 

Methodology

- Non-symbolic magnitude comparison tasks : modality (V-S requirement)

Continuous quantities	Discrete quantities
<p data-bbox="607 874 819 916">Durations</p> 	<p data-bbox="1332 874 1787 916">Sequences of sounds</p> 
<p data-bbox="629 1091 797 1133">Lengths</p> 	<p data-bbox="1279 1091 1839 1133">Sequences of flashed dots</p>  <p data-bbox="1442 1283 1675 1324">Collections</p> 

Methodology

- Non-symbolic magnitude comparison tasks : presentation mode (STM load)

Accumulation and maintenance of the elements

Continuous quantities

Durations



Lengths



Discrete quantities

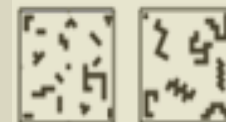
Sequences of sounds



Sequences of flashed dots



Collections



Methodology

Non-symbolic magnitude comparison tasks:

For each task, several ratios were used :

$1/2, 2/3, 3/4, 5/6, 7/8, 8/9$

→ to appreciate the precision of the magnitude representation

Results

Global profile :

	TS group		C group			
	Mean	SD	Mean	SD	t	P
Age (months)	219.20	87.09	219.75	91.75	-0.21	0.83
IQ measures						
Vocabulary (max. 68)	32.85	11.08	33.90	10.21	-1.57	0.13
Similarities (max. 44)	20.15	6.12	20.35	6.11	-0.45	0.66
Block design (max. 68)	35.40	11.50	42.45	10.07	-3.45	0.003
Picture concepts (max. 28)	17.45	4.32	18.70	2.92	-1.70	0.11

Results

Global profile :

	TS group		C group			
	Mean	SD	Mean	SD	t	P
Working memory						
Visuo-spatial sketchpad (max. 42)	35.15	7.00	38.75	5.54	-2.52	0.02
Phonological loop (max. 16)	7.70	1.63	9.00	2.29	-2.80	0.01
Central executive (max. 16)	6.75	1.86	7.25	2.20	-0.85	0.41

Results

Global profile :

	TS group		C group			
	Mean	SD	Mean	SD	t	P
Mathematical fluency						
Addition (ACC) (max. 81)	42.55	23.51	49.95	23.53	-1.90	0.07
Subtraction (ACC) (max. 81)	33.75	20.19	40.00	18.32	-2.01	0.06
Multiplication (ACC) (max. 81)	25.05	17.18	34.50	16.21	-2.74	0.01
Complex arithmetic (ACC) (max. 36)	10.71	5.02	13.65	5.29	-2.53	0.02
Counting speed (ms/item)	437.83	151.26	433.20	113.70	0.14	0.89
Speed processing (ms)	567.62	98.11	565.40	95.28	0.08	0.94

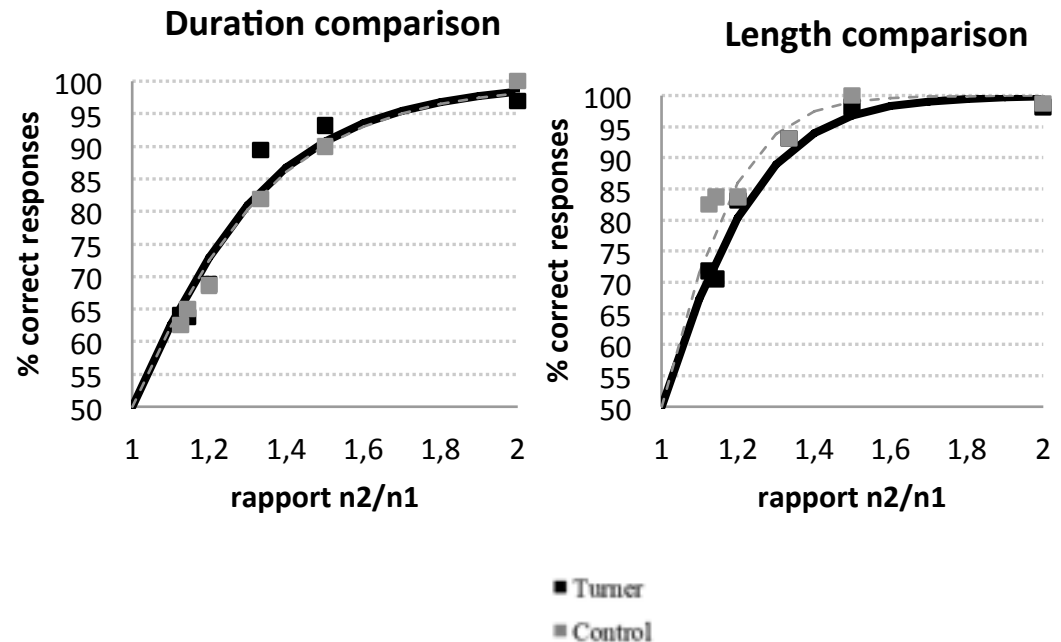
Results

Weber fraction

Ancova on continuous magnitude processing :

2 (group) x 2 (length vs. duration)

- **Task effect** ($F(1,37) = 8.88$, $\eta^2 = .19$, $p < .01$) (higher sensitivity length > duration)
- No Group effect ($F(1,37) = 0.38$, $\eta^2 = .01$, $p = .54$)
- No Interaction effect ($F(1,37) = 0.72$, $\eta^2 = .02$, $p = .40$)



Results

Weber fraction

Ancova on discrete magnitude processing :

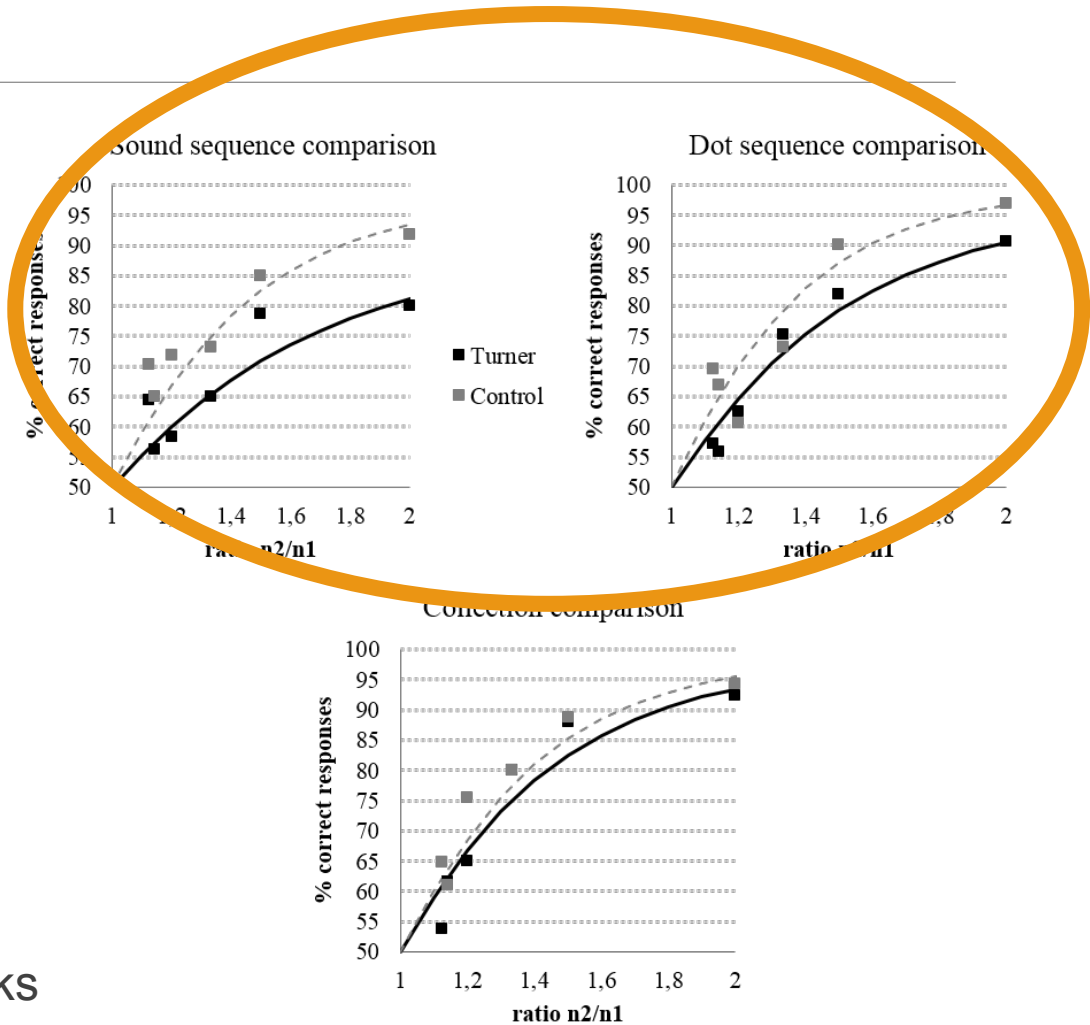
2 (group) x 3 (collection vs. dot sequence vs. sound sequence)

→ No task effect ($F(2,74) = 0.91$, $\eta^2 = .02$, $p = .41$)

→ Group effect ($F(1,37) = 8.71$, $\eta^2 = .19$, $p < .01$)

→ Interaction effect ($F(2,74) = 3.25$, $\eta^2 = .08$, $p < .05$)

Pot-hoc analysis : lower level of precision for TS in 2 sequential tasks



hierarchical regression analysis

Measures	DR ²	B	t(38)	p
Dependent variable	Dot sequence comparison (w)			
1. Age	0.08	-0.28	-1.80	0.08
2. Verbal WM	0.00	-0.02	-0.09	0.93
3. Visuo-spatial STM	0.07	-0.27	-1.61	0.12
4. Verbal STM	0.06	-0.22	-1.13	0.27
5. Group	0.03	-0.23	-1.36	0.18
Dependent variable	Sound sequence comparison (w)			
1. Age	0.05	-0.22	-1.41	0.17
2. Verbal WM	0.12	-0.41*	-2.27	0.03
3. Visuo-spatial STM	0.15	-0.45*	-2.83	0.00
4. Verbal STM	0.05	-0.34	-1.70	0.10
5. Group	0.04	-0.23	-1.56	0.13



hierarchical regression analysis

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5. Group	0.04	-0.23	-1.56	0.13

→ differences between groups in sequential numerical tasks were mostly due to the difference observed in STM tasks

Discussion

VS skills?

- No influence of VS skills in Turner syndrome
 - Length and collection comparison tasks OK
 - This is not the case in other syndromes (Rousselle et al., 2013; Attout et al. in progress) and developmental disorders (Crollen & Noël, 2015)
 - Effect of age and IQ level ?

Discussion

STM abilities?

- Specific impact of the presentation mode on performance : sequential vs. simultaneous
 - Not consistent with a general magnitude representation (Barth et al., 2005; Walsh, 2003)
 - Support behavioral and neuroimaging evidence (Dormal et al., 2010; 2012; Nieder et al., 2006; Tokita & Ishiguchi, 2012; Benoit et al., 2004)
- numerosity was processed independently in function of the presentation, simultaneous or sequential.

Discussion

- Implication to understanding numerical magnitude representation
- Implication in the methodology to assess the magnitude representation

Thank you for your attention



Results

Ancova on RTs

Continuous magnitude comparison tasks:

Task effect ($F(1,37) = 19.72, \eta^2 = .35, p < .001$), the length comparison (mean = 1286.86 ± 698.67 ms) being faster than the duration comparison (mean = 1985 ± 406.97 ms).

no group effect ($F(1,37) = 2.57, \eta^2 = .06, p = .12$) or interaction ($F(1,37) = 0.33, \eta^2 = .01, p = .57$).

Discrete magnitude comparison:

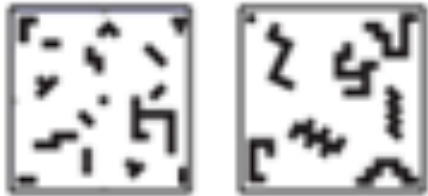
effect of task ($F(2,70) = 69.32, \eta^2 = .65, p < .001$), with faster reaction times for processing the magnitude of simultaneously presented collections (mean = 1562.16 ± 705.56 ms) as compared to the two sequential tasks (dot sequence: mean = 4413.22 ± 516.97 ms; sound sequence: mean = 4376.42 ± 713.98 ms). → This result is of course expected and rather trivial as the RT is recorded from the time when the second stimuli appeared, the numerosities therefore varying RTs.

No group effect ($F(1,35) = 1.54, \eta^2 = .04, p = .22$) and no interaction ($F(2,70) = 1, \eta^2 = .03, p = .37$)

Results

- arithmetic score correlated significantly with both STM abilities, verbal ($r_{(38)}=.57$, $p<.001$) and visuo-spatial ($r_{(38)}=.59$, $p<.001$) and verbal WM ($r_{(38)}=.40$, $p<.05$).
- arithmetic score correlated significantly with some non-symbolic comparison tasks (duration: $r_{(38)}= -.34$, $p<.05$; sound sequence: $r_{(38)}= -.60$, $p<.001$)
- but not with length ($r_{(38)}= -.24$, $p=.14$), collection ($r_{(38)}= -.19$, $p=.24$) and dot sequence ($r_{(38)}= -.27$, $p=.10$) comparison tasks.

Collection comparison tasks



Controlling for :

- Cumulative surface area and perimeter of pieces
- External perimeter