PHONOLOGICAL SHORT-TERM MEMORY FUNCTIONING IN DOWN'S SYNDROME: IMPLICATION FOR THE WORKING MEMORY MODEL

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INTRODUCTION:

What do we know about phonological STM in Down's syndrome subjects ?

- *Phonological short-term memory abilities are lower that the one expected regarding mental age and chronological age* (see, for example, Bilovsky & Share, 1965; Broadley & MacDonald, 1994; Broadley, MacDonald & Buckley, 1995; Comblain, 1996a; Marcell, Harvey, & Cothran, 1988; Mackenzie et Hulme, 1987; Hulme et Mackenzie, 1992; Marcell & Armstrong, 1982; Marcell & Weeks, 1988).

What do we know about short-term memory span development in Down's syndrome subjects ?

- See *Mackenzie & Hulme (1987)* and *Hulme & Mackenzie (1992)*: They conducted a longitudinal study on DS and non-DS mentally retarded subjects and in normally developing children.

  * 2 years after the first memory assessment:

    ° No significant progress in mentally retarded subjects' verbal short-term memory performances (DS and non-DS).

    ° Significant progress in verbal normal children verbal short-term memory performances.

  * 5 years after the first memory assessment:

    ° Significant progress in mentally retarded subjects' verbal short-term memory performances (DS and non-DS).

    ° Significant progress in verbal normal children verbal short-term memory performances.

- *Short-term memory development of mentally retarded subjects do not proceed at the expected rate regarding their mental age*.

What do we know about the articulatory loop functioning in Down's syndrome subjects ?

- *Hulme & Mackenzie (1992)*:

* Down's syndrome subjects are not sensitive to the word-length effect → this is due to the absence of rehearsal in DS subjects → DS subjects cannot use efficiently their articulatory loop.

* Down's syndrome subjects are sensitive to the phonological similarity effect but the size of the effect is inferior to the size of the same effect in normally developing children.

- *Broadley, MacDonald & Buckley (1995)*:

* Down's syndrome subjects are sensitive to the word-length effect

* Down's syndrome subjects are sensitive to the phonological similarity effect

→ According to *Baddeley (1986)* the presence of these two effects suggests that Down's syndrome subjects do possess a phonological store and that they are able to use a rehearsal process allowing the information storage and recall.

□ We propose 4 experiments in order to precise the development of phonological short-term memory and the functioning of the phonological store in Down's syndrome subjects.

EXPERIMENT 1: What about the improvement of the short-term memory span in DS subjects according to the mental age (MA) and the chronological age (CA) ?

SUBJECTS: ° 43 Down's syndrome subjects → CA: 6;10 years-old to 42;10 years-old (mean: 19;8 years-old).
MA: 3;2 years-old to 7;8 years-old (mean 4;4 years old).
° 50 non-retarded subjects → CA: 3;9 years-old to 48 years-old (mean 15;11 years old).

TASKS ° Digit span
° Letter span
° Phonologically dissimilar word span
° Phonologically similar word span
° Long word span

RESULTS:

Table 1a. Mean digit span, letter span, and word span in DS subjects according to their CA.

	Digits	Letters	Phonologically dissimilar words	Phonologically similar words	Long words
< 9 years-old	1.18	1.20	1.60	1.00	0.00
9-12;11 years-old	2.16	1.33	1.38	1.00	0.67
13-16;11 years-old	2.71	2.14	2.57	1.43	1.57
17-20;11 years-old	2.57	2.14	2.29	1.29	1.29
21-29;11 years-old	2.25	1.92	2.08	1.42	1.17
> 30 years-old	1.83	1.67	2.00	1.50	1.17

Table 1b. Mean digit span, letter span, and word span in normal subjects according to their CA

	Digits	**Letters**	**Phonologically dissimilar words**	**Phonologically similar words**	**Long words**
< 8 years-old	3.73	2.13	3.19	2.50	2.25
8-12;11 years-old	5.91	4.64	4.73	4.09	3.55
16-20;11 years-old	6.18	5.18	5.09	5.09	4.64
21-29;11 years-old	5.36	5.63	5.82	5.27	4.45
> 40 years-old	5.67	5.33	4.67	4.00	4.33

→ DS short-term memory span is very poor (at the 5 memory tasks).

→ Contrarily to normal subjects memory span, DS subjects' memory span does not seem to improve significantly with CA.

Table 2a. Correlations between CA and short-term memory span in normal subjects.

	Digits	**Letters**	**Phonologically dissimilar words**	**Phonologically similar words**	**Long words**
Chronological age	0.31**	0.53**	0.34**	0.41**	0.56**

* = significant at p<0.05, ** = significant at p<0.01

Table 2b. Correlations between CA, MA and short-term memory span in DS subjects.

	Digits	**Letters**	**Phonologically dissimilar words**	**Phonologically similar words**	**Long words**
Chronological age	- 0.10	0.09	0.02	0.12	0.04
Mental age	0.67**	0.72**	0.51**	0.40**	0.35*

* = significant at p<0.05, ** = significant at p<0.01

- *DS subjects' memory performances do not exceed the one of normally developing children aged 3 years-old to 7;11 years-old.*
- *Short-term memory span of normally developing children improves with CA. Short-term memory span of DS subjects does not significantly improve with CA.*
- *Improvement of DS subjects short-term memory span is strongly linked to MA.*

EXPERIMENT 2: Are DS subjects sensitive to the phonological similarity effect ? If this effect is present, is it more or less important according to the mental age (MA) and the chronological age (CA) of the subjects ?

SUBJECTS: ° 43 Down's syndrome subjects → CA: 6;10 years-old to 42;10 years-old (mean: 19;8 years-old).
MA: 3;2 years-old to 7;8 years-old (mean 4;4 years old).

TASKS: ° Phonologically dissimilar word span ° Phonologically similar word span

RESULTS:

Table 3. Mean phonologically similar and dissimilar word span (standard deviation) in DS subjects according to their CA.

	Children (N=11) 6;10 - 12;10 years-old	**Adolescents (N=15)** 14;5 - 21;8 years-old	**Adults (N=17)** 22;1 - 41;10 years-old
Phonologically dissimilar word span	1.73 (0.47)	2.47 (0.52)	2.00 (0.79)
Phonologically similar word span	1.00 (0.77)	1.40 (0.91)	1.41 (0.71)

ANOVA between-within: phonological similarity (2 levels: similar words, dissimilar words) x CA sub-groups (3 levels: children, adolescents, adults):

1] No main effect of CA: $F(2,40) = 2.42$, $p=0.1$, NS

2] Main effect of phonological similarity: $F(1,40) = 68.86$, $p<0.0001$

mean phonologically dissimilar word span: 2.09 (standard deviation: 0.68)

mean phonologically similar word span: 1.30 (standard deviation: 0.80)

3] No interaction between CA and phonological similarity: $F(2,40) = 2.47$, $p=0.097$, NS

Table 4. Mean phonologically similar and dissimilar word span (standard deviation) in DS subjects according to their MA.

	Group 1 (N=19) 3;0 - 3;11 years-old	**Group 2 (N=12)** 4;0 - 4;11 years-old	**Group 3 (N=12)** > 5;0 years-old
Phonologically dissimilar word span	1.89 (0.57)	2.33 (0.78)	2.17 (0.72)
Phonologically similar word span	1.21 (0.71)	1.17 (0.94)	1.58 (0.79)

ANOVA between-within: phonological similarity (2 levels: similar words, dissimilar words) x MA sub-groups (3 levels: group 1, group 2, group 3):

1] No main effect of MA: $F(2,40) = 0.89$, $p=0.42$, NS

2] Main effect of phonological similarity: $F(1,40) = 73.58$, $p<0.0001$

mean phonologically dissimilar word span: 2.09 (standard deviation: 0.68)

mean phonologically similar word span: 1.30 (standard deviation: 0.80)

3] Significant interaction between MA and phonological similarity: $F(2,40) = 3.31$, $p<0.05$

→ *Newman-Keuls a posteriori test*: ° Phonologically dissimilar word span: group 2 > group 1 ($p<0.01$)

° Phonologically similar word span: group 3 > group 1 and group 2

→ for the three groups phonologically dissimilar word span > phonologically similar word span

(differences between means → group 1: 0.68, group 2: 1.16, group 3: 0.59).

- *DS subjects are sensitive to the phonological similarity effect (with no influence of CA or MA) → = Broadley & al. (1995) and Hulme & Mackenzie (1992)*
- *Contrarily to what is observed in normally developing children, the size of the effect does not seems to increase with CA (or with MA).*

EXPERIMENT 3: Are DS subjects sensitive to the word-length effect ? If this effect is present, is it more or less important according to the mental age (MA) and the chronological age (CA) of the subjects ?

SUBJECTS: ° 43 Down's syndrome subjects → CA: 6;10 years-old to 42;10 years-old (mean: 19;8 years-old).
MA: 3;2 years-old to 7;8 years-old (mean 4;4 years old).

TASKS: ° Short word span ° Long word span

RESULTS:

Tableau 5. Mean short and long word span (standard deviation) in DS subjects according to their CA.

	Children 6;10 - 12;10 years-old	**Adolescents** 14;5 - 21;8 years-old	**Adults** 22;1 - 41;10 years-old
Short word span	1.73 (0.47)	2.47 (0.52)	2.00 (0.79)
Long word span	0.36 (0.67)	1.40 (0.63)	1.18 (0.95)

ANOVA between-within: word-length (2 levels: short words, long words) x CA sub-groups (3 levels: children, adolescents, adults):

1] Main effect of CA: $F(2,40) = 6.16$, $p<0.005$

children mean word span: 1.05 (sd: 0.90)

adolescents mean word span: 1.93 (sd: 0.78)

adults mean word span: 1.49 (sd: 0.96)

→ *Newman-Keuls a posteriori test*: ° adolescents and adults > children

° no significant difference between adolescents and adults

2] Main effect of phonological similarity: $F(1,40) = 122.7$, $p<0.0001$

mean short word span: 2.09 (sd: 0.68)

mean long word span: 1.05 (sd: 0.87)

3] No interaction between CA and word length effect: $F(2,40) = 2.45$, $p=0.098$, NS

Table 6. Mean short and long word span (standard deviation) in DS subjects according to their MA.

	Group 1 3;0 - 3;11 years-old	**Group 2** 4;0 - 4;11 years-old	**Group 3** > 5;0 years-old
Short word span	1.89 (0.57)	2.33 (0.78)	2.17 (0.72)
Long word span	0.89 (0.99)	1.08 (0.67)	1.25 (0.87)

ANOVA between-within: word length (2 levels: short words, long words) x MA sub-groups (3 levels: group 1, group 2, group 3):

1] No main effect of MA: $F(2,40) = 1.03$, $p=0.36$, NS

2] Main effect of word length: $F(1,40) = 106.55$, $p<0.0001$

mean short word span: 2.09 (sd: 0.68)

mean long word span: 1.07 (sd: 0.87)

3] No interaction between MA and word length: $F(2,40) = 0.86$, $p=0.43$, NS

 DS subjects are sensitive to the word length effect (with no influence of CA or MA) → = Broadley & al. (1995), ≠ Hulme & Mackenzie (1992)

EXPERIMENT 4: Is there a relationship between articulatory rate and short-term memory span in DS subjects? (experiments with young normally developing children show the presence of a strong word-length effect without a relationship between articulatory rate and short-term memory span).

SUBJECTS: ° 43 Down's syndrome subjects → CA: 6;10 years-old to 42;10 years-old (mean: 19;8 years-old).
MA: 3;2 years-old to 7;8 years-old (mean 4;4 years old).

TASKS ° Digit span ° Letter span
° Familiar word span ° Mean span: mean of the three preceding measures
° Articulation rate: articulate as fast as possible the word "bigoudi" (10 times)
° Non-verbal intelligence test: Progressive Color Matrix (Raven, 1965)

RESULTS:

Table 7. Correlations between short-term memory span, articulation rate, non-verbal intelligence and CA in DS subjects.

	1	2	3	4	5	6	7
1. Digit span	1.00						
2. Word span	0.70**	1.00					
3. Letter span	0.63**	0.63**	1.00				
4. Mean span	0.89**	0.88**	0.86**	1.00			
5. Articulation rate	**0.37***	**0.21**	**0.31***	**0.34***	**1.00**		
6. Non-verbal intelligence	0.53**	0.41**	0.52**	0.56**	0.39**	1.00	
7. Chronological age	- 0.1	0.02	0.09	0.004	- 0.16	- 0.22	1.00

* = significant at p<0.05, ** = significant at p<0.01

→ *significant correlations between the 4 memory measures (p<0.0001).*

→ *significant correlation between 3 memory measures and the articulation rate ($p<0.05$).*

→ *significant correlation between memory measure and non-verbal intelligence and between the articulation rate and non-verbal intelligence.*

→ ***What happens when we look at the subjects performances according to their non-verbal intelligence level (< 4 years-old, 4 years-old to 4;11 years old, 5 years-old to 5;11 years old, > 6 years-old) ?***

Table 8. Correlations between short-term memory span, articulation rate, non-verbal intelligence and CA in DS subjects.

	Non verbal MA < 4 years-old	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1.	Digit span	1.00						
2.	Word span	0.92**	1.00					
3.	Letter span	0.33	0.38	1.00				
4.	Mean span	0.91**	0.93**	0.67**	1.00			
5.	**Articulation rate**	**0.02**	**0.12**	**- 0.33**	**-. 007**	**1.00**		
6.	Non-verbal intelligence	0.22	0.26	0.70**	0.46	- 0.03	1.00	
7.	Chronological age	- 0.15	- 0.004	0.02	- 0.07	0.02	- 0.38	1.00

	Non verbal MA: 4;0 to 4;11 years-old	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1.	Digit span	1.00						
2.	Word span	0.52	1.00					
3.	Letter span	0.24	0.63*	1.00				
4.	Mean span	0.75**	0.90**	0.74**	1.00			
5.	**Articulation rate**	**0.21**	**- 0.11**	**0.16**	**0.10**	**1.00**		
6.	Non-verbal intelligence	0.52	0.00	- 0.52	- 0.006	- 0.14	1.00	
7.	Chronological age	- 0.46	- 0.08	0.16	- 0.18	- 0.26	- 0.30	1.00

	Non verbal MA: 5;0 to 5;11 years-old	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1.	Digit span	1.00						

2.	Word span	0.36	1.00					
3.	Letter span	0.69*	0.61	1.00				
4.	Mean span	0.80**	0.78**	0.92**	1.00			
5.	**Articulation rate**	**- 0.05**	**- 0.37**	**- 0.27**	**- 0.28**	**1.00**		
6.	Non-verbal intelligence	0.08	- 0.15	- 0.02	- 0.02	0.21	1.00	
7.	Chronological age	0.38	0.50	0.49	0.54	- 0.42	0.26	1.00

Non verbal MA > 6 years-old		**1**	**2**	**3**	**4**	**5**	**6**	**7**
1.	Digit span	1.00						
2.	Word span	0.68*	1.00					
3.	Letter span	0.86**	0.70*	1.00				
4.	Mean span	0.94**	0.84**	0.98**	1.00			
5.	**Articulation rate**	**0.85****	**0.44**	**0.74***	**0.77***	**1.00**		
6.	Non-verbal intelligence	0.72*	0.45	0.52	0.63	0.41	1.00	
7.	Chronological age	0.26	0.28	0.49	0.38	0.16	0.40	1.00

* = significant at p<0.05, ** = significant at p<0.01

 The correlations between memory span and articulation rate are significant only in the last group (non-verbal intelligence level > 6 years-old).

 The absence of significant correlation between familiar word span and articulation rate can be explained by the fact that these words are equally familiar for all the subjects and so are articulated at the same rate by all the subjects.

DISCUSSION AND CONCLUSION:

1] There is a impairment of phonological short-term memory in DS subjects (see, for example, Bilovsky & Share, 1965; Broadley & MacDonald, 1994; Broadley, MacDonald & Buckley, 1995; Comblain, 1996a; Marcell, Harvey, & Cothran, 1988; Mackenzie et Hulme, 1987; Hulme et Mackenzie, 1992; Marcell & Armstrong, 1982; Marcell & Weeks, 1988).

Short-term memory span in DS subjects is reduced comparing to the level expected regarding subjects MA and CA.

Short-term memory span is linked to MA's level but not to CA.

2] DS subjects are sensitive to the phonological similarity effect and to the word-length effect.

The size of these effects does not increase with MA or CA.

3] Our results suggest that the 2 components of the articulatory loop of the working memory system are preserved in DS subjects (see also Broadley & al., 1995; Comblain, 1996).

4] In DS subjects as in normally developing children there is no significant correlation between short-term memory span and articulation rate (see Gathercole & al., 1994, for data on normally developing children).

→ *Contrarily to Baddeley's hypothesis: the presence of a word-length effect does not prove the existence of a rehearsal mechanism and a strong relationship between articulation rate and short-term memory span).*