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Visuospatial support for verbal short-term memory in individuals with Down syndrome

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ABSTRACT

Individuals with Down syndrome (DS) tend to have impaired verbal short-term memory (STM), which persists even when visual support is provided for carrying out verbal tasks. *Objective*: The current study aims to investigate whether visuospatial support, rather than just visual, can compensate for verbal STM deficits in these individuals. The performance of 25 children and adolescents with DS (mean age = 12.5, SD = 3.8) on five word span tasks was compared with that of two groups of typically developing children, matched for mental age (*N* = 25; mean age = 6.0, SD = .2) and for receptive vocabulary (*N* = 25; mean age = 4.0, SD = .8). Four of the five tasks varied in terms of input and output – verbal and/or visual – and the fifth task included a spatial component in addition to visual input and output. DS individuals performed equally bad in the pure verbal task and in those with visual components; however, there was a significant improvement when the spatial component was included in the task. The mental age matched group outperformed DS individuals in all tasks except for that with the spatial component; the receptive vocabulary matched group, outperformed DS individuals only in the pure verbal task. We found that visuospatial support improves verbal STM in individuals with DS. This result may have implications for intervention purposes.

1. Introduction

Short-term memory (STM) refers to the ability to maintain a limited amount of information activated in mind for a short period of time. It is the memory that we use, for example, when we are to make a phone call; the numerical sequence is activated in our mind until we reach the telephone and dial the number, and then, the information fades away.

Separate systems are thought to deal with short-term storage of verbal and visuospatial information (Baddeley & Hitch, 1974). Individuals with Down syndrome (DS), for instance, tend to have impaired verbal STM with relatively preserved visuospatial STM (Baddeley & Jarrold, 2007; Jarrold & Baddeley, 2001).

In general, verbal STM is assessed by means of a digit span (or word span) task, in which the examinee must repeat a list of numbers (or words) in the same order provided by the examiner. Visuospatial STM, on the other hand, is commonly assessed by the Corsi span task, in which the examiner taps blocks arranged visuospatially in random sequence and participants must reproduce the block tapping in the same order. DS children and adolescents show impairment in digit span but not in Corsi

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span tasks, when compared to typically developing children (Azari et al., 1994; Jarrold & Baddeley, 1997; Jarrold, Baddeley, & Hewes, 2000).

DS individual's impairment in digit span tasks persists even when visual support is provided to complete the task. In other words, verbal STM deficits are not reduced when digits or words are presented visually (Broadley, MacDonald, & Buckley, 1995; Marcell, Harvey, & Cothran, 1988), or when response to the task is given by pointing numbers or pictures representing the digits or words listened, eliminating the need to provide a verbal response (Brock & Jarrold, 2005; Marcell & Weeks, 1988).

On dealing with nameable pictures, e.g. drawings, typically developing children between the ages of 5 and 8 progress from using no obvious strategy to using visual encoding, then to the use of both visual and verbal codes, and finally to a mature state where more efficient verbal encoding is preferred (Palmer, 2000). However, there are no similar studies on individuals with DS. One might expect that visual strategies could be used to compensate for the marked verbal STM deficit; however, the above mentioned studies do not support this hypothesis whereas performance in verbal tests does not improve when either input or output is visual.

To our knowledge, no study has investigated whether spatial strategies can compensate for verbal STM deficits in DS. Recent studies show that this might be the case: Laws (2002) demonstrated that visual STM is only minimally preserved in individuals with DS, and discussed that the unimpaired Corsi span performance found in this population might be due to the spatial component of the task, rather than the visual one. Moreover, there are indications that the visuospatial ability preserved in DS individuals is their capacity for spatial sequencing (Lanfranchi, Carretti, Spanò, & Cornoldi, 2009).

Verbal STM is crucial for language development and vocabulary acquisition (Baddeley, Gathercole, & Papagno, 1998) and is important for day-to-day activities by keeping task goals actively in mind (Miyake, Emerson, Padilla, & Ahn, 2004). Intervention programs for individuals with DS commonly focus on training verbal STM in order to increase verbal span (Broadley & MacDonald, 1993; Conners, Rosenquist, Arnett, Moore, & Hume, 2008; Conners, Rosenquist, & Taylor, 2001).

Therefore, finding ways to improve verbal span can be useful for efficient intervention. This study investigated whether visuospatial support, rather than just visual support, could compensate for the verbal STM deficits encountered in individuals with DS. Five word span tasks, using the same words – or drawings to represent the words – were created. Four of the five tasks varied in terms of input and output, which could be either verbal and/or visual; the fifth test contained a spatial component in addition to the visual input and output.

The aim of this experiment was to understand the interaction among different input/output modalities in verbal STM tasks for each group of individuals, with and without DS.

2. Method

2.1. Participants

Twenty-five individuals (9 girls) diagnosed with Down syndrome (DSGROUP), who used verbal language as means of communication, were evaluated and compared with two different groups of typically developing children (MENTALAGE and VOCAB), containing 25 individuals each.

Sixteen participants from the DSGROUP were enrolled in regular schools and nine in special-needs schools. DSGROUP and MENTALAGE were paired by mental age, as derived from their intelligence quotient (IQ) and chronological age; DSGROUP and VOCAB were paired by receptive vocabulary, as measured by their scores on the Peabody picture vocabulary test (PPVT – Brazilian version).

Participant's ages ranged from 7 to 18 years old (mean = 12.5, SD = 3.8) in the DSGROUP, from 6 to 7 years old (mean = 6.0, SD = .05) in the MENTALAGE and from 3 to 5 years old (mean = 4.0, SD = .8) in the VOCAB group.

2.2. Instruments

2.2.1. IQ

The Wechsler Intelligence Scale for Children (WISC-III) (Wechsler, 2002) and the Wechsler Adult Intelligence Scale (WAIS-III) (Wechsler, 2004) were used to measure IQ for individuals from DSGROUP and MENTALAGE groups according to their age. Mental age calculus derived from each participant's IQ and chronological age, i.e. mental age = (IQ * chronological age)/100.

2.2.2. Vocabulary

The Brazilian version of the PPVT (Dunn & Dunn, 1981) was used to assess receptive vocabulary. In this test, four pictures are shown, the examiner states a word describing one of the pictures and participants must point to the correct one. Score was given in terms of number of correct responses.

2.2.3. Short-term memory

Standard verbal and visuospatial short-term memory tasks and other five novel tasks, created specifically for this study, were applied.

2.2.3.1. Standard short-term memory tasks. Forward digit span (Wechsler, 2002) and forward Corsi span tasks (Lezak, 1995) were used to asses verbal and visuospatial STM, respectively. In the digit span test, subjects must repeat a series of digits presented orally by the examiner; in the Corsi-span test, the examiner taps blocks in a random sequence, and participants must reproduce the block tapping in the same order. In both tests, the number of stimuli (digits or blocks tapped) increases by one until the participant consecutively fails two trials of the same span. Score corresponds to the number of elements in the last series correctly recorded and reproduced by the participant, i.e. span.

2.2.3.2. Novel short-term memory tasks. Five novel tasks whereby input and output modality (verbal/visual/spatial) was manipulated were created for the purpose of this study. The same words, or drawings representing them, were used to compose all five tasks. Nine concrete dissyllable nouns in Brazilian Portuguese, with high frequency within the preschool context, were chosen. The corresponding English words are: cat; knife; bed; ball; kite; baby; candle; mouth; and house. In order to ensure familiarity with the drawings used in visual input or output conditions, the isolated pictures were shown to all subjects prior to task initiation; all participants were able to name them with no difficulty.

Four of the five tasks varied in terms of the input–output modality, with input and output being either verbal or visual. For tasks with verbal input, the examiner said the words out loud; for tasks with visual input, the examiner showed cards containing a single drawing corresponding to the words without saying anything, the cards were shown one at a time and subsequently placed face down to the table. For tasks with verbal output, subjects had to say the words in the same order they had been presented to them; in tasks with visual output, subjects pointed to the pictures, in the same order they had been presented, in a board containing only pictures presented during input phase (the pictures were displayed linearly in random order). The four tasks were created based on the combination of different input and output modalities: **verbal–verbal; verbal–visual; visual–verbal; and visual–visual**.

The fifth task, **spatial/visual–visual**, corresponded to a variation of the visual–visual task in such a way as to include a spatial component. In this task, a board containing nine pictures (3×3) was placed before each participant. Similarly to the Corsi-span task, the examiner pointed to the pictures, forming a sequence, and participants were asked to reproduce the same sequence, i.e. to point to the same pictures in the same order. In order to stress the spatial component over the visual component in this task, the same board was used for input and output. In other words, the position of the pictures did not change during the task.

For all novel tasks, the number of stimuli presented and the scoring method were similar to those employed in the standard short-term memory tasks.

2.3. Procedure

This study was approved by the local Research Ethics Committee and was duly registered with the CEP/UPM under no. 1086/10/2008 and with the CAAE under no. 0064.0.272.000-08 (UPM). The legal guardians of all participants signed an independent and informed consent form.

The order in which the tasks were administered was the same for all individuals: PPVT; digit span; Corsi span; verbal–verbal; verbal–visual; visual–verbal; visual–visual; and spatial/visual–visual. The WISC-III or WAIS-III was administered only for the DSGROUP and MENTALAGE groups in one or two sessions beforehand.

For statistical analysis, we used the PASW Statistics 18.0, with a significance level of 5%. All data were tested for normality by the Kolmogorov–Smirnov test; when normally distributed, group difference was tested by Student *t*-test or one-way ANOVA; when normality could not be assumed, Kruskal–Wallis test was used. In the latter case, Mann–Whitney test was used for pairwise comparison with Bonferroni correction for multiple comparisons; significance level in these cases was 1.2%. Bivariate correlations were calculated by Spearman's rho.

3. Results

Mental age, IQ and PPVT scores for each group are summarized in Table 1. DSGROUP and MENTALAGE did not differ in terms of mental age ($t = .02$, $p = .9$) and DSGROUP group had lower total IQ ($t = -21.7$, $p < .001$, $\eta^2 = .93$), verbal IQ ($t = -21.9$, $p < .001$, $\eta^2 = .92$) and execution IQ ($t = -15.8$, $p < .001$, $\eta^2 = .84$) than MENTALAGE. There was a group effect for performance

Table 1
Mental age, IQ and vocabulary scores for individuals with Down syndrome (DSGROUP) and typically developing children matched for mental age (MENTALAGE) and for receptive vocabulary (VOCAB) with the DSGROUP.

	DSGROUP Mean (SD)	MENTALAGE Mean (SD)	VOCAB Mean (SD)
Mental age	6.8 (2.4)	6.8 (.7)	–
IQ			
Total IQ	54.2 (5.4)	112.8 (12.4)	–
Verbal IQ	52.6 (7.3)	116.0 (12.5)	–
Execution IQ	55.2 (9.7)	107.8 (13.2)	–
Vocabulary			
PPVT accuracy	51.1 (7.8)	70.8 (9.1)	49.3 (8.0)

'–' = not tested.

Table 2
Scores on standard and novel working memory tasks for individuals with Down syndrome (DSGROUP) and typically developing children matched for mental age (MENTALAGE) and for receptive vocabulary (VOCAB) with the DSGROUP.

	DSGROUP Median (25–75 percentile)	MENTALAGE Median (25–75 percentile)	VOCAB Median (25–75 percentile)	Statistical differences
Standard tasks				
Digit span	2.0 (.0–2.0)	4.0 (4.0–5.0)	4.0 (3.5–4.0)	(VOCAB = MENTALAGE) > DSGROUP
Corsi span	2.0 (2.0–4.0)	5.0 (4.0–6.0)	3.0 (2.0–4.0)	(VOCAB = DSGROUP) < MENTALAGE
Novel tasks				
Verbal–verbal	2.0 (2.0–3.0)	4.0 (4.0–5.0)	3.0 (2.0–3.0)	DSGROUP < VOCAB < MENTALAGE
Verbal–visual	2.0 (2.0–3.0)	4.0 (3.5–4.0)	2.0 (2.0–3.0)	(VOCAB = DSGROUP) < MENTALAGE
Visual–verbal	2.0 (2.0–2.0)	4.0 (3.0–4.5)	2.0 (2.0–2.0)	(VOCAB = DSGROUP) < MENTALAGE
Visual–visual	2.0 (2.0–2.0)	4.0 (3.5–4.0)	2.0 (1.0–2.0)	(VOCAB = DSGROUP) < MENTALAGE
Spatial/visual–visual	4.0 (3.0–4.0)	4.0 (4.0–5.0)	3.0 (2.0–3.5)	VOCAB < MENTALAGE; DSGROUP = MENTALAGE; DSGROUP = VOCAB

Mann–Whitney test with Bonferroni correction for multiple comparisons was used for pairwise comparison; '<' was used for $p < .012$ and '=' was used for $p > .012$.

on PPVT ($F_{2,72} = 51.5$; $p < .001$): MENTALAGE had higher scores than the other two groups (with $p < .05$), but DSGROUP and VOCAB did not differ.

Table 2 summarizes groups' performances on standard and novel STM tasks. Due to non-normal data distribution, median and percentiles 25 and 75 are displayed; main statistical differences are also shown in Table 2.

3.1. Short-term memory: standard tasks

Group effect was found for digit ($H = 43.6$, $p < .001$) and Corsi span ($H = 33.7$, $p < .001$) tasks. Pairwise comparison for the digit span showed that MENTALAGE and VOCAB had similar performance ($U = 224.0$, $p = .05$, $r = -.27$), which was significantly better than that of the DSGROUP (DSGROUP × MENTALAGE: $U = 615.5$, $p < .001$, $r = .86$; DSGROUP × VOCAB: $U = 557.0$, $p < .001$, $r = .69$).

For the Corsi span test, on the other hand, DSGROUP's performance did not differ from that of VOCAB group ($U = 372.0$, $p = .22$, $r = .17$), but both had lower scores than the MENTALAGE group (DSGROUP × MENTALAGE: $U = 576.0$, $p < .001$, $r = .73$; MENTALAGE × VOCAB: $U = 78.0$, $p < .001$, $r = -.65$).

3.2. Short-term memory: novel tasks

Significant group effects were found for all novel STM tasks: verbal–verbal ($H = 45.76$, $p < .001$), verbal–visual ($H = 45.85$, $p < .001$), visual–verbal ($H = 45.54$, $p < .001$), visual–visual ($H = 43.76$, $p < .001$) and spatial/visual–visual ($H = 14.57$, $p = .001$). Pairwise comparison results for each task are described bellow.

Verbal–verbal: DSGROUP had lower scores than MENTALAGE ($U = 609.5$, $p < .001$, $r = .84$) and than VOCAB ($U = 447.0$, $p < .01$, $r = .39$) and the latter performed worse than MENTALAGE ($U = 55.5$, $p < .001$, $r = -.73$).

Verbal–visual: DSGROUP did not differ from VOCAB ($U = 285.0$, $p = .53$, $r = -.08$), but both had lower scores than MENTALAGE (MENTALAGE × DSGROUP: $U = 586.0$, $p < .001$, $r = .79$; MENTALAGE × VOCAB: $U = 21.0$, $p < .001$, $r = .84$).

Similar results were found for visual–verbal (DSGROUP × VOCAB: $U = 269.5$, $p = .30$, $r = -.15$; MENTALAGE × DSGROUP: $U = 583.0$, $p < .001$, $r = .78$; MENTALAGE × VOCAB: $U = 30.0$, $p < .001$, $r = -.81$) and visual–visual (DSGROUP × VOCAB: $U = 248.0$, $p = .11$, $r = -.22$; MENTALAGE × DSGROUP: $U = 570.0$, $p < .001$, $r = .74$; MENTALAGE × VOCAB: $U = 34.0$, $p < .001$, $r = -.80$).

Spatial/visual–visual elicited different results: DSGROUP did not differ from MENTALAGE ($U = 408.5$, $p = .04$, $r = .28$) or from VOCAB ($U = 217.5$, $p = .05$, $r = -.27$), but VOCAB had worse performance than MENTALAGE ($U = 129.0$, $p < .001$, $r = -.53$).

3.3. Correlations between standard and novel STM tasks

Bivariate correlation between novel and standard STM tasks were carried out for each group. Only significant correlations will be mentioned. For DSGROUP, digit span correlated with verbal–verbal (rho = .68, $p < .001$) and visual–verbal (rho = .54, $p < .01$); Corsi span correlated with visual–verbal (rho = .53, $p < .001$) and spatial/visual–visual (rho = .46, $p = .02$). For MENTALAGE group, digit span correlated with verbal–verbal (rho = .56, $p < .01$), verbal–visual (rho = .55, $p < .01$), visual–verbal (rho = .581, $p < .01$) and visual–visual (rho = .47, $p < .05$); Corsi span correlated with spatial/verbal–verbal (rho = .48, $p < .05$). Finally, for the VOCAB group, digit span correlated with verbal–verbal (rho = .40, $p < .05$) and verbal–visual (rho = .61, $p < .01$); Corsi span correlated with verbal–visual (rho = .57, $p < .01$) and visual–verbal (rho = .46, $p = .02$).

4. Discussion

The purpose of this study was to investigate whether visuospatial support in verbal STM tasks could compensate for the verbal STM deficit exhibited by individuals with DS. Standard STM tasks, e.g. digit and Corsi span, and novel verbal STM tasks, varying in terms of modality of input and output – verbal, visual or visuospatial – were administered in individuals with DS and in typically developing children.

Results for the standard STM tasks showed that individuals with DS performed worse than typically developing children for the digit span task; DS' performance on Corsi span task did not differ from that of very young children – matched by receptive vocabulary. These results replicate those reported in the related literature, which have generally found no difference between DS and control groups for the Corsi span task (Azari et al., 1994; Jarrold & Baddeley, 1997; Jarrold et al., 2000). Older children, matched by mental age with individuals with DS, had higher visuospatial span, though.

Regarding the novel STM tasks, individuals with DS had a pronounced deficit in the purely verbal task (verbal–verbal), performing worse than both groups of typically developing children. As reported by other studies (Broadley et al., 1995; Marcell et al., 1988; Marcell & Weeks, 1988), the presence of visual input or output did not improve performance in verbal STM tasks for this group.

DS individuals and children matched by receptive vocabulary performed similarly in tasks that included a visual component, this happened because younger children's performance decreased with visual support. This might have happened because they were using a visual rather than a verbal encoding strategy when performing the visual tasks (Palmer, 2000), which might not have been as effective. Performance of the older typically developing children (mental age paired group) was not altered by the presence of a visual component in the task, suggesting they were using a verbal strategy for all tasks. This hypothesis is corroborated by the fact that digit span correlated positively with all visual and verbal novel span tasks for the older, but not for the younger children.

Interestingly, when visuospatial support was added to the task (spatial/visual–visual), individuals with DS performed as well as both groups of typically developing children. These results indicate that given a situation where a spatial code can be used, individuals with DS benefit from such and better remember the location of verbal information.

The current study corroborates the few studies that show difference between visual and spatial abilities within STM in individuals with DS. It also sheds light on the relation between the relatively preserved visuospatial abilities and verbal STM deficit, indicating that the presence of a spatial component can improve performance in word span tests. Other studies are needed to verify how the spatial component can be used to aid individuals with DS in their day-to-day activities and/or classrooms in order to improve their quality of life.

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References

Azari, N. P., Horwitz, B., Pettigrew, K. D., Grady, C. L., Haxby, J. V., Giacometti, K. R., et al. (1994). Abnormal pattern of cerebral glucose metabolic rates involving language areas in young adults with Down syndrome. *Brain and Language, 46*, 1–20.

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. In G. Bower (Ed.), *The psychology of learning and motivation* (pp. 47–89). New York: Academic Press.

Baddeley, A. D., Gathercole, S. E., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological Review, 105*(1), 158–173.

Baddeley, A., & Jarrold, C. (2007). Working memory and Down syndrome. *Journal of Intellectual Disability Research, 51*(12), 925–931.

Broadley, I., & MacDonald, J. (1993). Teaching short-term memory skills to children with Down syndrome. *Down Syndrome Research and Practice, 1*, 56–62.

Broadley, I., MacDonald, J., & Buckley, S. J. (1995). Working memory in children with Down syndrome. *Down Syndrome Research and Practice, 3*(1), 3–8.

Brock, J., & Jarrold, C. (2005). Serial order reconstruction in Down syndrome: Evidence for a selective deficit in verbal short-term memory. *Journal of Child Psychology and Psychiatry, 46*(3), 204–316.

Conners, F. A., Rosenquist, C. J., Arnett, L., Moore, M. S., & Hume, L. E. (2008). Improving memory span in children with Down syndrome. *Journal of Intellectual Disability Research, 52*(3), 244–255.

Conners, F. A., Rosenquist, C. J., & Taylor, L. A. (2001). Memory training for children with Down syndrome. *Down Syndrome Research and Practice, 7*(1), 25–33.

Dunn, L. M., & Dunn, L. M. (1981). *Peabody picture vocabulary test: Revised. Circle pines*. MN: American Guidance Service.

Jarrold, C., & Baddeley, A. (1997). Short-term memory for verbal and visuospatial information in Down's syndrome. *Cognitive Neuropsychiatry, 2*, 101–122.

Jarrold, C., & Baddeley, A. (2001). Short-term memory in Down syndrome: Applying the working memory model. *Down Syndrome Research and Practice, 7*(1), 17–23.

Jarrold, C., Baddeley, A. D., & Hewes, A. K. (2000). Verbal short-term memory deficits in Down syndrome: A consequence of problems in rehearsal? *Journal of Child Psychology and Psychiatry, 40*(2), 233–244.

Laws, G. (2002). Working memory in children and adolescents with Down syndrome: Evidence from a colour memory experiment. *Journal of Child Psychology and Psychiatry, 43*(3), 353–364.

Lanfranchi, Carretti, B., Spanò, G., & Cornoldi, C. (2009). A specific deficit in visuospatial simultaneous working memory in Down syndrome. *Journal of Intellectual Disability Research, 53*(5), 474–483.

Lezak, M. D. (1995). *Neuropsychological assessment*. England: Oxford University Press.

Marcell, M. M., Harvey, C. F., & Cothran, L. P. (1988). An attempt to improve auditory short-term memory in Down's syndrome individuals through reducing distractors. *Research in Developmental Disabilities, 9*, 405–417.

Marcell, M. M., & Weeks, S. L. (1988). Short-term memory difficulties and Down's syndrome. *Journal of Mental Deficiency Research, 32*, 153–162.

Miyake, A., Emerson, M. J., Padilla, F., & Ahn, J. (2004). Inner speech as a retrieval aid for task goals: The effects of cue type and articulatory suppression in the random task cuing paradigm. *Acta Psychologica, 115*, 123–142.

Palmer, S. (2000). Working memory: A developmental study of phonological recoding. *Memory, 8*, 179–193.

Wechsler, D. (2002). *Escalas de Inteligência Wechsler para Crianças: Manual* (3rd ed., V.L. Marques de Figueiredo, Adaptação e padronização brasileira). São Paulo, SP: Casa do Psicólogo.

Wechsler, D. (2004). *WAIS-III: Escala de inteligência Wechsler para adultos (WAIS-III: Wechsler scale for adults)*. São Paulo: Casa do Psicólogo.