A specific deficit in visuospatial simultaneous working memory in Down syndrome

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Abstract

Background Recent studies have demonstrated that individuals with Down syndrome (DS) present both central and verbal working memory deficits compared with controls matched for mental age, whereas evidence on visuospatial working memory (VSWM) has remained ambiguous. The present paper uses a battery of VSWM tasks to test the hypothesis that individuals with DS can also encounter specific difficulties in VSWM.

Method Four tasks were administered to 34 children and adolescents with DS and 34 controls matched for verbal mental age. In two of these tasks, participants had to remember a series of locations sequentially presented on a matrix (spatial-sequential WM); in another two, they had to remember locations simultaneously presented (spatial-simultaneous WM).

Results and Conclusions Results showed that individuals with DS are poorer than controls in the spatial-simultaneous tasks, but not in the spatial-sequential tasks. These findings were not due to a difference in speed of visuospatial processing. In fact, when performances of the two groups in VSWM were compared using speed measures as covariates, differences between groups remained. It is suggested that the simultaneous VSWM deficit of individuals with DS could be due to the request for processing more than one item at a time.

Keywords Down syndrome, intellectual disability, processing speed, visuospatial working memory

Working memory (WM) is defined as a temporary system that allows various elements to be held in memory, manipulated and processed during the execution of cognitive tasks (Baddeley 1986). Many studies have demonstrated the critical role of WM in a variety of cognitive activities required in everyday situations, such as learning, reading, writing, linguistic processing, orientation, mental imagery, reasoning, comprehension and arithmetical processing (see Baddeley 1986 for a seminal review). In his theorisation, Baddeley (1986) describes WM as a system composed of separable but interacting components. Functioning in concert, these components provide a kind of flexible mental workspace that can be used to maintain and transform information in the course of demanding cognitive activities, and that acts as a temporary bridge between externally

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and internally generated mental representations. One component is the central executive, which is responsible for controlling resources and monitoring information processing across informational domains. Storage of information is mediated by two domain-specific slave systems: the phonological loop, which provides temporary storage of verbal information, and the visuospatial sketchpad, that is, visuospatial WM (VSWM), specialised for the maintenance and manipulation of visual and spatial representations (see Baddeley 2000 for a review). In particular, the visuospatial sketchpad stores material in terms of its visual or spatial features (Logie 1995). More recently, a fourth component of this model has been added, the episodic buffer, responsible for binding information across informational domains and memory subsystems into integrated chunks (Baddeley 2000).

Research has also attempted to describe the structure of each component. In particular, it has been suggested that the VSWM might be split into a spatial component (involved, for example, in memory of landmark positions) and a separate visual component (involved in memory of objects and their visual properties, such as colours, surfaces, etc.) (Logie 1995; Klauer & Zhao 2004). However, several authors (see for example Pickering et al. 2001) have proposed splitting the spatial component still further. In particular, Pazzaglia & Cornoldi (1999) suggested distinguishing between a spatial-sequential and a spatial-simultaneous component. According to Pazzaglia & Cornoldi (1999), the spatial-sequential component is involved in memory for information presented sequentially, as measured by the Corsi block task, whereas spatial-simultaneous component is called upon in memory for patterns describing spatial locations simultaneously presented, as in the Visual Pattern Test (Della Sala et al. 1999). Even though also processing simultaneously presented different locations requires a sequential exploration of the locations through rapid eye movements, the subject’s awareness of the representation stored in WM is mainly simultaneous. Consequently, a subject’s WM must be able to simultaneously maintain information about different locations and any relationships they might have. Empirical evidence (Pazzaglia & Cornoldi 1999) supported the distinction. For example, in a study of children with non-verbal disabilities, Mammarella et al. (2006) reported a selective failure either on spatial-simultaneous or on spatial-sequential WM tasks, suggesting a dissociation between these two processes. Other evidence for distinction between spatial-simultaneous and spatial-sequential processes comes from neuroimaging. For example, Kesner et al. (1994) found impairment in spatial order recognition memory in individuals with damage on the prefrontal cortex, despite an unimpaired recognition of spatial locations. Moreover, where the damage involved only the left prefrontal cortex, patients showed item-order dissociation only for words and abstract pictures, but not for spatial locations. Zarahn et al. (2000), in a neuroimaging study, found that the maintenance of information about the relative location of sequentially presented stimuli activated the dorsolateral area of the prefrontal cortex.

The sets of cognitive and neuroimaging evidence mentioned above can also be viewed in the light of the Cornoldi & Vecchi WM model (2003), which is based on the hypothesis that both verbal and VSWM tasks can be described according to two continuous dimensions: the horizontal continuum, which refers to the type or format of stimulus characteristics (e.g. verbal, visual, spatial-simultaneous and spatial-sequential), and the vertical continuum, which refers to the level of control, some tasks requiring a higher level of WM control (active tasks), others a lower level (passive tasks). Cornoldi & Vecchi (2003) reviewed evidence supporting their proposed description of the VSWM, including the distinction between visual, spatial-simultaneous and spatial sequential tasks. This evidence concerned both typical adult populations and particular groups. With young adults, for example, Pazzaglia & Cornoldi (1999) found that processing of descriptions presenting visual details or organisation of locations or routes was selectively disrupted by concurrent WM tasks, requiring memorisation of objects, locations in an array and sequences of locations, respectively.

However, according to Cornoldi & Vecchi (2003), the structure of WM can be more clearly determined by studying groups of very distinct individuals, in particular groups with genetic syndromes. Accordingly, Lanfranchi et al. (2004) explored the role of control processes in verbal and VSWM performance of individuals with Down syndrome (DS).
For verbal WM, as expected on the basis of literature (Jarrolld et al. 2000), the DS group showed poorer performance regardless of the involvement of control. In contrast, in the case of VSWM, the results demonstrated that individuals with DS are poorer in highly controlled VSWM, whereas they can be as good as typically developing (TD) children with the same mental age in low-control VSWM tasks. Lanfranchi et al. (2004) concluded that a core deficit of mentally retarded individuals could reside in a controlled WM deficit, thus contributing to the debate on the nature of intelligence. In their study, Lanfranchi et al. (2004) did not directly examine the implications of different types of processes involved in their VSWM battery, but focused on control variations, without including tasks specifically designed for separate testing of the different components of VSWM. The results for this latter respect were unclear, partly because the low mental age of their subjects (around 4 years and 6 months) and their relatively low performance in the tasks precluded observation of specific subtle dissociations. In fact, it has been suggested that clearer differentiations within tasks and more stable strategies for tackling VSWM tasks may appear later, from a mental age of 5:6–6 years (Pickering et al. 2001).

Nevertheless, the literature has also suggested that individuals with DS might be poorer in some aspect of visuospatial processing. An early study by Ellis et al. (1989) found in individuals with DS an unimpaired performance in spatial memory compared with visual memory. A subsequent study by Laws (2002) found that individuals with DS performed significantly better than TD controls, matched for receptive vocabulary, in the Corsi block task (spatial WM), while the performances of the two groups were not significantly different in a memory for colour task (visual WM). Similar observations were made by Vicari et al. (2005) for long-term memory. The hypothesis of a dissociation between visual and spatial memory seems to be also supported by the results of neuroanatomical studies: Wisniewski (1990) found volumetric reduction in frontal and temporal brain regions that might be related to poor performances in visual memory tasks in individuals with DS, while Pinter et al. (2001) showed a relative preservation of the dorsal stream that may be related to the relatively strong spatial WM.

Partially different results were obtained by Vicari et al. (2006). In their study, a dissociation between visual and spatial processes was found because individuals with DS, compared with TD children with the same mental age, showed a deficit in visual tasks (both perception and imagery) while the performances of the two groups did not differ in spatial tasks (both perception and imagery). However, the study also found reduced performance in both spatial and visual WM tasks, although this might result from both involving a visual component. In fact, the spatial task required participants to indicate the order and position on the screen in which several non-verbalisable geometric shapes appeared. It should be noted that in both tasks information to be remembered was presented sequentially. It should also be observed that, after adjusting for performance level on a visual perceptual task, performance of individuals with DS and TD no longer differed in either visual-spatial or visual-object WM tasks.

In conclusion, evidence suggests that DS may be also associated with weaknesses in VSWM, but the data are still unclear and mainly limited to the dissociations between high- and low-control processes (Lanfranchi et al. 2004) and between visual and spatial components (Laws 2002). As regards the latter result, the literature suggests a further distinction between spatial-simultaneous and spatial-sequential components of VSWM (Pazzaglia & Cornoldi 1999), and that this distinction might be critical for the study of WM deficits (Mammarella et al. 2006). The dissociation between these components may be valuable in understanding the results briefly reviewed here: it seems that DS individuals perform at the same level as the TD group when spatial tasks involve a sequential processing of information (see for example, the results of Vicari et al. 2006), or those obtained with the Corsi Block task by Laws (2002) and by Rowe et al. (2006). However, conclusion that DS individuals have preserved visuospatial processing might be broadened by understanding whether similar patterns of results can be obtained with tasks requiring the simultaneous processing of different pieces of spatial information.

The present study closely examined the hypothesis that preservation of VSWM in DS individuals depends on the specific component examined. In
particular, the distinction proposed by Pazzaglia & Cornoldi (1999) between spatial-simultaneous and spatial-sequential processes was analysed. To test this hypothesis, 34 individuals with DS and 34 TD children matched for verbal mental age were administered a battery of four VSWM tasks: in two of these, participants had to remember a series of locations sequentially presented on a matrix (spatial-sequential WM); in another two, locations simultaneously presented had to be remembered (spatial-simultaneous WM). Three of these tasks were versions of tasks used by Lanfranchi et al. (2004), modified to make the tasks less difficult and more able to capture specific differences in the types of processes, while a fourth task (the selective position task) was introduced to give a second spatial-simultaneous task, mirroring the characteristics of the second spatial-sequential task. It should be noted that in the current research, we chose tasks with low-medium demand for control processes; the purpose was to preclude between-group differences due to the difficulties of DS individuals in tasks demanding in terms of attentional control, as would be expected from the conclusions of Lanfranchi et al. (2004).

Moreover, the two groups were also tested with three tasks assessing processing speed for visual information. It has been demonstrated that processing speed might affect the performance of individuals with intellectual disability (ID) (see for example Kail 1992). In particular, we wanted to control for the possibility that a spatial simultaneous deficit was simply due to lower processing speed and thus lower ability to move quickly between different locations in order to include them in WM at the same time. Processing speed measures were therefore used to ensure that potential differences in spatial-simultaneous and spatial-sequential could not be explained by differences in basic aspects of cognitive processing.

### Method

#### Participants

Thirty-four children and adolescents with DS took part: 19 boys and 15 girls aged from 7 years to 17 years 11 months (mean = 12;6, SD = 2;5). DS participants were matched on the basis of receptive vocabulary (Peabody Picture Vocabulary Test-Revised (PPVT-R) Scale, Dunn & Dunn 1997) \( t(66) = 0.162, P = 0.872 \) and Raven’s coloured matrices (Raven et al. 1992) \( t(66) = 1.04, P = 0.301 \) to a control group of 34 TD children, which included 14 boys and 20 girls, aged from 3 years 10 months to 7 years 10 months (mean = 4;5, SD = 0;8) (see Table 1). A TD child was included in the control group when his or her raw scores on the PPVT lay within (in either direction) 4 points of the score of the corresponding DS child. The group of individuals with DS could be considered typical of the larger population of individuals with DS as regards relationship between chronological and mental age (e.g. Dykens et al. 2000). But somewhat surprising is the fact that in this group, verbal and visuospatial mental age are almost the same, while it is well known that in the DS population visuospatial abilities are usually higher than verbal abilities (e.g. Dykens et al. 2000). However, we should consider that in the present study verbal abilities are assessed using a measure of receptive vocabulary, that is, the language aspect less impaired in DS

#### Table 1  Group characteristics

<table>
<thead>
<tr>
<th></th>
<th>DS</th>
<th>TD</th>
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<tbody>
<tr>
<td>n</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>Female</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>Chronological age</td>
<td>Mental age Peabody</td>
<td>Mental age Raven</td>
</tr>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>12;6</td>
<td>2;5</td>
<td>6;0</td>
</tr>
<tr>
<td>4;5</td>
<td>0;8</td>
<td>5;9</td>
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DS, Down syndrome; TD, typically developing.

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(e.g. Rondal 1996) and often considered a relative strength like non-verbal abilities (e.g. Laws 2004). No participant had any associated physical deficit that might have compromised the experiment. Parental consent for participation in the study was obtained prior to testing.

Materials

Processing speed tasks

Line comparison. This task requires quick examination of simple patterns. The child is presented with 90 pairs of lines and has to judge as quickly as possible whether or not they are the same length. One minute is allowed for the task. For each pair correctly judged, a score of 1 is given. The total score is the number of correct answers given in the allocated time.

Pattern comparison. This task is a modified version of the speed pattern comparison of Salt-house (1993), and requires quick examination of complex patterns. Here, 60 pairs of patterns are presented, and the child has to decide as quickly as possible whether or not the two patterns of each pair are identical. Again, one minute is allowed for completion of the task. The total score is the number of correct answers given in the allocated time.

Coding subtest, A form, of the WISC-R (Wechsler 1991). This task involves reproduction of rows of simple shapes (made up of different lines) corresponding to the associated forms given, following a code, as quickly as possible for 2 min. The total score is the number of shapes correctly reproduced in the allocated time.

Spatial-sequential and spatial-simultaneous working memory tasks

Two specific tasks for spatial-sequential and two for spatial-simultaneous WM. As already mentioned, for each spatial component we selected tasks with low and medium demand, respectively, in terms of attentional control. According to Cornoldi & Vecchi (2003), a low control task requires without further manipulation reproduction of the presented position, a classic example of this category of tasks being the forward digit span. Instead, a medium control task usually implies selection of information to be remembered following a criterion – for example, the request that participants retain only the first or last item of each presented sequence. Each task progressed gradually from the simplest to the most complex series, each complexity level having two series of items. For each task the minimum score was 0 and the maximum 10. To avoid frustration and other issues, however, the task was interrupted if the child failed both lists of a particular length, and the remaining items were considered incorrect. Each task was preceded by instructions and practice trials at the simplest task level. The experimental phase was started only if the child appeared to have understood the nature of the task by responding correctly on a practice trial.

Pathway recall (spatial-sequential). The child was shown a path taken by a small frog on a 3 × 3 or 4 × 4 chessboard, then had to recall the pathway immediately after presentation by moving the frog from square to square, reproducing the experimenter’s moves. There were five levels of difficulty, depending on the number of steps in the frog’s pathway and the size of board (3 × 3 for 1st and 2nd levels with 2 and 3 steps, respectively, and 4 × 4 at 3rd, 4th and 5th levels, with 2, 3 and 4 steps, respectively). Steps were presented at approximately 2-second intervals.

Selective pathway recall (spatial-sequential). The child was shown one or two frog’s pathways on a 4 × 4 chessboard (for the two-pathway case these were showed consecutively) and had to recall the starting positions of each frog. The number of pathways and steps in each pathway determined the level of complexity. At 1st and 2nd levels, one pathway with 2 steps and one with 3 steps were administered, respectively. At 3rd, 4th and 5th levels, two pathways, with 2, 3 and 4 steps, respectively, were presented. Instructions and practice were carefully designed to make the child confident with the task and ensure the whole pathway was sequentially processed, even though only the starting location had to be recalled.

Position recall (spatial-simultaneous). The child was given 10 s to observe the positions of the green
squares on a $2 \times 2$, $3 \times 3$ or $4 \times 4$ chessboard. Immediately after removal of the board, the child had to remember the locations of the green squares and point to their positions on a blank chessboard. The task had five levels of complexity depending on the number of squares to be remembered (from 2 to 3) and the size of board, $2 \times 2$ at 1st level, $3 \times 3$ at 2nd and 3rd levels (with 2 and 3 green squares, respectively), and $4 \times 4$ at 4th and 5th levels (2 and 3 green squares). Each level had two trials.

Selective position recall (spatial-simultaneous). The child was given 10 s to observe a $2 \times 2$, $3 \times 3$ or $4 \times 4$ chessboard containing an equal number of red and green squares, and then had to remember the positions of the coloured squares. Immediately after removal of the board, the child had to look at a blank chessboard and point out the locations of the red squares (half the trials) or green squares (again half). The child was not warned which colour would have to be recalled. The task had five levels of complexity depending on the number of squares to be recalled (from 2 to 3) and the size of the board, $2 \times 2$ at 1st level, $3 \times 3$ at 2nd and 3rd levels (with 2 and 3 green squares, respectively), and $4 \times 4$ at 4th and 5th levels (2 and 3 green squares). There were two trials for each level.

Two studies (Lanfranchi & Vianello, in press; Lanfranchi & Vianello 2008) have shown that the above tasks have an alpha-coefficient ranging from 0.70 to 0.75, which can be considered acceptable values for basic research (e.g. Nunnaly & Bernstein 1994). The studies ensured that the pre-defined degrees of complexity actually corresponded to the degrees of difficulty met by the children. Furthermore, despite the fact that, at the first levels, the selective tasks seem very simple (in particular only one item of information has to be remembered in the selective pathway task), evidence has shown that they are demanding. In addition, it has been shown that the selective tasks are matched for difficulty (for TD children) with the other two WM tasks (see Lanfranchi & Vianello 2008), as they involve control for memory interference owing to irrelevant presented locations (Re et al., unpublished data).

Procedure

In a first session, participants completed the Raven test and PPVT-R. The raw score at this latter test of each individual with DS was used to identify the matched child of the control group, whereas the Raven scores were used as a further control for the similarity of the groups. The participants subsequently completed the four VSWM tasks and the three processing speed tasks. Participants were also administered a dual task which will not be considered here. All tasks were administered individually in two sessions with an interval of approximately 1 week, each session lasting approximately 25 min. The task presentation order was counterbalanced across participants.

Results

Processing speed tasks

The univariate analyses of variance on the scores obtained in the Line comparison and Pattern task did not reveal significant differences between groups ($F_{1,66} = 0.40, P = 0.841$ and $F_{1,66} = 1.08, P = 0.302$). In contrast, a significant effect of Group emerged in the case of the Coding subtest ($F_{1,66} = 9.81, \eta^2 = 0.13, P = 0.003$), the DS group performing better than the control group (see Table 2).

<table>
<thead>
<tr>
<th>Group</th>
<th>Down syndrome</th>
<th>Typical developing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Line comparison</td>
<td>20.09</td>
<td>8.23</td>
</tr>
<tr>
<td>Pattern comparison</td>
<td>14.50</td>
<td>4.86</td>
</tr>
<tr>
<td>Coding subtest</td>
<td>28.71</td>
<td>11.83</td>
</tr>
</tbody>
</table>

Table 2 Statistics (mean and standard deviation) for the number of correct answers for the two groups in the processing speed tasks.
Spatial-sequential vs. spatial-simultaneous tasks

A 2 × 2 × 2 ANOVA for mixed design with Group (DS vs. TD group) as between-group variable and VSTM Sub-components (spatial-simultaneous vs. spatial-sequential) and Control (low vs. medium) on the number of correct trials showed a significant interaction Group × Sub-components ($F_{1,66} = 6.16$, $\eta_p^2 = 0.09$, $P = 0.016$). Post hoc analysis with the Tukey method showed significant differences between the two groups in the spatial simultaneous tasks ($P < 0.05$; $d = 0.49$, based on Cohen (1988)), but not in the spatial-sequential tasks (post hoc power = 0.11, based on Faul et al. 2007) (see Fig. 1). The interaction Sub-components × Control was also significant ($F_{1,66} = 15.11$, $\eta_p^2 = 0.18$, $P = 0.001$), owing to the fact that the selective pathway task produced the lowest performance, in absolute values. No other main effects or interactions were significant. However, as can be seen in Fig. 1, DS children were slightly impaired, with respect to TD children, by increases in the control required by either the simultaneous or the sequential active task.

To control for the effect of processing speed on the results, a composite score of processing speed was computed averaging the $z$ score of each measure. The score obtained was then used as covariate. Not surprisingly, if we consider the substantial absence of differences in speed between the groups, the ANCOVA comparing the two groups in the four tasks demonstrated that the pattern of results in the VSTM tasks was not substantially affected by speed. Again, from the results, the interaction between Group and Sub-components emerged ($F_{1,65} = 6.62$, $\eta_p^2 = 0.09$, $P = 0.012$), showing that the two groups were significantly different in the spatial-simultaneous tasks ($P < 0.01$) but not in the spatial-sequential tasks. From this analysis, it appears clear that the poorer performance of the group of DS individuals in the two spatial-simultaneous tasks cannot be ascribed to basic processing differences.

Discussion

The present study shows that individuals with DS may be poorer than controls in a series of VSTM tasks, but also suggests that the WM deficit in DS is selective rather than pervasive. The main evidence in the field concerns the dissociation between verbal and VSTM, the former being markedly poorer in DS individuals than in TD children, but the latter relatively preserved (see for example Jarrold et al. 2000). However, recent research has suggested that VSTM might also be impaired in the DS, though only in some respects. The present study clearly supports this conclusion, as individuals with DS – matched for verbal intelligence with controls – were poorer in only some VSTM tasks.

The main result of the present study is the dissociation between tasks measuring spatial-sequential and those measuring spatial-simultaneous WM, the former being relatively preserved in DS, the latter relatively impaired in comparison with TD children of the same mental age. In fact, DS individuals were able to perform even better than controls in spatial-sequential memory, whereas in both spatial-

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1 Similar results were obtained when the analysis took into account the performance for only the most difficult items (from levels 3 to 5) of selective pathway. The selective pathway performance of DS and of TD groups was actually relatively unchanged ($F_{1,66} < 1$ (DS mean = 1.61, SD = 1.95; TD mean = 1.29, SD = 1.48)).
simultaneous tasks they were significantly poorer. Research to date in this field is still unclear, but some indications along these lines were found by Ellis et al. (1989), Laws (2002) and Rowe et al. (2006). This result offers evidence in favour of a dissociation between sequential and simultaneous VSTM (Pazzaglia & Cornoldi 1999; Mammarella et al. 2006), and confirms that the study of a condition of genetically rooted ID may offer relevant information here. The distinction shares some features with two other distinctions offered by the literature on VSTM, namely, between static and dynamic processes (Pickering et al. 1998), and between different types of representation (Lecerf & de Ribaupierre 2005). However, the exact specification of the distinction between simultaneous- and sequential-spatial processes is still under debate. In fact, it could also be argued that simultaneous VSTM also involves sequential processes, insofar as a pattern has to be sequentially explored, and the speed of integration of information collected through sequential exploration becomes critical. However, this remark is diminished in importance by the dissociation found in the present study and by the fact that, when speed was also taken into account, the dissociation persisted.

On the other hand, some authors (e.g. Logie 1995) have stressed that the processing of simultaneously presented locations mainly involves visual processes. In our view, some main differences between visual and spatial-simultaneous VSTM representation concern the fact that in visual representations ‘what’ information (i.e. well-defined objects and their properties) is processed, whereas in the simultaneous case, only ‘where’ information (i.e. locations and their relationships) is processed. Why individuals with DS should be particularly poorer in simultaneous-spatial processing is unclear, but one possibility is that they encounter difficulties when more than one item of spatial information has to be processed at a time, as is the case in the simultaneous tasks.

Further support for the dissociation between spatial-sequential and spatial-simultaneous WM comes from neuroimaging studies. For example, Postle et al. (2000) showed that the ventrolateral and dorsolateral areas of the prefrontal cortex are involved in the maintenance and manipulation of spatial information, respectively (see also Rowe et al. 2000; but see Slotnick 2005 for partially different results). Furthermore, Zarahn et al. (2000) found that the dorsolateral areas of the prefrontal cortex were also involved in maintenance of information concerning the relative location of sequentially presented stimuli. On the basis of our results and of the neuroimaging studies in the literature (see also Pinter et al. 2001), a specific weakness in the functioning of ventrolateral prefrontal cortex in DS individuals can be predicted. However, this prediction is still in need of empirical support.

It is worth noting that the differences found in the spatial-simultaneous task are not linked to aspects related to control processes. In the study of Lanfranchi et al. (2004), in fact, it had been shown that DS individuals performed increasingly poorly in VSTM tasks with increase of active control demanded by the task, whereas this aspect only emerged as a tendency in our present study. However, it should be noted that we have attempted here to minimise the role of control processes in order to focus on the differentiation between sequential and spatial VSTM. Differences in the results of the present study and that by Lanfranchi et al. (2004) might be related to differences in the tasks and in the mental age of participants: in particular, simultaneous spatial memory seems to substantially increase in TD children (Pickering et al. 2001), but not in DS children. This could be due to an increased capacity of TD children to simultaneously treat different pieces of spatial information and to support processing with appropriate strategies. However, the specific implications of the various VSTM tasks we used should be further explored in order to improve them by identifying the boundary conditions, which can affect performance pattern. For example, the complexity levels of our tasks should be better controlled to ensure that passage to a particular level is no more demanding than any other. This point appears particularly critical in span-type tasks, where the range of scores and the variability measures are typically very small.

An important finding of this study is that the processing speed not only was unable to explain the VSTM differences between groups, but also was similar in the two groups, even better – in one measure – in the DS group. Research has repeatedly shown that individuals with ID are slower
than TD individuals of the same age; however, there is no clear evidence for a speed deficit when individuals with ID are matched for verbal mental age. For example, Welsh & Elliott (2001) found a DS weakness in processing speed of verbal information, but not visuospatial. There is a strong debate in the literature on the relationship between processing speed and WM, and it has been suggested that the former could explain the latter and its relationship with intelligence (see Wilhelm & Oberauer 2006 for a discussion). One suggestion might have been that VSWM impairment in a condition of general intellectual impairment, such as DS, was actually due to slower processing speed. However, this was not the case, as the deficit persisted even when three different measures of speed were used as covariates.

In conclusion, our data offer further evidence for the central importance of WM in the study of intellectual impairment, and the specific role of VSWM. Even although DS individuals are generally better in VSWM than in verbal WM, they may present some specific weaknesses in VSWM. A specific deficit in spatial-simultaneous WM was revealed in the relatively large group of DS individuals studied, thus offering further evidence in favour of a dissociation between spatial-simultaneous and spatial-sequential WM. However, the results need further generalisation, through use of larger samples of tasks and different groups of individuals. Furthermore, understanding the exact nature of the distinction between these two VSWM components and how far it is rooted in different biological structures requires further observation and analysis.

References


Visuospatial working memory in Down syndrome


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