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Spatial-simultaneous and spatial-sequential working memory in individuals with Down syndrome: The effect of configuration

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ABSTRACT

Earlier research showed that visuospatial working memory (VSWM) is better preserved in Down syndrome (DS) than verbal WM. Some differences emerged, however, when VSWM performance was broken down into its various components, and more recent studies revealed that the spatial-simultaneous component of VSWM is more impaired than the spatial-sequential one. The difficulty of managing more than one item at a time is also evident when the information to be recalled is structured. To further analyze this issue, we investigated the advantage of material being structured in spatial-simultaneous and spatial-sequential tasks by comparing the performance of a group of individuals with DS and a group of typically-developing children matched for mental age.

Both groups were presented with VSWM tasks in which both the presentation format (simultaneous vs. sequential) and the type of configuration (pattern vs. random) were manipulated.

Findings indicated that individuals with DS took less advantage of the pattern configuration in the spatial-simultaneous task than TD children; in contrast, the two groups' performance did not differ in the pattern configuration of the spatial-sequential task.

Taken together, these results confirmed difficulties relating to the spatial-simultaneous component of VSWM in individuals with DS, supporting the importance of distinguishing between different components within this system. The findings are discussed in terms of factors influencing this specific deficit.

1. Introduction

Down syndrome (DS) is due to abnormalities on chromosome 21 and it is the most common cause of intellectual disability (Kittler, Krinsky-McHale, & Devenny, 2008). The IQ generally ranges between 25 and 70, with few individuals reaching a mental age beyond 7–8 years. The cognitive functioning of individuals with DS is characterized by speech and language impairments (Chapman & Hesketh, 2000) and their difficulties are often greater in expressive language than in language comprehension. Their non-verbal skills are usually less impaired than their verbal abilities and much the same pattern is observable in their performance in working memory (WM) tasks. In particular, several studies found that children (Jarrold & Baddeley, 1997), adolescents (Hulme & Mackenzie, 1992; Marcell & Weeks, 1988), and adults (Kittler, Krinsky-McHale, & Devenny, 2004; Kittler et al., 2008; Numminen, Service, Ahonen, & Ruoppila, 2001) with DS had a weaker verbal

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WM than individuals of the same mental age with severe intellectual disabilities or typical development (TD). On the other hand, most of the research on visuospatial working memory (VSWM) suggested that individuals with DS obtain the same scores as TD children matched for mental age (Jarrold & Baddeley, 1997; Laws, 2002; Numminen et al., 2001). It is important to remember, however, that VSWM is not conceived as a unitary system. According to the Logie (1995) model, it consists of a visual store (known as the *visual cache*) and a rehearsal mechanism (known as the *inner scribe*). Consistent with this distinction, there is a large body of evidence to support a dissociation between visual and spatial memory, based on studies using the paradigm of selective interference (Della Sala, Gray, Baddeley, Allamano, & Wilson, 1999; Klauer & Zhao, 2004; Quinn & McConnell, 1996) and on neuropsychological (Carlesimo, Perri, Turriziani, Tomaiuolo, & Caltagirone, 2001; Farah, Hammond, Levine, & Calvanio, 1988; Luzzatti, Vecchi, Agazzi, Cesa-Bianchi, & Vergani, 1998), and developmental studies (Gathercole & Pickering, 2000; Hamilton, Coates, & Heffernan, 2003; Logie & Pearson, 1997; Pickering, Gathercole, Hall, & Lloyd, 2001; Pickering, Gathercole, & Peaker, 1998).

Lecerf and de Ribaupierre (2005) considered three VSWM components rather than two, including an extra-figural encoding responsible for anchoring objects in relation to an external frame of reference, and an intra-figural encoding based on the relations of each item within a pattern, further broken down into pattern encoding (leading to a global visual image), and path encoding (leading to spatial-sequential positions). Pazzaglia and Cornoldi (1999) and Mammarella, Pazzaglia, and Cornoldi (2008) likewise suggested distinguishing between three components: a visual component in charge of processing shapes and colors, and two kinds of spatial component, both involved in memorizing patterns of spatial locations but presenting them in a different format and consequently using different spatial processes, simultaneous in one case, sequential in the other. Evidence collected with various groups of children supported the distinction between visual and spatial-simultaneous processes (Mammarella, Cornoldi, & Donadello, 2003) and between spatial-simultaneous and spatial-sequential processes (Mammarella et al., 2006).

The possibility of the pattern of performance differing depending on the VSWM components considered also emerges from the literature on individuals with DS. For instance, an early study by Ellis, Woodley Zanthos, and Dulaney (1989) found that individuals with DS have an unimpaired spatial memory, but an impaired 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 blocks task (testing spatial working memory), while the two groups' performance did not differ significantly in a memory for color task (testing visual working memory). Vicari, Bellucci, and Carlesimo (2006) reported individuals with DS having a worse spatial and visual working memory (WM) span than TD individuals, but the difference disappeared after controlling for the role of perceptual and visual abilities.

More recently, Lanfranchi, Carretti, Spanò, and Cornoldi (2009) examined the performance of individuals with DS in spatial WM tasks distinguished in terms of presentation format (simultaneous vs. sequential) and demand for controlled attention. The results reported by Lanfranchi et al. (2009) showed that individuals with DS fared worse than TD children of the same mental age on spatial-simultaneous WM tasks, but not on spatial-sequential tasks, thus supporting the distinctions in VSWM drawn by Pazzaglia and Cornoldi (1999). Lanfranchi et al. tentatively interpreted the DS individuals' worse performance on spatial-simultaneous WM tasks as being due to the difficulty of processing more than one item at a time. This hypothesis finds support in the results of a study by Carretti and Lanfranchi (2010), who showed that individuals with DS were unable to take advantage of structured materials in spatial-simultaneous WM tasks. The task they used contained a confounder, however: the characteristics of the structured pattern were not appropriately controlled because some, but not all, of the pattern could lead to a phonological recoding of the stimuli. This is a point of particular importance because one of the explanations for their results concerned the different use of strategies by DS individuals and TD children.

To study these aspects in depth, we analyzed in the present study whether individuals with DS are as able as TD children of the same mental age to take advantage of structured material in spatial-simultaneous and spatial-sequential tasks. Two versions of spatial-sequential and spatial-simultaneous tasks were devised, i.e. pattern configurations (in which the filled cells were grouped to create a pattern), and random configurations (in which the filled cells were separated by spaces and did not create patterns). Unlike the material used by Carretti and Lanfranchi (2010), all the patterns were controlled to avoid the use of phonological recoding strategies. In particular, patterns similar to the shapes of letters were avoided.

The main aim of the present study was therefore to analyze whether individuals with DS have a general problem in using structured material (i.e. pattern configurations) to memorize information, or whether this problem applies specifically to spatial-simultaneous WM tasks. Previous findings suggested that structured materials are generally easier to recall than non-structured materials. For example, Attneave (1955) found that memory performance for regular figures was better than for irregular figures. To be more specific, he varied the symmetry in the stimulus, observing memory performance in immediate reproduction, delayed reproduction and recognition paradigms. He demonstrated that symmetrical patterns were always remembered better than asymmetrical patterns containing the same number of cells, and that random patterns were more difficult to remember. More recently, Kemps (2001) examined quantitative and structural complexity using a spatial-sequential task (i.e. the Corsi blocks task) and demonstrated that memory span correlated inversely with the number of blocks in a sequence (quantitative complexity), but it improved when the blocks were put in a matrix rather than a random pattern (structural complexity). Judging from these results, TD children will plausibly take advantage of structured materials in both spatial-simultaneous and spatial-sequential tasks, while we would expect less of an improvement in the performance of individuals with DS, particularly in the spatial-simultaneous tasks (in which they revealed greater difficulties) (Carretti & Lanfranchi, 2010; Lanfranchi et al., 2009).