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Training spatial-simultaneous working memory in individuals with Down syndrome

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ABSTRACT

Recent studies have suggested that the spatial-simultaneous component of working memory (WM), which is involved when stimuli are presented simultaneously, is selectively impaired in individuals with Down syndrome (DS).

The main objective of the present study was to examine whether WM performance can be enhanced in individuals with DS by analyzing the immediate and maintenance effects of a training program. For this purpose, 61 individuals with DS were randomly assigned to three groups: one trained on simultaneous components of visuospatial WM; one serving as an active control group, that completed activities on vocabulary; and one serving as a passive control group, that only attended the pre- and post-test and follow-up assessments. The efficacy of the training was analyzed in terms of specific (spatial-simultaneous WM tasks), near transfer (spatial-sequential and verbal WM tasks), far transfer (spatial abilities, everyday competences), and maintenance effects (with a follow-up at 1 month). The results showed an overall significant effect on the WM on the group receiving the training. The benefit was generally specific, however, with some transfer to other WM tasks, but only in the immediate (post-test) assessment.

What this paper adds?

- Previous research has shown that spatial-sequential working memory is an area of weakness in individuals with Down syndrome. The paper analyzes the possibility of improving it through a computerized training. Direct effects, as well as near and far transfer and maintenance effects have been explored. Two control groups have been considered: one active that completed activities on vocabulary, and one passive, that only attended the pre-test, post-test and follow-up assessments. So far only few studies have tested the efficacy of training programs to improve working memory in Down syndrome, and most of them considered only few generalization and maintenance effects. Moreover only very few studies so far considered an active and a passive control group.

1. Increasing spatial-simultaneous working memory in individuals with Down syndrome

Down syndrome (DS) is characterized by abnormalities on chromosome 21 and it is the most common cause of intellectual

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disability (Kittler, Krinsky-McHale, & Devenny, 2008). The cognitive profile of this syndrome is characterized by a relative weakness in verbal abilities, while visuospatial skills seem to be relatively preserved (Dykens, Hodapp, & Finucane, 2000).

One of the cognitive processes explored in DS is WM. Baddeley and Hitch (1974) first described WM as a limited capacity system in which the central executive component interacts with two subsidiary subcomponents used for the temporary storage of different information: the speech-based phonological loop, responsible for the temporary storage of verbal information; and the visuospatial sketchpad, that temporarily stores visuospatial information (see also Baddeley & Logie, 1999). Both storage systems depend on the central executive, an attentional control system of limited capacity.

A different approach to the analysis of WM was proposed by Cornoldi and Vecchi (2003), who suggested that WM functions are not strictly separate, but can be thought of as being linked continuously along horizontal and vertical dimensions. On the vertical continuum, tasks range from relatively passive memory tasks, or *simple storage tasks* (based on the rote rehearsal of items strictly related to the nature of the stimuli to retain) to active memory tasks, or *complex span tasks* (requiring both the retention and a concurrent processing of the information), depending on the level of attentional control required. The horizontal continuum, on the other hand, relates to the various types of material involved (e.g. verbal vs. visuospatial).

For example, when applied to the study of WM in individuals with DS, the above models have identified deficits in executive processing (e.g. Lanfranchi, Jerman, Dal Pont, Alberti, & Vianello, 2010), and verbal WM (e.g. Hulme & Mackenzie, 1992; Jarrold & Baddeley, 1997; Marcell & Weeks, 1988), whereas performance on visuospatial WM tasks has long been considered a point of relative strength in individuals with DS. Several researchers have reported finding their performance in visuospatial WM tasks (typically a Corsi span task) comparable with that of typically-developing (TD) children matched for mental age (e.g. Jarrold & Baddeley, 1997). Some data indicate, however, that the profile of individuals with DS is not homogeneous in the visuospatial domain, and that their abilities depend on which specific aspect is considered (see Yang, Conners, & Merrill, 2014 for a review). Lanfranchi, Carretti, Spanò, and Cornoldi (2009) reported, for example, that a group of individuals with DS performed less well than TD children of the same mental age in spatial-simultaneous tasks, but equally well when a spatial-sequential task was considered. The authors explained their findings on the grounds of the hypothesis advanced by Pazzaglia and Cornoldi (1999; see also Mammarella, Borella, Pastore, & Pazzaglia, 2013; Mammarella, Pazzaglia, & Cornoldi, 2008) that the visuospatial sketchpad originally included in the Baddeley and Hitch model (1974) can be divided into three separate components: a visual component in charge of maintaining and processing shapes and colors; and two spatial components, both involved in memorizing patterns of spatial locations, but presenting and retrieving them in different formats and consequently using different spatial processes, simultaneous in one case, sequential in the other. Data gathered on various groups of children support these distinctions between visual and spatial-simultaneous processes (Mammarella, Cornoldi, & Donadello, 2003), and between spatial-simultaneous and spatial-sequential processes (Mammarella et al., 2006). Further studies attempted to clarify the impairment in spatial-simultaneous tasks seen in individuals with DS (Carretti & Lanfranchi, 2010; Carretti, Lanfranchi, & Mammarella, 2013). For instance, Carretti and Lanfranchi (2010) analyzed the advantage associated with a structured pattern in spatial-simultaneous tasks, and demonstrated that individuals with DS benefited less from structured materials (in which the positions to remember formed a pattern) than a control group of TD children matched for mental age, but only in spatial-simultaneous tasks, not in spatial-sequential ones (Carretti et al., 2013).

In the light of the above-mentioned findings on the particular weakness in spatial-simultaneous WM identified in individuals with DS, the aim of the present study was to investigate the feasibility of improving visuospatial WM in children and adolescents with DS. We feel that it is particularly important to foster spatial-simultaneous WM in individuals with DS not only because it has emerged as an area of weakness in this syndrome, but also because it is particularly involved in school learning activities such as mathematics (Caviola, Mammarella, Cornoldi, & Lucangeli, 2014), and in everyday life activities such as representing spatial environments, and in spatial orientation.

Previous studies on the efficacy of WM training programs in individuals with DS focused on the verbal component of WM, and some authors found improvements in auditory and/or visual span measures, for instance, after using rehearsal training (e.g. Broadley & MacDonald, 1993; Comblain, 1994; Conners, Rosenquist, Arnett, Moore, & Hume, 2008; Conners, Rosenquist, & Taylor, 2001; Laws, MacDonald, & Buckley, 1996). Only a few recent studies have investigated the visuospatial component. For example Bennett, Holmes, and Buckley (2013) assessed the effectiveness of 3 months of training with the preschool version of the Cogmed Working Memory Training (which includes different visuospatial memory training tasks) in reducing the memory difficulties of children with DS between 7 and 12 years old. Their results showed improvements in both trained and untrained short-term visuospatial memory tasks, with no transfer to short-term verbal memory or WM tasks.

In a case study, Costa, Purser, and Passolunghi (2015) administered a school-based treatment targeting visuospatial WM to two individuals with DS for 6 weeks, after which one of them showed good direct and transfer effects to passive and active verbal WM tasks, while the other only showed direct effects on visuospatial WM. The two cases apparently differed in baseline WM level, and the one with a weaker WM at the start improved more than the other.

A recent meta-analysis by Danielsson, Zottarel, Palmqvist, and Lanfranchi (2015) quantitatively reviewed the existing literature on the efficacy of WM training for individuals with intellectual disabilities (ID). More than half of the studies involved individuals with DS as the experimental group. The findings indicated that training procedures combining activities on verbal and visuospatial WM, and focusing on learning and using strategies, seemed to be more effective in improving WM in individuals with ID, but with a stronger effect on passive than on active verbal and visuospatial tasks.

The aim of the present study is to investigate the feasibility of enhancing spatial-simultaneous WM in individuals with DS trough a computerized training specifically readapted on the basis of DS cognitive profile. A computer-based training program was chosen for the present study, partly for its motivational value, but also because previous studies have shown that the computer can be used to