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Numerical skills in children with Down syndrome. Can they be improved?

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ABSTRACT

The present study aims to explore the impact of a numerical skills training program on the basic mathematical skills and logical thinking in children with Down syndrome (DS). The training program was built specifically for children with DS, bearing the strengths and weaknesses of their particular cognitive profile in mind. Two groups of children with DS took part in the study. All children were tested before and after the training on measures of numerical skills and logical thinking. One group of 27 children was trained in numerical skills twice a week for 2 months, for about 30 min per session. A control group of 9 children was not involved in any training session. After training, children in the intervention group performed better in numerical tests, while those in the control group did not. These results suggest that our training program is both feasible and effective for children with Down syndrome.

Down syndrome (DS) is caused by an extra copy of chromosome 21 and it is the most common cause of intellectual disability (Kittler, Krinsky-McHale, & Devenny, 2008). The IQ of individuals with DS generally ranges between 25 and 70, and only a few of them reach a mental age beyond 7 years, with particular problems in abstract reasoning (e.g. Dykens, Hodapp, & Finucane, 2000). These individuals' cognitive functioning is characterized by speech and language impairments (Chapman & Hesketh, 2000), and their difficulties are greater in expressive language than in auditory language comprehension. On the other hand, their non-verbal skills are usually less severely impaired, although recent studies have shown a variable picture depending on which aspect of visuospatial cognition is considered (Yang, Conners, & Merrill, 2014). Research has also shown that individuals with DS are extremely limited in terms of memory span, especially in auditory verbal memory (Jarrold, Baddeley, & Hewes, 1999; Vicari, Carlesimo, & Caltagirone, 1995), and in executive functions, particularly working memory (Lanfranchi, Baddeley, Gathercole, & Vianello, 2012; Lanfranchi, Cornoldi, & Vianello, 2004), inhibition, planning, and cognitive flexibility (Lanfranchi, Jerman, Alberti, Dal Pont, & Vianello, 2010; Lee et al., 2011).

Several studies have reported that individuals with DS have difficulties in mathematics too (e.g. Gelman & Cohen, 1988; Nye, Fluck, & Buckley, 2001; Porter, 1999). The origin of these difficulties is a debated topic. Some researchers support the *developmental hypothesis* (Zigler, 1969), according to which the numerical difficulties of individuals with DS stem from their low general cognitive level (e.g. Caycho, Gunn, & Siegal, 1991). For instance, Lanfranchi, Berteletti, Torrisi, Vianello, and Zorzi (2015) found that numerical estimation and the developmental transition between logarithmic and linear estimation

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patterns in children with DS resembles the picture seen in typically developing children of the same mental age (MA) rather than that of children of the same chronological age; linearity was also related to their cognitive level. Other studies support the *difference hypothesis* (e.g., Gelman & Cohen, 1988; Nye et al., 2001), focusing on the worse performance of individuals with DS by comparison with typically developing children of the same MA. Gelman and Cohen (1988), for example, found that children with DS performed less well in both counting and cardinality tests. Porter (1999) likewise found that children with DS were unable to detect errors violating counting principles. Nye et al. (2001) reported that children with DS produced fewer words and shorter counting sequences, as well as counting smaller arrays of objects, than typically developing children matched for MA. Finally, numerosity discrimination is less efficient in individuals with DS than in typically developing children of the same MA, but only for small numerosities (i.e., within the subitizing range; Paterson, Girelli, Butterworth, & Karmiloff-Smith, 2006; Sella, Lanfranchi, & Zorzi, 2013), while for larger numerosities individuals with DS are as capable as typically developing children of the same MA (Camos, 2009; Paterson et al., 2006; Sella et al., 2013).

Another important issue concerning mathematical abilities in individuals with DS is whether they have only a superficial or a thorough understanding of counting (for a review, see Abdelahmeed, 2007). Some studies have suggested that individuals with DS use counting as a mere routine, lacking an understanding of cardinality principles. Gelman and Cohen (1988), for example, found that children with DS performed worse than children of the same MA in both counting and cardinality tests. Similarly, Porter (1999) also found that children with DS were unable to detect errors that violated counting principles. Other studies have reported instead that individuals with DS understand cardinality principles and counting procedures just as well as typically developing children of the same MA, suggesting an in-depth understanding of math processes. For example, Caycho et al. (1991) found a similar understanding of counting principles in children with DS and typically developing children matched on receptive vocabulary. Bashash, Outhred and Bochner (2003) also examined the performance of a sample of children with DS aged from 7 to 18 years, and found that the whole sample was able to apply the three fundamental principles of counting in several counting tasks. Finally, Nye et al. (2001) reported a pattern of results indicating that children with DS had a conceptual understanding of cardinality even though they made more mistakes in counting procedures than typically developing children of the same MA.

In the light of this literature, and of the evidence of individuals with DS having problems with mathematics, the present study was designed to examine the feasibility of improving the numerical skills of children with DS. In particular, we tested the effectiveness of a program adapted specifically to DS, bearing these individuals' particular cognitive profile in mind. As a consequence, most of the learning activities included a higher proportion of visuo-spatially than of verbally presented materials. The activities were based on concrete situations, the working memory load was reduced, and the use of verbal instructions was minimized. Situations in the form of games were used, rather than formal lessons, in order to sustain the child's motivation.

It is well known that numerical skills encompass a broad range of abilities that are gradually acquired as children grow up. The fundamental skills to develop involve lexical, semantic, and pre-syntactic processes, as well as counting skills. The lexical processes relate to learning number names and stable number sequences (Temple, 1991, 1997). The semantic processes provide a link between numbers and their quantity representations (Cohen & Dehaene, 2000; McCloskey, Caramazza, & Basili, 1985). The pre-syntactic processes involve spatial relationships between digits, including an understanding of place values. Lexical and semantic competences support counting skills in preschool children. Counting is essentially a form of measurement and calculation. For example, the simple additions taught at school can be seen as a natural extension of counting. Our training program was designed to foster numerical skills in these four areas (counting and lexical, semantic and pre-syntactic).

The aim of the present study was therefore to explore the effectiveness of our training program in improving lexical, semantic and pre-syntactic processes, as well as counting abilities, in individuals with DS. We additionally aimed to explore near transfer effects to other aspects of logical thinking not trained directly by our program.

1. Method

1.1. Participants

An experimental group of 27 children with DS (15 males) with a mean chronological age of 11:9 years (SD = 2:1, range 10–15), and a mean mental age of 5:4 years (*SD* = 0:10) took part in the study. These children received the training and formed our training group (TG).

A passive control group (CG) of 9 children with DS (5 males) was matched with the TG for chronological age (M_{age} = 12:2 years, SD 2:6 years, range 10–15) and MA (M_{age} = 5:7 years, SD = 0:9). These children only took part in the pre- and post-training assessments. The proportion of males was the same in the two groups (55.6%).

Some children were contacted through mainstream schools, some through public clinical services, and some through an association of people with Down syndrome. All these institutions were informed about the purposes of the study, in both oral and written form. Exclusion criteria were associated psychiatric disorders or severe visual or hearing impairments. According to these criteria 3 children were not contacted. All the remaining children aged between 10 and 15 at the schools, services, and association contacted were invited to take part in the study. We chose this age range because we believe that it is at this age that most children with Down syndrome reach a mental age of between 4 and 6 years that we consider the most