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Local and global processing in block design tasks in children with dyslexia or nonverbal learning disability

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ABSTRACT

Visuo-constructive and perceptual abilities have been poorly investigated in children with learning disabilities. The present study focused on local or global visuospatial processing in children with nonverbal learning disability (NLD) and dyslexia compared with typically-developing (TD) controls. Participants were presented with a modified block design task (BDT), in both a typical visuo-constructive version that involves reconstructing figures from blocks, and a perceptual version in which respondents must rapidly match unfragmented figures with a corresponding fragmented target figure. The figures used in the tasks were devised by manipulating two variables: the perceptual cohesiveness and the task uncertainty, stimulating global or local processes.

Our results confirmed that children with NLD had more problems with the visuo-constructive version of the task, whereas those with dyslexia showed only a slight difficulty with the visuo-constructive version, but were in greater difficulty with the perceptual version, especially in terms of response times. These findings are interpreted in relation to the slower visual processing speed of children with dyslexia, and to the visuo-constructive problems and difficulty in using flexibly-experienced global vs local processes of children with NLD. The clinical and educational implications of these findings are discussed.

1. Introduction

1.1. Learning disabilities and visuospatial abilities

The term 'specific learning disorder' is used to describe a group of learning difficulties characterized by an impaired performance in a particular academic domain (e.g. reading decoding or comprehension, spelling, written expression, or calculation), despite an average or above average intelligence (DSM5, American Psychiatric Association [APA], 2013).

A large subgroup of children with specific learning disorders has developmental dyslexia, characterized by problems with accurate or fluent decoding, and weak spelling abilities (DSM5, APA, 2013). Deficits involving the verbal abilities (including phonological processing) have been extensively described in children with dyslexia (Ackerman and Dykman, 1993 Gould & Glencross, 1990; Helland and Asbjørnsen, 2004; Palmer, 2000), while there are conflicting findings on these children's performance in visuospatial tasks (Garcia, Mammarella, Tripodi, & Cornoldi, 2014). Previous studies found higher (Swanson, 1984; von Károlyi, 2001), lower (Benton, 1984; Menghini, Finzi, Carlesimo & Vicari, 2011; Morris et al., 1998; Winner et al., 2001), or

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comparable visuospatial abilities of individuals with dyslexia with those of controls (Jeffries and Everatt, 2004; Siegel & Ryan, 1989; Sinatra, 1988; Winner et al., 2001). It has also been reported, however, that children with dyslexia may have deficits in visual attention tasks (Bosse, Tainturier, & Valdois, 2007; Heiervang, & Hugdahl, 2003), or difficulties in tasks that measure processing speed, such as the WISC Coding and Symbol Search (Kail, Hall & Caskey, 1999), which involve visual stimuli; and their weakness becomes particularly evident when response times are considered (see also Cornoldi, Giofré, Orsini, & Pezzuti, 2014; Shanahan et al., 2006). One likely explanation for the diversity seen in the above-mentioned results in children with dyslexia concerns the different measures used to assess visuospatial abilities (e.g. tasks that involve copying unnamed complex visual forms, pattern-matching tasks, the block design task), which do not seem to involve the same visuospatial processes (von Károlyi, Winner, Gray & Sherman, 2003). For example, both visuo-constructive and visuospatial memory skills are involved in Rey's Complex Figure test (Rey, 1941; Rey, 1968), in which children are asked to copy a complex figure and then, a few minutes later, to reproduce it from memory. On the other hand, memory is not primarily involved in the block design task (WISC, WAIS: Wechsler, 2003; Wechsler, 2008), which demands visuo-constructive abilities, since children are asked to reproduce a configuration consisting of several colored blocks within a limited time interval. Another explanation for the inconsistent results found in children with dyslexia may relate to the hypothesis that there are different subtypes of this condition, and only some children with dyslexia would have visual processing deficits (Cestnick and Coltheart, 1999).

Unlike children with dyslexia, with their typically poor reading skills, other children with specific learning disorders feature deficits in the non-verbal area, such as visuospatial and visuo-constructive difficulties (Semrud-Clikeman, Walkowiak, Wilkinson, & Christopher, 2010), fine motor coordination impairments, and poor mathematics achievement (Mammarella et al., 2013), associated with well-developed language skills (Rourke and Tsatsanis, 2000). This condition is typically described as a nonverbal learning disability (NLD), but has also been termed: *nonverbal disorder of learning* (Myklebust, 1975); *visuospatial learning disability* (Cornoldi, Venneri, Marconato, Molin, & Montinari, 2003); and *right hemisphere developmental learning disability* (Tranel, Hall, Olson, & Tranel, 1987). The formulation of an inclusive set of criteria is still under debate (Mammarella and Cornoldi, 2014; Semrud-Clikeman, Fine & Bledsoe, 2013; Spreen, 2011), and this condition has not been included in either the Diagnostic and Statistical Manual of Mental Disorders (DSM 5; APA, 2013) or the International Classification of Diseases and Related Disorders (ICD-10; World Health Organization, 1992), although this subgroup of NLD seems to have specific, clinically important characteristics that warrant careful investigation (Cornoldi, Fine, & Mammarella, 2016).

Although a crucial aspect of the NLD profile relates to poor visuospatial abilities, the visuo-constructive and visual perceptual skills of children with this condition have been less explored than abilities such as visuospatial working memory (e.g., Mammarella and Cornoldi, 2005). Available evidence suggests that children with NLD may be impaired in tasks involving visuo-constructive skills, and particularly in the Bender Gestalt test (Gross-Tsur, Shalev, Manor, & Amil, 1995), the Rey-Osterrieth complex figure test (Gross-Tsur et al., 1995; Semrud-Clikeman et al., 2010), and the visual-motor integration test (Roman, 1998; Semrud-Clikeman et al., 2010).

Concerning their visual perceptual abilities, Rourke (1989), Rourke (1995) hypothesized a neuropsychological deficit in the visual perception of children with NLD when it came to discriminating between and recognizing visual details and relationships, but no objective data were reported. Roman (1998) subsequently described a single case of a child with NLD performing poorly in the Benton Judgment of Line Orientation test (Benton, Hamsher, Varney, & Spreen, 1983). Semrud-Clikeman et al. (2010) reported similar findings in a group of children with NLD using the same task, and Chow and Skuy (1999) showed that children with NLD performed less well than children with specific language disorders on gestalt configuration tasks. Finally, Mammarella and Pazzaglia (2010) found that children at risk of NLD performed worse than controls in visual perception tasks that entailed comparing visual stimuli and locations in space (without involving memory), and in reversing an ambiguous figure.

To date, however, few studies have distinguished explicitly between the global and local characteristics of a perceptual stimulus in children with dyslexia (e.g. Keen and Lovegrove, 2000), and none have explored these perceptual characteristics in cases of NLD, despite this distinction proving crucial when examining the perceptual difficulties associated with other, related developmental disabilities (e.g. Happé, 1999), and despite evidence to suggest that it could be relevant in the case of NLD as well (Chow and Skuy, 1999).

1.2. Global and local visuospatial processing

In the field of developmental disabilities, an interesting approach to exploring visuo-constructive and perceptual abilities consists in investigating global vs local visuospatial processing. In fact, people may use different processing styles: a global processing style in which they consider the gestalt of a set of stimuli; and a local processing style in which they focus on details (Förster and Dannenberg, 2010; Navon, 1977; Schooler, 2002). The classic experiment that best illustrates the distinction between these processing styles is Navon's global-local paradigm dating from 1977 (Cassia, Simion, Milani, & Umiltà, 2002; Forster & Dannenberg, 2010), which used hierarchical patterns consisting of large letters composed of numerous small letters (i.e., a large "H" composed of small "S" letters). Previous research showed that participants were quicker to identify the global than the local target letters. This result suggested a sequential processing, from global to local level, providing evidence for a global dominance hypothesis (Förster and Higgins, 2005). Some clinical populations, such as children with autism spectrum disorders (Caron, Mottron, Berthiaume & Dawson, 2006; Happé, 1999), Williams syndrome (Farran, Jarrold & Gathercole, 2003), or Down syndrome (Bellugi, Lichtenberger, Jones, Lai, & St George, 2000), showed no such classical global effect, however. In particular, individuals with autism spectrum disorders (ASD) revealed a diminished sensitivity to perceptual cohesiveness and a locally oriented approach to processing visuospatial material (Caron et al., 2006 Happé, 1999; Happé and Frith, 2006; Mottron, Burack, Iarocci, Belleville, & Enns, 2003). In other words, children with ASD found it easier to divide a whole into parts, while they struggled when they had to organize visuospatial stimuli globally (Shah and