Research in Developmental Disabilities 34 (2013) 3997–4008

Contents lists available at ScienceDirect

Research in Developmental Disabilities

Space representation in children with dyslexia and children without dyslexia: Contribution of line bisection and circle centering tasks

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ARTICLE INFO

Article history:
Received 4 April 2013
Received in revised form 17 August 2013
Accepted 19 August 2013
Available online

Keywords:
Dyslexia
Children
Space representation
Line bisection
Circle centering
Spatial attention

ABSTRACT

Line bisection tasks (different space locations and different line lengths) and circle centering tasks (visuo-proprioceptive and proprioceptive explorations, with left or right starting positions) were used to investigate space representation in children with dyslexia and children without dyslexia. In line bisection, children with dyslexia showed a significant rightward bias for central and right-sided locations and a leftward bias for left-sided location. Furthermore, the spatial context processing was asymmetrically more efficient in the left space. In children without dyslexia, no significant bias was observed in central lines but the spatial context processing was symmetrical in both spaces. When the line length varied, no main effect was shown. These results strengthen the 'inverse pseudoneglect' hypothesis in dyslexia. In the lateral dimension of the circle centering tasks, children showed a response bias in the direction of the starting hand location for proprioceptive condition. For radial dimension, the children showed a forward bias in visuo-proprioceptive condition and more backward error in proprioceptive condition. Children with dyslexia showed a forward bias in clockwise exploration and more accurate performance in counterclockwise exploration for left starting position which may be in accordance with leftward asymmetrical spatial context processing in line bisection. These results underline the necessity to use the line bisection task with different locations as an appropriate experimental paradigm to study lateral representational bias in dyslexia. The contribution of the present results in the understanding of space representation in children with dyslexia and children without dyslexia is discussed in terms of attentional processes and neuroanatomical substrate.

1. Introduction

Developmental dyslexia is classically described as a neurological condition afflicting the school-age population that persists throughout the lifespan (Habib, 2000). This mild hereditary neurological disorder manifests as a persistent difficulty in learning to read sometimes associated with sensory difficulties in the visual, auditory and tactile domains, problems with balance and motor control (Nicolson & Fawcett, 1990; Quercia, Demougeot, Dos Santos, & Bonnetblanc, 2011; Ramus, 2003;

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http://dx.doi.org/10.1016/j.ridd.2013.08.031

Stein & Walsh, 1997; Vieira, Quercia, Michel, Pozzo, & Bonnetblanc, 2009) with otherwise normal intellectual functioning and educational opportunities (for a review see Shaywitz, 1998). Several theories have been proposed to account for the various deficits in these numerous functions. One of the most influential theories is the phonological theory of dyslexia. The phonological theory postulates that children with dyslexia have a specific impairment in the representation, storage and/or retrieval of speech sounds. It explains reading impairment of dyslexia by appealing to the fact that learning to read an alphabetic system requires learning the grapheme–phoneme correspondence, i.e. the correspondence between letters and constituent sounds of speech. If these sounds are poorly represented, stored or retrieved, the learning of grapheme–phoneme correspondences, the foundation of reading for alphabetic systems, is affected accordingly (Ramus et al., 2003). An alternative theoretical approach gives a primary explanatory role to the sensory and/or motor symptoms. This approach has led to the formulation of theories of dyslexia tracing the cause of reading disability back to auditory processing deficits (via the phonological deficit) (e.g. Cantiani, Lorusso, Valnegri, & Molteni, 2010), visual dysfunction (Lovegrove, Heddle, & Slaghuis, 1980), and/or cerebellar dysfunction (Nicolson & Fawcett, 2011; Nicolson, Fawcett, & Dean, 2001). This theory accounts for reading disabilities both through auditory–phonological and visual–spatial deficits, and encompasses all known cognitive, sensory and motor manifestations of dyslexia (see Stein & Walsh, 1997 for a review). Furthermore, early indicators of dyslexia could be detected at preschool and primary education as psychomotor ability (e.g. spatio-temporal orientation, grapho-motor ability), neuro-physiological development and cognitive mechanisms (e.g. auditory and visual perception, short term memory), phonological awareness, prereading and prewriting skills (Kujala & Näätänen, 2001; Rouse & Fantuzzo, 2006; Temple et al., 2003; Zakopoulou et al., 2011).

1.1. Dyslexia and spatial attention

Dyslexia is known to co-occur with other developmental disorders (e.g. Snowling, 2012). The evidence for visual–spatial or auditory attention deficits in children with dyslexia and adults is mixed (e.g., Gooch, Snowling, & Hulme, 2011). In children with dyslexia the manifestations of visuo-spatial disturbances take different forms. They may manifests as deficits in target stimuli distinction amongst distractive stimuli (Casco, Tressoldi, & Dellantonio, 1998; Iles, Walsh, & Richardson, 2000; Wright, Conlon, & Dyck, 2012), as increase in the time necessary for the identification of visual stimuli (Buchholz & Aimola Davies, 2007; Hari, Valta, & Uutela, 1999; Visser, Boden, & Giaschi, 2004), as a diffuse spatial distribution with difficulties in focally orienting visual attention (Facoetti, Paganoni, & Lorusso, 2000) or as an alteration of the processes used for flexibility of attention (Facoetti, Lorusso, Paganoni, Umiltà, & Mascetti, 2003; Facoetti & Turatto, 2000). It is likely that these deficits contribute to reading disorders in dyslexia. It has been shown that the visual attention span, which corresponds to the amount of distinct visual elements which can be processed in parallel in a multi-element array, is reduced in children with dyslexia (Bosse, Tainturier, & Valdois, 2007). Even if the phonological and visual attentional processing skills may contribute independently to reading performance (Valdois, Bosse, & Tainturier, 2004), visual attention span could appear as a second and distinct cognitive factor in the origin of dyslexia (Peyrin et al., 2012).

1.2. Asymmetrical distribution of spatial attention in dyslexia

In addition to these attentional disturbances in dyslexia, lateralized visuo-spatial impairments which concern the left part of the space have been shown. In psychological temporal order judgement and line motion illusion task, adults with dyslexia processed stimuli in left visual hemifield more slowly than normal readers (Hari, Renvall, & Tanskanen, 2001). Children with dyslexia exhibited a reduced interference effect in the left visual field (left inattention) concomitant with a strong interference effect in the right visual field (Facoetti & Turatto, 2000) and asymmetrical distribution of spatial attention (left inattention) measured by reaction times with spatial gradient paradigm (Facoetti & Molteni, 2001). Many studies showed that lesion to the right parietal cortex elicit left attentional deficits (e.g. Posner, Walker, Friedrich, & Rafal, 1987; Smania et al., 1998). These findings point out to a reduced right parietal cortex functioning in children with dyslexia during visual information processing (e.g. Hari et al., 2001; Lorusso, Facoetti, Toraldo, & Molteni, 2005; Sireteanu, Goertz, Bachert, & Wandert, 2005) and more generally on supramodal spatial attention (Stein & Walsh, 1997).

1.3. Space representation in dyslexia

Asymmetrical spatial attention is responsible for asymmetrical distribution of space representation which is considered as the mental representation of the environment topographically structured and mapped across the brain (Bisiach, Luzzatti, & Perani, 1979). The most classical task used to assess space representation is the line bisection where individuals have to estimate the centre of horizontal lines (Jewell & McCourt, 2000). Children with dyslexia exhibit a small rightward bias in a perceptual (Sireteanu et al., 2005) and manual (Waldie & Hausmann, 2010) bisection tasks. In a recent study we observed a significant rightward bias in line bisection with a preservation of the context spatial processing when using a cueing paradigm (geometric symbols placed on the extremities of the lines). Indeed children with dyslexia showed a displacement of their spontaneous rightward bias in the direction of the unilaterally cued extremities. This means that children with dyslexia showed a distinctive bias in space representation with an intermediate level between left neglect (mild rightward bias in space representation compared to brain damaged neglect patients) and pseudoneglect (healthy preservation of the