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Graphomotor skills in children with developmental coordination disorder (DCD): Handwriting and learning a new letter

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ABSTRACT

The aim of the present study was to analyze handwriting difficulties in children with developmental coordination disorder (DCD) and investigate the hypothesis that a deficit in procedural learning could help to explain them. The experimental set-up was designed to compare the performances of children with DCD with those of a non-DCD group on tasks that rely on motor learning in different ways, namely handwriting and learning a new letter. Ten children with DCD and 10 non-DCD children, aged 8–10 years, were asked to perform handwriting tasks (letter/word/sentence; normal/fast), and a learning task (new letter) on a graphic tablet. The BHK concise assessment scale for children's handwriting was used to evaluate their handwriting quality. Results showed that both the handwriting and learning tasks differentiated between the groups. Furthermore, when speed or length constraints were added, handwriting was more impaired in children with DCD than in non-DCD children. Greater intra-individual variability was observed in the group of children with DCD, arguing in favor of a deficit in motor pattern stabilization. The results of this study could support both the hypothesis of a deficit in procedural learning and the hypothesis of neuromotor noise in DCD.

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1. Introduction

Developmental coordination disorder (DCD) is a condition that occurs in childhood and affects motor coordination. The DSM-5 criteria include motor performances that are considerably below the expected level, given the child's chronological age and previous opportunities for skill acquisition. Furthermore, the difficulties should disturb daily-life activities, and should not be due to a general medical condition (American Psychiatric Association, 2013).

There is a wide variation in how the disorder presents. DCD can affect gross-motor skills (e.g., Asonitou, Koutsouki, Kourtessis, & Charitou, 2012) and balance (e.g., Deconinck, Savelsbergh, De Clercq, & Lenoir, 2010; Tsai, Wu, & Huang, 2008), but also bimanual coordination (e.g., Jover, Schmitz, Centelles, Chabrol, & Assaiante, 2010) and fine-motor skills (Smits-Engelsman, Niemeijer, & van Galen, 2001). Graphomotricity is a crucial fine-motor skill in the classroom, whether it involves drawing or handwriting. Children with DCD have been shown to be less accurate and faster than non-DCD children in performing the flower-trail drawing item of the Movement Assessment Battery for Children (M-ABC, Henderson & Sugden, 1992; Smits-Engelsman et al., 2001) and the cyclic joining of two targets (Bo, Bastian, Kagerer, Contreras-Vidal, & Clark, 2008; Smits-Engelsman, Wilson, Westenberg, & Duysens, 2003).

Epidemiological studies have highlighted frequent handwriting problems in DCD. Despite considerable heterogeneity, 78–88% of children with DCD display poor handwriting or dysgraphia (O'Hare and Khalid, 2002; Schoemaker, Niemeijer, Reynders, & Smits-Engelsman, 2003; Vaivre-Douret et al., 2011). Above and beyond the frequency of dysgraphia, several studies have investigated the specific handwriting characteristics of children with DCD. The handwriting produced by children with DCD is less legible and less well organized (Jolly, Huron, Albaret, & Gentaz, 2010; Rosenblum & Livneh-Zirinski, 2008; Rosenblum, Margieh, & Engel-Yeger, 2013; Smits-Engelsman et al., 2001). Analysis of the process of handwriting (Jolly et al., 2010; Smits-Engelsman et al., 2001) or producing loops (Overvelde & Hulstijn, 2011) has revealed more deceleration and acceleration peaks in the movements (i.e., greater disfluency). Furthermore, children with DCD write fewer letters than non-DCD children when copying out a paragraph (Prunty, Barnett, Wilmut, & Plumb, 2013; Rosenblum & Livneh-Zirinski, 2008; Rosenblum et al., 2013). By contrast, they spend more time pen in air and on paper than non-DCD children (Rosenblum & Livneh-Zirinski, 2008; Rosenblum et al., 2013), and exhibit greater handwriting velocity (Jolly et al., 2010; Smits-Engelsman et al., 2001). Indeed, Prunty et al. (2013) demonstrated that rather than being slow, children with DCD spend more time pausing than their non-DCD peers. Although poor handwriting may be related to many intrinsic and extrinsic factors (Feder & Majnemer, 2007), three main hypotheses have been put forward to explain the handwriting difficulties encountered by children with DCD. The first hypothesis is that they have a problem with muscle stiffness and the recruitment of muscle force (Chang & Yu, 2010; Smits-Engelsman et al., 2001), while the second hypothesis concerns difficulty organizing the motor output (Rosenblum et al., 2013). The third hypothesis is that motor learning ability is less effective. In other words, children find it hard to switch from feedback to feedforward control of handwriting, which prevents the stabilization of a given motor pattern (Chang & Yu, 2010; Velay et al., 2009). In the present study, we aimed to test the hypothesis whereby a deficit in motor learning explains the graphomotor difficulties observed in children with DCD.

Nicolson and Fawcett (2007, 2011) and Nicolson, Fawcett, Brookes, and Needle (2010) surmised that the difficulties observed in many learning disorders can be attributed to a deficit in the procedural learning system. Two types of protocol have been developed to investigate motor learning in DCD: the serial reaction time paradigm (SRT) and the learning of a new motor skill per se (for a review, see Bo & Lee, 2013). To date, studies using the SRT paradigm have yielded inconclusive results (Gheysen, Van Waelvelde, & Fias, 2011; Lejeune, Catale, Willems, & Meulemans, 2013; Wilson, Maruff, & Lum, 2003). As for the learning of a new motor skill, Missiuna (1994) showed that despite a similar rate of learning and ability to generalize the movements they had learned, children with DCD were slower and took longer to react to changes than non-DCD children. Handwriting is clearly a procedural task, and graphomotor learning may therefore offer a particularly relevant means of validating this hypothesis. Unfortunately, studies exploring graphomotor learning in DCD are scarce. Velay and