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Examining the relationship between motor assessments and handwriting consistency in children with and without probable Developmental Coordination Disorder

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ABSTRACT

Children with Developmental Coordination Disorder (DCD) often experience difficulties in handwriting. The current study examined the relationships between three motor assessments and the spatial and temporal consistency of handwriting. Twelve children with probable DCD and 29 children from 7 to 12 years who were typically developing wrote the lowercase letters "e" and "l" in cursive and printed forms repetitively on a digitizing tablet. Three behavioral assessments, including the Beery–Buktenica Developmental Test of Visual-Motor Integration (VMI), the Minnesota Handwriting Assessment (MHA) and the Movement Assessment Battery for Children (MABC), were administered. Children with probable DCD had low scores on the VMI, MABC and MHA and showed high temporal, not spatial, variability in the letter-writing task. Their MABC scores related to temporal consistency in all handwriting conditions, and the Legibility scores in their MHA correlated with temporal consistency in cursive "e" and printed "l". It appears that children with probable DCD have prominent difficulties on the temporal aspect of handwriting. While the MHA is a good product-oriented assessment for measuring handwriting deficits, the MABC shows promise as a good assessment for capturing the temporal process of handwriting in children with DCD.

1. Introduction

Children with Developmental Coordination Disorder (DCD) are characterized as having motor impairment that interferes with their activities of daily living. Criteria for diagnosis of DCD include (a) the acquisition and execution of coordinated movements is substantially below that expected given the individual's chronological age and daily living; (b) the motor deficits significantly and persistently interfere with academic achievement and activities of daily living; and (c) the motor deficits cannot be explained by intellectual disability or visual impairment and are not due to a neurological condition (e.g., cerebral palsy, muscular dystrophy, degenerative disorder, APA, 2013). Up to 6% of American school children are thought to

Abbreviations: DCD, Developmental Coordination Disorder; VMI, The Beery–Buktenica Developmental Test of Visual-Motor Integration; MHA, The Minnesota Handwriting Assessment; MABC, The Movement Assessment Battery for Children.

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be affected by DCD (APA, 2000) and as high as 87% of these children will not "grow out" of their difficulties (Cousins & Smyth, 2003).

Difficulties in handwriting are especially prevalent among children with DCD (Smits-Engelsman, Niemeijer, & van Galen, 2001), and it is known that children with DCD are at particular risk for handwriting deficiency (O'Hare, 2007; O'Hare & Khalid, 2002). Such difficulties interfere with their abilities in essay writing (Graham, 1990), typing (Freeman, MacKinnon, & Miller, 2004), calculating (Sandler et al., 1992), and reading and spelling (Nazir, Jeannerod, Hauk, Thomson, & Goswami, 2008). Despite the widespread use of keyboards, handwriting is still one of the most important activities in school (McHale & Cermak, 1992; Rosenblum, Parush, & Weiss, 2003a). Studies indicate that difficulty with handwriting in children with DCD is a major predictor of more general learning difficulties later on in adolescence and adulthood (e.g., Graham, 1990; Harvey & Henderson, 1997). Unfortunately, however, assessing handwriting in DCD is difficult as standardized tools and assessments evaluating handwriting performance in this population are particularly scarce (Blank, Smits-Engelsman, Polatajko, & Wilson, 2012).

Some researchers believe that the fundamental component of handwriting is Visual-Motor Integration (e.g., Tseng & Murray, 1993). Previous studies revealed that the scores on the Beery–Buktenica Developmental Test of Visual-Motor Integration (VMI; Beery, Buktenica, & Beery, 2010) correlated with handwriting performance in young children (e.g., Cornhill & Case-Smith, 1996; Daly, Kelley, & Krauss, 2003) and could be used for screening and early identification of handwriting difficulties in a clinical setting (e.g., Marr & Cermak, 2002). However, other researchers have claimed that instead of Visual-Motor Integration tasks, standardized handwriting assessment tools should be used when evaluating handwriting performance (e.g., Hammerschmidt & Sudsawad, 2004). The Minnesota Handwriting Assessment (MHA, Reisman, 2004) has been identified to be one of the most promising tools to discriminate poor handwriters. Until now, however, neither the VMI nor the MHA have been evaluated and validated in DCD.

Previous studies reveal that children with DCD tend to have poor letter arrangement and high spatial variability (Rosenblum & Livneh-Zirinski, 2008). Smits-Engelsman and Van Galen (1997) have claimed that control of spatial accuracy, allograph retrieval, and size control are the discriminating features of handwriting in children with DCD. The same group has also reported that the Movement Assessment Battery for Children (MABC, Henderson & Sugden, 2007) is a good predictor of handwriting difficulties (Smits-Engelsman et al., 2001) in DCD. In particular, performance on the "flower tracing" item (one of the manual-dexterity items in MABC) maybe useful for evaluating handwriting deficits in children with DCD (Smits-Engelsman et al., 2001). In that study, handwriting quality was based on the writing product (a standardized assessment on a sample of handwriting) and teachers' questionnaires. These measures only focus on the handwriting legibility or readability; however it is argued that handwriting assessments based on the handwriting product are of limited value due to static characteristics and low reliability. In addition, it is believed that a comprehensive description of the real-time, dynamic characteristics of a child's handwriting can provide insight into the motor control mechanisms of handwriting and an understanding of the underlying mechanism of handwriting difficulties (See Rosenblum & Livneh-Zirinski, 2008). Therefore, the performance on the "flower tracing" in MABC may only reflect the spatial characteristics of handwriting, as it is a similar task. Thus, a comprehensive analysis of both the handwriting product and the real-time dynamic characteristics of a child's handwriting process is needed.

Recently, it has been argued that deficits in temporal control significantly relate to poor handwriting performance in children with DCD (e.g., Ben-Pazi, Kukke, & Sanger, 2007; Rosenblum & Livneh-Zirinski, 2008). Multiple studies revealed that children with DCD demonstrated much higher temporal variability than age-matched controls in a variety of tasks that require precise timing (Ben-Pazi et al., 2007; Bo, Bastian, Contreras-Vidal, Kagerer, & Clark, 2008). High temporal variability has been found in drawing (Bo, Bastian, Contreras-Vidal, et al., 2008), perceptual discrimination, and finger tapping (i.e., Lundy-Ekman, Ivry, Keele, & Woollacott, 1991). A few studies focusing on temporal aspects of handwriting have reported that children with DCD tend to write more slowly (Tseng & Chow, 2000) and variably in time than their controls (Rosenblum, Parush, & Weiss, 2003b). In particular, children with poor handwriting showed more frequent "in air" movements above the writing surface than the proficient writers (Rosenblum, Parush, & Weiss, 2003b). Rosenblum and Regev (2013) have asked children with and without DCD to write their name, copy a paragraph, and write alphabet letters; and reported that children with DCD had significantly slower writing speed than their control participants. Such slower speed in DCD was due to the longer "on paper" time per stroke and the longer "in air" movements during writing. Furthermore, children with slower speed in handwriting demonstrated higher temporal variability in an interactive metronome task when they were asked to clap with their hands and tap their toes with a fixed rhythm. Similarly, Ben-Pazi et al. (2007) reported a strong relationship on temporal variability between rhythmic tapping and repetitive letter-writing tasks. High temporal variability in handwriting specifically relates to a group of children who had poor performance in rhythmic finger tapping. Taken together, these findings indicate that the deficits in temporal controls may play a significant role in handwriting deficits in children with DCD. The evaluation of temporal process of handwriting, in addition to the spatial domain, can help us understand the underlying mechanism of handwriting difficulties in DCD.

Proficient handwriting refers to the ability to produce legible text in a reasonable amount of time (see Rosenblum, Parush, et al., 2003a for details). Wann (1987) has argued that one of the most salient features of "good" handwriting is temporal and spatial consistency across repetition over time due to the minimized physical cost of movements (e.g., less jerky movements). Children with DCD have impairment in both the temporal and spatial characteristics of handwriting (e.g., Rosenblum & Livneh-Zirinski, 2008; Rosenblum, Parush, et al., 2003b). In this context, understanding the relationships between behavioral assessments and the characteristics of handwriting in DCD can have significant contributions to the DCD evaluation conducted in clinical settings.