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Timing abilities among children with developmental coordination disorders (DCD) in comparison to children with typical development

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ABSTRACT

Timing ability is essential for common everyday performance. The aim of the study was to compare timing abilities and temporal aspects of handwriting performance and relationships between these two components among children with Developmental Coordination Disorders (DCD) and a control group. Forty two children, 21 diagnosed as DCD and 21 with typical development, aged 7–12, were matched for age, gender and school performed 14 tasks of the interactive metronome (IM) and three functional handwriting tasks on an electronic tablet that was part of a computerized system (ComPET – computerized penmanship evaluation tool). The IM supplies response time, while on-paper and in-air time per written stroke is received from the ComPET. Results indicated significant differences between the groups for both IM and handwriting tasks (ComPET). Linear regression indicated that the mean IM response time explained 37% of variance of the in-air time per stroke during a paragraph-copying task. Furthermore, based on one discriminate function including two measures reflected timing ability, 81% of all participants were correctly classified into groups. Study results strongly recommend consideration of the IM as an evaluation and intervention tool for children with DCD who are faced with timing deficits in their everyday functioning.

1. Introduction

Developmental coordination disorders (DCD) are prevalent among five to 9% of school-aged children (Cairney, Hay, Faught, & Hawes, 2005). Two features included in the definition of DCD at the DSM-IV (American Psychiatric Association, 1994) are difficulties in performing activities of daily living (ADL) and handwriting difficulties (Cantin, Polatajko, Thach, & Jaglal, 2007; May-Benson, Ingolias, & Koomar, 2002). What is common to these and other everyday functional activities is that they are expected to be completed with appropriate reaction time, within a reasonable time span, and continuous movement, while taking the spatial environment into consideration (Ben-Pazi, Kukke, & Sanger, 2007; Missiuna, Rivard, & Bartlett, 2003; Rao, Mayer, & Harrington, 2001). Such timing of actions is essential for developing skilled movements, and is crucial for many aspects of human performance as for the survival of living organisms (Buhusi & Meck, 2005; Johnston, Burns, Brauer, & Richardson, 2002; Rao et al., 2001). Timing abilities while performing various sequential motor tasks are dependent on the close interrelation of motor and cognitive development involving the cerebellum and dorsolateral prefrontal cortex (Diamond, 2000; Wassenberg et al., 2005). Hence, deficient timing abilities could be a manifestation of both cognitive and motor function deficits that co-occur in children with DCD (Hamilton, 2002; Kaplan, Dewey,Crawford, & Wilson, 2001; Mandich, Buckolz, & Polatajko, 2003; Pitcher, Piek, & Hay, 2003; Visser, 2003).

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The International Classification of Functioning, Disability and Health (ICF, 2001) would consider deficits in timing and its components as problems in body functions. According to the ICF, understanding both *body function* components and *activity* process performance features is relevant for understanding the participation limits of children with DCD. The question is: do children with DCD indeed exhibit timing deficiency? What are the characteristics of their temporal organization during activity performance (activity) and is their timing ability associated with their temporal organization during activity performance?

Findings indicate that children with DCD indeed have internal deficits in sense of time that affect their ability to perform precise, synchronized movements at a reasonable pace and that their movements are more temporally variable in comparison to controls (e.g., Ben-Pazi et al., 2007; Geuze & Kalverboer, 1987, 1994; Johnston, Burns, Brauer, & Richardson, 2002; Mackenzie et al., 2008). However, most previous studies were focused on discrete movements or on a sequential movement using one finger (such as finger-tapping) or specific limbs (Van Waelvelde et al., 2006) and did not address functional every day task. Functional, sequential, continuous everyday tasks involving timing ability are more demanding and require more cortical activation than discrete movements (Schaal, Sternad, Osu, & Kawato, 2004; Zelanznik, Spencer, & Ivry, 2002). Moreover, the requirements are dynamic and rapidly changing, as are the conditions in the environment.

Hence, further studies are needed including objective measures of the process of performing functional, dynamic everyday tasks, to enable decoding of the underlying timing mechanism among children with DCD.

In the current study, the Interactive Metronome® (IM) was implemented to evaluate timing abilities considered as *body functions* while temporal measures of handwriting *activity* were evaluated using the computerized penmanship evaluation tool (ComPET, Rosenblum, Parush, & Weiss, 2003). The Interactive Metronome® (IM)[1] is a computerized intervention tool designed to improve timing, sequencing and coordination through training (Bartscherer & Dole, 2005), which requires the participant to synchronize his or her movements with an auditory stimulus. Movement synchronization manifested in reaction time reflects timing abilities.

Although a preliminary evaluation of the IM user is implemented before training, as far as we know, only one study by Kuhlman and Schweinhart (1999) examined the IM evaluation's reliability and validity. To address the need to establish the evaluation's reliability and validity further, internal reliability will be presented in the current study, as well as discriminant validity – meaning the ability to distinguish between children with and without DCD.

Further to the IM evaluation, handwriting as a sequential, continuous functional activity was evaluated, as it is an essential skill for school-aged children. For both children and adults, proficient handwriting means the ability to produce legible text in a reasonable amount of time (see Rosenblum, Weiss, & Parush, 2003 for more details).

In this context, understanding the relationships between timing abilities and temporal organization in sequentional functional activity, while validating the preliminary evaluation of the IM, can contribute to future development of appropriate evidence-based evaluation tools and intervention methods that are necessary for children with DCD (e.g., Holsti, Grunau, & Whitfield, 2002).

Therefore, the aim of the study was to compare timing abilities and temporal aspects of handwriting performance and the relationships between these two components among children with DCD and those with TD. Through the study, the preliminary evaluation of the Interactive Metronome® for evaluation of timing ability among children with DCD was validated.

Therefore, the study hypotheses were as follows:

1. Significant differences will be found in timing abilities, as manifested by the IM scores, between children with DCD and those with TD.
2. Significant differences will be found in temporal measures of handwriting performance between children with DCD and those with TD.
3. Significant correlations will be found between timing abilities (the three categories of IM scores) and temporal measures of handwriting performance in each group (DCD versus TD).
4. Timing abilities, as supplied by the IM, will predict handwriting performance time among children with DCD.
5. Timing abilities as supplied by the IM with certain handwriting measures will best differentiate between groups (DCD versus TD).

2. Methods

2.1. Participants

Twenty-one children with DCD (eight girls, 13 boys), ranging in age from seven to 10 years, and 21 age- and gender-matched children in a control group participated in the study.

The mean age of the DCD group was nine years and nine months, SD = 1 month, and the mean age of the control group was nine years and eight months, SD = 1.3 months. No significant age differences were found between the two groups ($t(40) = .086$, $p = .93$).

The children with DCD were recruited from schools and clinical centers based on educators' or clinicians' reports about motor coordination problems interfering with ADL performance and handwriting deficiencies (based on the criteria of DSM-IV for DCD (American Psychiatric Association, 1994)). To verify their status as children with DCD, they were then tested with