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Children with developmental coordination disorder demonstrate a spatial mismatch when estimating coincident-timing ability with tools

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ABSTRACT

Coincident timing or interception ability can be defined as the capacity to precisely time sensory input and motor output. This study compared accuracy of typically developing (TD) children and those with Developmental Coordination Disorder (DCD) on a task involving estimation of coincident timing with their arm and various tool lengths. Forty-eight (48) participants performed two experiments where they imagined intercepting a target moving toward (Experiment 1) and target moving away (Experiment 2) from them in 5 conditions with their arm and tool lengths: arm, 10, 20, 30, and 40 cm. In Experiment 1, the DCD group overestimated interception points approximately twice as much as the TD group, and both groups overestimated consistently regardless of the tool used. Results for Experiment 2 revealed that those with DCD underestimated about three times as much as the TD group, with the exception of when no tool was used. Overall, these results indicate that children with DCD are less accurate with estimation of coincident-timing; which might in part explain their difficulties with common motor activities such as catching a ball or striking a baseball pitch.

1. Introduction

Developmental Coordination Disorder (DCD) is a condition that defines children with motor coordination problems despite having average to high intelligence levels. This disorder impacts about 2–7% of school-age children (American Psychiatric Association, 2013). The evidence is clear that children with DCD have less accurate and slower movements than typically developing (TD) children (Elders et al., 2010; Johnston, Burns, Brauer, & Richardson, 2002; Smits-Engelsman, Bloem-van der Wel, & Duysens, 2006). Recent literature has suggested that these difficulties are the result of an underlying deficit in generating and/or monitoring internal models of action, termed the internal modeling deficit (IMD) hypothesis (e.g., Adams, Lust, Wilson, & Steenbergen, 2014; Deconinck, Spitaels, Fias, & Lenoir, 2009; Lewis, Vance, Maruff, Wilson, & Cairney, 2008; Williams, Thomas, Maruff, & Wilson, 2008; Williams, Omizzolo, Galea, & Vance, 2013; Wilson, Ruddock, Smits-Engelsman, Polatajko, & Blank 2013). Internal models provide accurate visuospatial mental representation of intended actions and make predictions (estimates) about the mapping of the self to parameters of the external world. These processes enable successful planning and subsequent execution of movement.

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Estimation of reach ability involves making judgments about distance in relation to oneself, therefore being a useful approach to testing the IMD hypothesis. Recently, it has been suggested that children with DCD have difficulty estimating reach distance (Gabbard, Caçola, & Bobbio, 2012). These findings were argued to be the result of an inability to formulate an appropriate mental representation of the required reaching action. One important aspect of creating this mental representation is the accurate perception of how much one can extend themselves from the center of the body toward an object of interest. Furthermore, evidence indicates that the estimation problem is also seen when using tools (Caçola, Gabbard, Ibana, & Romero, 2014). A tool is an implement (such as a racquet) that modifies the representation of the body, at least temporarily, and is considered a functional element for perceiving one's own body in space (e.g., Baccarini et al., 2014; Caçola & Gabbard, 2012). On a comparison of TD children and those with DCD on an estimation of reach task with and without tools of different lengths, Caçola et al. (2014) found that those with DCD perform similarly to TD children with and without a small tool, but were significantly less accurate with a longer tool. Arguably, the length of the tool may influence the richness of the sensory experience used to make accurate judgments about reach. Thus, this study suggests that tool length influences the nature of internal modeling in children with DCD.

The paradigm used in Caçola et al. (2014)'s study was "static" in nature, that is, estimating reach to a target that is in a fixed position. Arguably, it does not represent all real-world contexts, because in many aspects of our daily lives the objects that we attempt to interact with are not stationary. This supported the need for the creation of a dynamic (moving) task that explored the IMD hypothesis for reach estimation. Tracking or tracing a certain stimulus smoothly requires a high degree of predictive control (Langaas, Mon-Williams, Wann, Pascal, & Thompson, 1998). Since children with DCD respond slower and make fewer and less effective anticipatory responses with a predictive stimulus (Debrabant, Gheysen, Caeyenberghs, Van Waelvelde, & Vingerhoets, 2013), it is likely that the motion of a target influences accuracy of reach estimation. In a dynamic context, reach estimation becomes an issue of "interception" – intercepting or stopping a moving object accurately. To date, no studies have explored accuracy of the interception point from a dynamic estimation perspective in this population.

Therefore, the purpose of the present study was to explore the IMD hypothesis in a task that simulated estimating interception points of objects with and without tools of varying lengths. To that end, we adapted a coincident timing task where typically developing children and those with DCD had to estimate (via use of motor imagery) interception points. Coincident timing or interception ability can be defined as the capacity to precisely time sensory input and motor output, regardless of the direction of the object motion. In order to explore whether the accuracy of the estimated interception ability depends on the direction of a moving object, we used two tasks: (1) target moving toward and (2) target moving away. One might expect that estimation of objects moving toward will be more accurate since most real-world situations involve motion toward the individual (e.g., catching a ball). Based on previous reports of static reach estimation, it was also expected that children with DCD would be less accurate than the TD group, however; we also predicted that the accuracy distinction would only be significant when using longer tools. In addition to gaining a better understanding of how children with DCD plan motor actions, the results will be important to clarify the IMD hypothesis further, thus shedding light on the issues underlying DCD.

2. Method

2.1. Participants

A total of 48 children ranging from 7- to 13 years of age completed this study: 25 children categorized with DCD (17 boys, 8 girls; mean age: 8.84 ± 1.57 years) and 23 TD children (10 boys, 13 girls; mean age: 9.6 ± 1.94 years). For the DCD group, licensed occupational therapists were asked to refer children diagnosed with DCD or Dyspraxia. That is, those without diagnosed cognitive impairments and/or co-morbidities. Qualification for DCD was based on the fit to the diagnostic criteria defined by the DSM-5 (APA, 2013): (A) a score below the 9th percentile on the Movement Assessment Battery for Children, 2nd edition, MABC-2 (Henderson, Sugden, & Barnett, 2007); (B) motor coordination difficulties that had an impact on their daily function as assessed by a parental report (Developmental Coordination Disorder Questionnaire, DCD-Q, Wilson et al., 2009); (C) elimination of another general medical condition such as cerebral palsy, hemiplegia or muscular dystrophy (report from pediatrician/parent). All children were identified as right-handed based on verbal preference for writing and drawing.

The TD (control group) children were recruited from flyers in and around the university and nearby schools. They were identified as having age-appropriate motor skills, scoring at or above the 20th percentile on the MABC-2 and scoring as "probably not DCD" on the DCD-Q questionnaire.

The experimental protocol and consent form were approved by the Institutional Review Board (IRB) for the ethical treatment of human subjects. Children and parents were informed of the experimental procedures before participating in this study, parents signed the consent form and all children provided verbal consent.

2.2. Measures and procedures

Participants completed two experiments: (1) target moving toward and (2) target moving away, in reference to target direction. Fig. 1 provides a visual description of the general paradigm for both experiments. Participants were asked to accurately determine the interception point (where their arm or tool meets the moving target), without actually moving. That process (estimation) was performed via use of motor imagery. The correct interception point was based on the