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Differences in accuracy and vividness of motor imagery in children with and without Developmental Coordination Disorder

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ABSTRACT

Motor imagery (MI) provides a unique window on the integrity of movement representation. Studies have shown that children with Developmental Coordination Disorder (DCD) experience problems with tasks thought to rely on an internal model of movements. Therefore, the purpose of this study was to compare MI accuracy and MI vividness between typically developing (TD) and children with DCD. Ninety-three children with ages between 7 and 12 years (TD: n = 51; DCD: n = 42) were tested with the Movement Imagery Questionnaire (MIQ-c) to assess MI vividness and the Florida Praxis Imagery Questionnaire (FPIQ) to assess MI accuracy. To compare differences between the groups for each assessment and in the subscales, two separate general linear model analyses were conducted: A 2 × 3 (Group [TD, DCD] × Subscales [internal visual imagery, external visual imagery, kinesthetic imagery]) for MI vividness and a 2 × 4 (Group [TD, DCD] × Subscales [position, object, kinesthetic, action]) for MI accuracy. Results indicated that children with DCD scored significantly lower ($p < .05$) on MI accuracy than TD children, but there were no significant differences between the groups on MI vividness. Additionally, there were significant differences in the subscales for both measurements of MI. Specifically, results showed lower scores overall for the kinesthetic subscale. These findings indicate that the MI deficit seen in children with DCD is probably associated with MI accuracy, not MI vividness. These results suggest the need of further exploration into specific measurements of MI in children with DCD.

1. Introduction

Developmental Coordination Disorder (DCD) is a condition that defines children with problems in their motor coordination development despite their intelligence levels and affects about 2–7% of school-age children (American Psychiatric Association, 2013). While the severity of motor impairment varies, common symptoms include marked delays in motor milestones and clumsiness, typically associated with poor balance, coordination, and handwriting skills. A strong line of research has documented deficits in motor imagery in children with DCD (Deconinck, Spitaels, Fias, & Lenoir, 2009; Maruff, Wilson, Trebilcock, & Currie, 1999; Williams, Thomas, Maruff, Butson, & Wilson, 2006; Williams, Thomas, Maruff, & Wilson, 2008; Wilson, Maruff, Ives, & Currie, 2001; Wilson, Maruff, Butson, & Williams, 2004).

Motor imagery (MI) refers to the imagination of a motor task without actual movement execution (Decety & Grèzes, 2006), and is believed to represent one's ability to accurately utilize forward internal models of motor control (Williams et al., 2006). Moreover, MI seems to rely on a network involving motor related regions including fronto-parietal areas and subcortical structures, supporting the view that MI and motor execution are very similar processes (Hétu et al., 2013). Additionally, extensive research has found motor

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imagery deficits in other common disorders such as spastic hemiplegia (Williams, Anderson, Reddihough, Reid, Vijayakumar, & Wilson, 2011), attention-deficit-hyperactivity-disorder (Lewis, Vance, Maruff, Wilson, & Cairney, 2008; Williams, Omizzolo, Galea, & Vance, 2013), and cerebral palsy (Mutsaarts, Steenbergen, & Bekkering, 2007).

Children with DCD experience problems with tasks thought to rely on an internal model of movements such as MI, action planning and rapid online control of movements (Adams, Lust, Wilson, & Steenbergen, 2014). Therefore, MI ability is thought to be reflective of one's ability to accurately form internal models of motor control (Skoura, Papaxanthis, Vinter, & Pozzo, 2005) and there is a deficit in MI ability for children with DCD. Internal models provide stability to the motor system by predicting the outcome of movements before sensorimotor feedback is available. Adams, Ferguson, Lust, and Steenbergen (2016) showed that children with DCD are able to use MI, however; they are slower and less accurate than their typically developing (TD) peers. They also have an impaired ability, when compared to TD children, to produce familiar gestures, dependent on the type of gesture and presentation modality (Sinani, Sugden, & Hill, 2011). Additionally, two systematic reviews revealed that predictive control of movements is linked specifically to underlying deficits in motor control and learning, such as what is seen in DCD (Adams et al., 2014; Wilson, Ruddock, Smits-Engelsman, Polatajko, & Blank, 2013).

Most studies of MI in children with DCD have employed two main paradigms: mental rotation and mental chronometry. A commonly used task for mental rotation is the hand rotation task (Adams, Lust, Wilson, & Steenbergen, 2017a), in which laterality judgments of limb stimuli are made (*e.g.*, left and right hands) based on a display of different angles of rotations, and from different viewpoints (*e.g.,* back vs. palm view). For mental chronometry (Dahm & Rieger, 2016), evidence of a MI deficit is taken by comparing the durations of imagined and executed movements. In mental rotation tasks, MI performance in children with DCD has been shown to be slower and less accurate when compared to control groups (Deconinck et al., 2009). However, O'Shea & Moran (2017) raised caution to the use of mental chronometry paradigms as they offer information on the timing of MI but no information on MI accuracy.

However, little research has been conducted to explore MI ability in children with DCD through the use of questionnaires. According to Morris, Spittle, and Watt (2005), MI ability is a multidimensional construct, that can be assessed in terms of factors such as controllability, vividness, and maintenance. Here, we used two questionnaires that assess MI through an individual's accuracy and vividness. A questionnaire measuring MI accuracy asks questions that have "correct" and "incorrect" answers. For example, with the Florida Praxis Imagery Questionnaire (FPIQ, Ochipa et al., 1997), participants are presented with the image of objects and asked to spatially manipulate the objects, and have to choose, from a set of alternatives, the object that would be in the correct orientation following manipulation. Questionnaires that measure MI vividness, on the other hand, rely on the self-report or perception of an individual's ability to imagine movements. The Movement Imagery Questionnaire for Children (MIQ-c, Martini, Carter, Yoxon, Cumming, & Ste-Marie, 2016) is in this category, as it asks participants to physically perform a task and then visualize the same task either through internal, external or kinesthetic imagery. Then they are asked to rate the difficulty of visualizing that movement on a 7-point likert scale (1 is very hard and 7 is very easy).

To date, only one study explored the components of MI ability in children with DCD through the use of questionnaires (Chang & Yu, 2016). Chang and Yu measured MI ability through a modified version of the FPIQ (adapted to be suitable for use in Taiwan) and aimed to understand characteristics of MI ability in children with varying levels of motor difficulty. The authors suggested that children with DCD did not consistently exhibit deficits in MI. These results were not entirely in line with previous results from Wilson et al. (2001) and further support the need to explore the components of MI through questionnaires. Implementing questionnaires to assess MI ability is appealing because: 1) They are relatively easy to administer to multiple participants at once 2) They require lower levels of training for administration, and 3) Minimal amount of resources are needed when compared to the other paradigms, such as the hand rotation task.

Therefore, the purpose of this study was to (1) compare MI ability between TD children and children with DCD, and to (2) investigate potential differences between MI accuracy and vividness within these groups. It is expected that TD children will show higher accuracy with their MI than children with DCD (Deconinck et al., 2009; Williams et al., 2013). Additionally, we predicted that children with DCD would have higher MI vividness scores when compared to MI accuracy, due to the perceptual nature of the MIQ-c questionnaire.

2. Methods

2.1. Participants

A total of 101 children ranging from 7 to 12 years of age (*M* age = 9.97, *SD* = 1.71) from a large metropolitan area in North Texas were recruited for this study. None of the children had any known comorbidities (such as Attention-Deficit/Hyperactivity Disorder (ADHD); Autism Spectrum Disorder (ASD); Dyslexia, etc). Cognitive testing was conducted on all children and eight participants were excluded from the sample due to their performance on the Kaufmann Brief Intelligence Test – 2 (KBIT-2; Kaufman & Kaufman, 2004), with IQ composite scores either at the lower extreme or below average (14th percentile). After this exclusion, a total of 93 children remained in the study, with 42 children categorized with DCD (23 boys, 19 girls*; M* age = 9.81, *SD* = 1.73) and 51 TD children (26 boys, 25 girls*; M* age = 10.11, *SD* = 1.79).

We categorized children in the DCD group if they met the criterion A defined by the Diagnostic and Statistical Manual of Mental Disorders – 5th edition (DSM-5; American Psychiatric Association, 2013). The confirmation of criterion A (motor skills below age level given opportunities for learning) was based on scores on the red and amber zone of the Movement Assessment Battery for Children, 2nd edition (MABC-2; Henderson, Sugden & Barnett, 2007) and criterion D (motor difficulties are not explained by other conditions) were confirmed through the parents, whom stated that none of the children had any diagnoses. We wish to note that both