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Motor imagery is less efficient in adults with probable developmental coordination disorder: Evidence from the hand rotation task

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ABSTRACT

The present study aimed to provide preliminary insight into the integrity of motor imagery (MI) in adults with probable developmental coordination disorder (pDCD). Based on a strong body of evidence indicating that paediatric samples of DCD often experience difficulties engaging MI, we hypothesised that young adults with pDCD would demonstrate similar difficulties. The performance of 12 young adults (19–35 years) with pDCD was compared to 47 age-matched controls on a traditional mental hand rotation task. Mean inverse efficiency scores were generated for each participant by dividing each participant's mean RT by their proportion of correct responses at each of the stimuli presentation conditions. Preliminary analysis revealed that the performance profiles of individuals with pDCD and age-matched controls showed evidence of being constrained by the biomechanical and postural constraints of real movement, suggesting that both groups engaged in an embodied (MI) strategy to complete the task. Despite engaging in a MI strategy, however, young adults with pDCD were nonetheless significantly less efficient when doing so, shown by significant main effects for group on all group efficiency comparisons. Based on the assumption that MI provides insight into the internal 'neural' action representation that precedes action, we argue that the less efficient MI performance demonstrated by young adults with pDCD may indicate inefficiencies engaging or implementing internal action representations. Implications and directions for future research are discussed.

Developmental coordination disorder (DCD) is characterised by delayed motor development in the absence of an identifiable developmental or neurological impairment, and affects an estimated 5–6% of school-aged children (Zwicker, Harris, & Klassen, 2012a). Affected individuals present with a reduced capacity to learn and/or perform fundamental motor skills which interferes with their ability to complete a variety of tasks of everyday living including dressing themselves, eating with utensils, brushing their teeth, toileting, handwriting and playing sports and musical instruments (Zwicker et al., 2012a).

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Critically, the impact of DCD often extends beyond the motor domain with *clumsy* individuals presenting with higher rates of psychological (e.g. depression and anxiety), social (e.g. decreased quality of social relationships, isolation, social anxiety, social withdrawal), educational (e.g. decreased educational achievement) and health (e.g. increased risk of obesity and cardiovascular disease, Rivilis et al., 2011) problems in comparison to their typically developing peers (see Zwicker, Missiuna, Harris, & Boyd, 2012b for a good review). It was once thought that the poor motor skill typical of DCD was transitory and hence, these individuals were expected to grow-out of their motor impairment through the natural process of experiential learning and neuro-cognitive development. However, a burgeoning body of longitudinal and cross-sectional research beginning in the early 1990s has demonstrated that without targeted intervention the motor impairment characteristic of DCD often persists into adolescence and adulthood (Cantell, Smyth, & Ahonen, 1994; Cantell, Smyth, & Ahonen, 2003; Losse et al., 1991; Rasmussen & Gillberg, 2000). Critically, this also appears to be the case for the aforementioned associated health and psychosocial difficulties (Kirby, Edwards, & Sugden, 2011; Kirby, Williams, Thomas, & Hill, 2013).

While the aetiology of atypical motor development remains the source of rigorous debate, the past decade has seen a significant increase in research investigating neuro-cognitive mechanisms that may be responsible (see Wilson, Ruddock, Smits-Engelsman, Polatajko, & Blank, 2013). To this end, a number of research groups, including our own, have suggested that motor impairment may arise, at least in part, due to difficulties representing movement at an internal (neural) level (Gabbard & Bobbio, 2011; Williams, Thomas, Maruff, Butson, & Wilson, 2006; Williams, Thomas, Maruff, & Wilson, 2008; Williams et al., 2011). This suggestion is supported by a strong body of research showing that children with DCD demonstrate atypical performance profiles when engaging in tasks of motor imagery (MI); that is, the mental representation of movement in the absence of overt action (Deconinck, Spitaels, Fias, & Lenoir, 2009; Gabbard & Bobbio, 2011; Williams et al., 2006; William et al., 2011; Wilson, Maruff, Butson, Lum, & Thomas, 2004). Furthermore, pilot evidence demonstrates that MI training may be as effective as traditional movement therapies at improving motor skill in children with poor motor skill (Wilson, Thomas, & Maruff, 2002). While this body of work provides compelling evidence that MI, and by extension the capacity to generate or use internal action representations, may be impaired in DCD, to date all available evidence has been obtained from paediatric samples. That is, the integrity of MI beyond childhood in this group is yet to be investigated. Doing so is critical to our understanding of the development of atypical motor skill, whether the underlying deficits contributing to poor motor skill might change across development, as well as the planning and implementation of age-appropriate and targeted interventions for motor skill difficulties beyond childhood. Accordingly, as a window into the capacity of adults with poor motor skill to generate and/or use internal representations of action, the following study was the first of its kind to investigate the ability of young adults with probable DCD (pDCD) to complete a well-validated measure of MI; the hand rotation task.

1. Motor imagery is compromised in children with DCD

Briefly, current motor theory holds that prior to movement execution, the nervous system uses a copy of the intended motor command (sometimes referred to as an *efference copy*) to anticipate the sensory consequences of an action (Desmurget & Grafton, 2000; Izawa & Shadmehr, 2011; Wolpert, Diedrichsen, & Flanagan, 2011). Once movement begins, this internal representation of action is used to compare the predicted sensory consequences of movement with actual sensory inflow. In some instances, discrepancy may arise between the two – e.g. following unexpected target or effector perturbation mid-movement. In these instances, an error signal is generated which is sent to the controller to correct the un-folding motor command. This 'predictive modelling' system provides stability to the motor system in an ever-changing environment. Specifically, by comparing the expected (according to internal action representation) and actual sensory consequences of movement, the nervous system is able to detect errors of action while circumventing processing delays that are associated with simple sensory feedback which can take upwards of 250 ms (Frith, Blakemore, & Wolpert, 2000). In doing so, action can be corrected with minimal time-delay (i.e., within 100 ms) allowing for fluent and efficient movement. Hence, the integrity of this predictive modelling system is critical to efficient and mature motor planning, control and correction.

The importance of action representation to the development of motor skill is highlighted by evidence demonstrating that children with atypical motor skill are less able to generate and/or implement internal representations of action. Specifically, the last 15 years has seen a strong body of evidence emerge demonstrating that children with DCD experience difficulties engaging in tasks of MI (for a good review, see Gabbard & Bobbio, 2011). It is widely assumed that conscious mental simulation of movement provides insight into the unconscious internal representations that precede and support action (de Lange, Roelofs, & Toni, 2008; Jeannerod, 2001; Munzert, Lorey, & Zentgraf, 2009). Support for this notion can be seen in research highlighting that simulated movement largely adheres to the same temporal and biomechanical constraints as real movement (Decety, Jeannerod, & Prablanc, 1989; Parsons, 1994; Sirigu et al., 1996). For example, the speed-accuracy trade-offs associated with overt movement are also seen in imagined movement, and physically demanding and awkward tasks take longer to imagine than simple ones (Jeannerod, 2006). At the psychophysiological level, similar neural (Jeannerod, 2001; Munzert et al., 2009) and cortico-spinal pathways (Stinear, Byblow, Steyvers, Levin, & Swinnen, 2006; Williams, Pearce, Loporto, Morris, & Holmes, 2012) are also activated.

Children with DCD have shown a consistent pattern of impairment on several tasks of MI including the visually guided pointing task (VGPT) (Lewis, Vance, Maruff, Wilson, & Cairney, 2008; Wilson, Maruff, Ives, & Currie, 2001) and more recently the well-validated mental limb rotation task (Deconinck et al., 2009; Williams et al., 2006; Williams et al., 2008; Williams et al., 2011; Wilson et al., 2004). In the case of the latter, mental limb rotation paradigms require participants to make