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Motor imagery training enhances motor skill in children with DCD: A replication study

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ABSTRACT

Background: Children with impaired motor coordination (or DCD) have difficulty using *motor imagery*. We have suggested that this difficulty is explained by the internal modeling deficit (IMD) hypothesis of DCD. Our previous training study lent support for this hypothesis by showing that a computerized imagery training protocol (involving action observation, and mental- and overt-rehearsal) was equally effective to perceptual-motor therapy (PMT) in promoting motor skill acquisition.
Aims: The study presented here was designed to replicate and extend this finding, targeting a select group of children with moderate-to-severe DCD.
Methods and Procedures: All 36 children with DCD who participated were referred to the study and scored below the 10th percentile for their age on the Movement Assessment Battery for Children (MABC). Using a randomized control trial, the referred children were assigned randomly to one of three groups using a blocked procedure: imagery training, perceptual-motor training (PMT), and wait-list control. Motor proficiency was measured using the MABC, pre and post-training. Individual training consisted of 60-min sessions, conducted once a week for 5 weeks.
Results: Results showed that the imagery protocol was equally effective as PMT in promoting motor skill acquisition, with moderate-to-large effect sizes. Individual differences showed that the majority of children in the two intervention groups improved their motor performance significantly.
Conclusions: Overall, these results further support the use of motor imagery protocols in the treatment of DCD, and tentative support for the IMD hypothesis. Developmental and dose issues in the implementation of imagery-based intervention are discussed.

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1. Introduction

Motor skill learning difficulties in children (or DCD) is a relatively common issue that has attracted considerable research into causal factors and remediation. A recent systematic review and meta-analysis have shown that task-oriented approaches to treatment can muster the most compelling case for efficacy (Blank, Smits-Engelsman, Polatajko, & Wilson, 2012; Smits-Engelsman et al., 2013). These approaches – like Neuromotor Task Training (NTT) and Cognitive Orientation to Occupational Performance (CO—OP) – are well credentialed and based on sound motor learning principles (Thornton et al., 2015; Wilson, 2005). However, there have been relatively few approaches to treatment that derive from the accumulating body of empirical work on basic mechanisms. One exception to this rule was an early study supporting the use of motor imagery (MI) training in children with motor impairments (Wilson, Thomas, & Maruff, 2002), informed by the IMD account of DCD (Wilson & Butson, 2007). Interestingly, since this paper, no additional papers have been published on use of this approach in DCD, while discussions have appeared in the cerebral palsy (CP) literature (Steenbergen, Crajé, Nilsen, & Gordon, 2009). In the paper presented here, we provide an important replication study of this approach, the first using a group screened rigorously for DCD using DSM-5 criteria (APA, 2013). Such a study is important at a time when our understanding of motor imagery and action observation is quite advanced in fields of learning, rehabilitation, and training (Vogt, Di Rienzo, Collet, Collins, & Guillot, 2013).

DCD is not a trivial issue but occurs in 5–10% of all children and, without adequate intervention, often persists over time into adulthood (Wilson, 2005). The impacts of DCD are also not just confined to daily activities and educational function, but are associated with poorer physical health and fitness, and psychological and social outcomes including poor self-concept, anxiety, and social isolation (Kirby & Sugden, 2007; Zwicker, Harris, & Klassen, 2013). As such, the concerted effort of many researchers has been to bring the underlying basis of the disorder into focus and to consider fully ways of optimising treatment outcomes. Indeed, advances in treatment for DCD are tied to the development of brain-behavior models for the disorder and knowledge of the contribution of motor and cognitive factors.

In two recent systematic reviews of the DCD literature, available evidence was analysed (Adams, Lust, Wilson, & Steenbergen, 2014; Wilson, Ruddock, Smits-Engelsman, Polatajko, & Blank, 2013) to reveal a prime underlying deficit in predictive motor control and learning—also termed the *internal modeling deficit* (IMD) (Wilson & Butson, 2007; Wilson et al., 2013). While a detailed description of this account is beyond the scope of this paper, it suffices to say that predictive control is critical to online motor control, the general stability of the motor system, and motor learning; online control is based on forward estimates of limb position (Desmurget & Grafton, 2003). Without motor prediction, the performer is unable to anticipate the impending consequences of action and is reliant on slower feedback control based on sensory inputs alone (Pisella et al., 2004, 2009). This slower mode of control explains the signature kinematics of movement seen in DCD: slower performance, increased jerk, poor perceptual-motor coupling (Kagerer, Bo, Contreras-Vidal, & Clark, 2004; Kagerer, Contreras-Vidal, Bo, & Clark, 2006), reduced smoothness, and multiple corrective movements (Wilson et al., 2013). Also strongly associated with their problems of predictive control is a reduced ability to imagine a motor act (esp. from a first-person perspective), which has been shown repeatedly in research using mental limb rotation and visually guided pointing tasks (Adams et al., 2014). Indeed, other work shows that MI ability is correlated with the ability to implement online (reach) corrections in healthy adults (Hyde, Wilmut, Fuelscher, & Williams, 2013) and children with DCD (Fuelscher, Williams, Enticott, & Hyde, 2015).

Motor imagery that is well developed conforms to the same physiological and biomechanical constraints as real movement (Wilson et al., 2013) and shares a common neural network with key aspects of motor planning and prediction (Gatti et al., 2013). This network includes prefrontal, posterior parietal and cerebellar cortices, as well as basal ganglia. Imagery deficits are likely to involve this same network and methods to train motor imagery in DCD will tap existing neuroplasticity within it.

In an earlier study we showed that MI training enlisting peer modelling and verbal cuing can improve motor performance in DCD (Wilson et al., 2002). A cohort of 54 children of below-average motor skill was randomly assigned to one of three intervention groups: MI training, perceptual-motor training (PMT) or wait-list control. The MI training consisted of three main components: action observation of skilled peers performing fundamental motor skills (presented using digital video), mental reproduction of the observed movement from a 3rd-person perspective, and internal simulation of the same movement from a 1st-person perspective. The PMT consisted of a suite of fine- and gross-motor tasks that commonly form part of the training repertoire of occupational therapists, an approach with a sound evidential base (Smits-Engelsman et al., 2013). A short course of training (or five $\times$ 1-h sessions) resulted in significant gains in movement skill in the MI and PMT groups; as reflected by improved performance on the MABC. Effect sizes were moderate-to-large and did not differ between these two groups. However, the children were not fully representative of DCD, with a number entering the study with motor ability levels lying between the 15th and 50th percentile. Surprisingly, no MI intervention study of DCD has been published since 2002 and few targeting children with cerebral palsy (CP). The closest we see is in the CP area, conducted by Sgandurra and colleagues (Sgandurra et al., 2013), who showed that three weeks of action observation training – but without explicit MI training – could enhance daily upper-limb activities, post-test, as measured by the Assisting Hand Assessment (AHA). However, Sgandurra and colleagues failed to include a no-treatment control group, which limits the impact of these findings. In other areas of neurodisability like stroke or traumatic brain injury, there is good evidence that MI training does afford meaningful change in performance and some transfer to everyday function (Hovington & Brouwer, 2010; Schuster et al., 2011). For example, Bajaj, Butler, Drake, and Dhamala (2015) have recently shown behavioural and neural changes in