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An 18-month follow-up investigation of motor coordination and working memory in primary school children

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ABSTRACT

The aim of the current study was to examine the relationship between motor coordination and visual working memory in children aged 5–11 years. Participants were 18 children with movement difficulty and 41 control children, assessed at baseline and following an 18-month time period. The McCarron Assessment of Neuromuscular Development provided a measure of motor skills and the CogState One-Back task was used to assess visual working memory. Multi-level mixed effects linear regressions were used to assess the relationship between fine motor skills, gross motor skills, and visual working memory. The results revealed that for children with movement difficulty, better fine motor skills at baseline significantly predicted greater One-Back accuracy and greater (i.e., faster) speed at 18-month follow-up. Conversely, fine motor skills at baseline did not predict One-Back accuracy and speed for control children. However, for both groups, greater One-Back accuracy at baseline predicted better fine and gross motor skills at follow-up. These findings have important implications for the assessment and treatment of children referred for motor difficulties and/or working memory difficulties.

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1. Introduction

It is now generally agreed that there is an important relationship between motor and cognitive development. Diamond (2000) argued that the two domains may be fundamentally interrelated and summarizes evidence from various developmental disorders and neuroimaging studies suggesting that that the important relationship between motor and cognitive development is mediated by the close co-activation of the cerebellum and the prefrontal cortex. Research also supports parallel development for motor and cognitive processes as both show an accelerated developmental progression between ages 5 and 10 years (Anderson, 2002; Ferrel-Chapus, Hay, Olivier, Bard, & Fleury, 2002) as well as continued development into early adulthood (Diamond, 2000). Further evidence for the relationship between motor and cognitive development comes from studies involving individuals with deficits in either domain. For example, there is accumulating evidence that children with motor deficits such as Developmental Coordination Disorder (DCD) demonstrate difficulties in complex cognitive functioning, including executive functions (EF) (Alloway, 2007; Michel, Roethlisberger, Neuenschwander, & Roebers, 2011; Piek, Dyck, Francis, & Conwell, 2007).

Recently, a number of studies have shown an important relationship between motor skills and the EF domain of working memory (Alloway, 2007; Piek et al., 2007; Rigoli, Piek, Kane, & Oosterlaan, 2012), that is, the ability to store and manipulate information over a brief period of time (Baddeley & Hitch, 1974). Specifically, children with DCD have shown poorer performance on working memory tasks than both controls and children with Attention Deficit Hyperactivity Disorder (ADHD) (Piek et al., 2007). Alloway et al. demonstrated a deficit across both visuospatial and verbal working memory in children with DCD but have also suggested a more pronounced deficit in visuospatial memory (Alloway & Temple, 2007). These are concerning findings as working memory has been shown to be a reliable predictor of academic achievement including reading and mathematics skills (Alloway, 2007).

Given findings of a link between DCD and EF, such as working memory, it has been suggested that complex cognitive functions may be involved in the mastery of motor skills (Michel et al., 2011). Although there is a suggestion that EF affects motor performance, longitudinal studies are needed to facilitate causal inferences. Few longitudinal studies have provided evidence for the direction of the relationship between the cognitive and motor domains, although there is initial evidence that early motor development predicts later performance on complex cognitive tasks including working memory (Murray et al., 2006; Piek, Dawson, Smith, & Gasson, 2008; Ridler, Veijola, Tanskanen, et al., 2006). For example, Murray et al. found that early gross motor development, namely the age of learning to stand without support, was related to adult executive functioning such as working memory. Similarly, Piek et al. (2008) found a relationship between early gross motor (but not fine motor) development and later school-aged working memory ability. Thus, it has been proposed that the better the development of the neural systems involved with infant motor function, the better the development of more complex neural circuits involved in executive functions (Murray et al; Ridler et al.). However, these longitudinal studies did not control for baseline cognitive functioning.

A more recent study investigated the cross-sectional and longitudinal relationships between motor skills and spatial working memory in preschool children, while also controlling for potential confounding variables such as age, sex, and parental education (Niederer et al., 2011). Both motor and spatial working memory performance were measured at baseline and again 9 months later. It was found that baseline motor skills (specifically, dynamic balance) was associated with improvements in spatial working memory 9 month later, whereas baseline memory was not associated with an improvement in motor skills (Niederer et al.). Niederer et al. suggested that these results provide evidence that motor skills predict spatial working memory, but not vice versa.

Additional evidence for the predictive relationship from motor to cognitive functioning comes in several forms. First, research shows that sensory and motor regions of the brain are typically the first to mature (Casey et al., 2005). Second, there is also accumulating evidence that physical activity and high levels of aerobic fitness during childhood may enhance neurocognition, including working memory (Sibley & Etnier, 2003). These data provides indirect evidence that motor coordination may predict EF given the link between motor coordination and physical activity (Cairney et al., 2005). It has also been suggested, however, that complex cognitive and motor functions display an equally protracted developmental course continuing into early adulthood, with both the prefrontal cortex and cerebel-