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Full Length Article

The relationship between motor performance and parent-rated executive functioning in 3- to 5-year-old children: What is the role of confounding variables?

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ABSTRACT

It is generally agreed that motor performance and executive functioning (EF) are intertwined. As the literature on this issue concerning preschool children is scarce, we examined the relationship between motor performance and parent-rated EF in a sample of 3- to 5-year-old children with different levels of motor skill proficiency, while controlling for age, gender, socio-economic status (SES), and attention-deficit-hyperactivity disorder (ADHD) symptomatology. EF was reported by parents of 153 children (mean age 4 years 1 months, SD 8 months; 75 male) by means of the Behaviour Rating Inventory of Executive Function–Preschool version (BRIEF-P). Parent-reported ADHD symptoms were assessed using the Hyperactivity-Inattention subscale of the Strengths and Difficulties Questionnaire3-4. In addition, the children performed the Movement Assessment Battery for Children-2 (MABC-2). Several weak to moderate relationships were found between the MABC-2 Total Score and the EF subscales. Once other variables such as age, gender, SES, and ADHD symptomatology were taken into account, the only BRIEF-P subscale that was associated with the MABC-2 Total Score was the Working Memory subscale. Compared to their typically developing peers, children who are at risk for motor coordination difficulties ($\leqslant$the 16th percentile on the MABC-2) performed poorly on the Working Memory subscale, which confirms the results of the regression analyses. The at risk group also performed significantly worse on the Planning/Organize subscale, however. This is one of the first studies investigating the relationship between motor performance and parent-rated EF in such a young age group. It shows that the relationship between motor performance and EF in young children is complex and may be influenced by the presence of confounding variables such as ADHD symptomatology.

1. Introduction

Early in life, children go through a period of remarkable growth and learning in their motor repertoire. During early childhood, they gain fundamental movement skills upon which more complex motor skills needed for activities of daily living and participation in physical activity are formed (Gabbard, 2008; Piek, Hands, & Licari, 2012). Children's ability to move also has important implications for their cognitive and social development (Diamond, 2007). The attainment of motor skills provides

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children with new opportunities for learning about their environment, both regarding objects and other individuals (Adolph & Joh, 2007; Von Hofsten, 2009). Being able to act upon their environment allows children to gain knowledge about their surroundings, which leads to changes in various perception-action systems (Von Hofsten, 2009). These changes bring about advances in cognition, both mental and social, which in turn will affect how children examine and manipulate their environment (Campos et al., 2000; Von Hofsten, 2007). The idea that there is a relationship between motor and cognitive development stems in part from the embodied cognition perspective, in which cognition is considered to occur in the context of the individual's bodily interaction with the physical and social environment (Barsalou, 1999; Gibbs, 2005; Oudgenoeg-Paz, Volman, & Leseman, 2012; Smith & Gasser, 2005), a coupling that was also proposed already by Piaget (1952) in his cognitive-developmental theory and by Gibson (1979) in his theory of ecological psychology.

Recent brain data support the theorized association between the two domains (Abe & Hanakawa, 2009; Diamond, 2000; Hanakawa, 2011). Neuroimaging techniques have shown that regions important to motor and cognitive performance, such as the cerebellum, dorsolateral prefrontal cortex, and the connecting structures (including the basal ganglia) are co-activated during motor and cognitive tasks. In addition, motor and cognitive development share a common developmental timetable: e.g., both develop markedly in the preschool period (Howard, Okely, & Ellis, 2015; Piek et al., 2012). Not surprisingly, motor and cognitive problems often co-occur in children with neurodevelopmental disorders (Alloway, 2007; Diamond, 2000; Hellendoorn et al., 2015; Punt, de Jong, de Groot, & Hadders-Algra, 2010). For example, children with motor coordination difficulties, such as Developmental Coordination Disorder (DCD) have been shown to have deficits in certain cognitive processes, known as 'executive functioning' (EF)[1] (Leonard, Bernardi, Hill, & Henry, 2015; Molitor, Michel, & Schneider, 2015; Rahimi-Golkhandan, Steenbergen, Piek, & Wilson, 2014), and vice versa, motor problems have been identified in children with cognitive difficulties (Houwen, Visser, van der Putten, & Vlaskamp, 2016). This, again, is consistent with the notion that motor and cognitive functioning are inter-related.

Despite the different lines of evidence indicating a strong link between motor and cognitive development, a recent review showed that there is little behavioural evidence to support a global-to-global relation between motor and cognitive development in typically developing children (Van der Fels et al., 2015). Instead, support has been found for some distinct associations: results from studies in 4- to 16-year-old children using cross-sectional data have shown associations between specific aspects of motor and cognitive performance, including complex motor skills and higher-order cognitive abilities, i.e., fluid intelligence and visual processing (Van der Fels et al., 2015). With respect to the relationship between motor performance and EF, perhaps the quintessence of higher-order cognitive functioning, strong evidence is still missing for typically developing children (Van der Fels et al., 2015). The few studies that have investigated the relationship between motor performance and EF show inconsistent results (Van der Fels et al., 2015). Looking in more detail to the studies that examined these relationships in typically developing children (e.g., Livesey, Keen, Rouse, & White, 2006; Piek, Dawson, Smith, & Gasson, 2008; Piek et al., 2004; Rigoli, Piek, Kane, & Oosterlaan, 2012; Roebers & Kauer, 2009; Wassenberg et al., 2005), it appears that adjustment for confounding variables attenuated many of them.

In 7-year old typically developing children, weak-to-moderate correlations were reported between several motor and performance-based EF subtests (e.g., balance and working memory), however, when controlling for age and processing speed only a few of the correlations remained significant (Roebers & Kauer, 2009). In a 6- to 14-year old normative sample, several weak but significant correlations were found between motor performance and several performance-based EF tasks (i.e., inhibition, working memory, and the ability to plan and respond to goal-directed tasks; Piek et al., 2004). Once variables such as age, gender, and inattention were taken into account, the only EF task that was associated with motor performance was a combined measure of working memory and inhibition. When the impact of early fine and gross motor development was examined in relation to different EF indices at school-age in typically developing children, both working memory and processing speed were found to be predicted by early gross motor development, but not fine motor development, after controlling for gestational age and socio-economic status (SES; Piek et al., 2008). Livesey et al. (2006) found that overall motor performance, and more specifically manual dexterity and ball skills, were moderately to strongly related to performance-based measures of inhibition in typically developing 5- to 6-year-olds. When controlling for age, only manual dexterity was significantly related to inhibition. Another study using a sample of 5- to 6-year old children attending normal kindergarten found that several motor scores (total, quality, and quantity) were related to a performance-based measure of working memory and verbal fluency, which remained significant after controlling for attention. In a normative adolescent sample, weak-to-moderate correlations were found between overall motor performance, manual dexterity, ball skills, and balance and a performance-based measure of inhibition (Rigoli et al., 2012). In addition, significant correlations were found between overall motor performance and ball skills and a performance-based measure of working memory. When controlling for verbal ability and ADHD symptomatology, overall motor performance and ball skills still accounted for a significant proportion of variance in working memory, while only overall motor performance and balance accounted for a significant proportion of variance in the inhibition tasks. These studies provide evidence that several child-related variables may influence the relationship between motor performance and EF in typically developing children.

[1] Although there is still no consensus on the definition of EF, most researchers would agree on the notion that EF encompasses a set of higher-order cognitive abilities, such as inhibition, working memory, and cognitive flexibility, which are instrumental in supporting action control and the flexible adaptation to changing environments (e.g., Karbach & Unger, 2014). The broad definition of EF indicates that the essence of EF is the ability to control behaviour, a concept which is also the foundation of movement and action control (Koziol & Barker, 2013).

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