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Full Length Article

The mediating role of cognitive ability on the relationship between motor proficiency and early academic achievement in children☆

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ABSTRACT

The aim of this study was to examine the relationship between motor proficiency and academic achievement in 7 years-old children. A mediating model in which the relation between motor proficiency and academic achievement is mediated by cognitive ability was tested. Participants included 152 children from the longitudinal study *Jeunes enfants et leurs milieux de vie (Young Children and their Environments)*. Motor proficiency was evaluated with the Bruininks-Oseretsky Test of Motor Proficiency (BOT2), cognitive ability with the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV) and academic achievement with the Wechsler Individual Achievement Test II (WIAT II). Results showed that motor proficiency, cognitive ability and academic achievement were positively correlated with each other. A structural equation modeling analysis revealed that motor proficiency had a positive effect on academic achievement through an indirect path via cognitive ability. These results highlight the fundamental importance of motor skills in children's academic achievement in early school years.

1. Introduction

Research on the development of motor behavior has shown that body actions play a critical role in children's cognition (Needham & Libertus, 2011). Since Piaget's theory (1954), according to which infants, toddlers and children construct their understanding of the physical world through their own actions, numerous evidence have shown that movements contribute to children perception, provide them the means to acquire knowledge and to interact with people (Adolph & Franchak, 2017). During development, the child's repertoire of coordinated and skillful movements broadens and enriches his interaction with the world. For example, control of the sitting posture facilitates bimanual object exploration, such as fingering, transferring and rotating, which in turn facilitates learning about three-dimensionality of objects (Soska, Adolph, & Johnson, 2010). As proposed by Adolph and Franchak (2017), improved

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motor proficiency provides new or enhanced opportunities for learning and doing.

In recent years, there has been a renewed interest on the role of motor proficiency in children's academic achievement (Davies, Janus, Duku, & Gaskin, 2016; Diamond, 2010). Several studies showed that motor proficiency was related to academic achievement (Da Silva Pacheco, Gabbard, Kittel Ries, & Godoy Bobbio, 2016; Ericsson & Karlsson, 2014; Grissmer, Grimm, Aiyer, Murrah, & Steele, 2010). For example, it has been found that children with motor coordination disorders or motor insufficiency had a higher probability of low academic achievement in comparison with children without motor difficulties (Lopes, Santos, Pereira, & Lopes, 2013; Westendorp, Hartman, Houwen, Smith, & Visscher, 2011). At the opposite, a better motor performance during infancy or early childhood has been related to better academic achievement later in school. For instance, an evaluation of data sets from three longitudinal studies found that fine motor skills in kindergarten children were a strong predictor of later reading and math achievement in fifth grade (Grissmer et al., 2010). In a longitudinal study lasting 14 years and beginning when participants were infants, Bornstein, Hahn, and Suwalsky (2013) showed that infants who had better motor control and who explored their environment more actively at 5 months obtained higher cognitive scores at 4 and 10 years, and performed also higher on academic achievement tests at 10 and 14 years. There were indirect effects of motor maturity and exploratory activity at 5 months on 14-year academic achievement through cognitive abilities at 4 and 10 years. As proposed by Bornstein et al. (2013), motor-exploratory competence appeared to serve as a foundation for cognitive functioning in childhood and academic achievement in adolescence.

The influence of motor proficiency on academic achievement does not seem to be limited to long term effects in adolescence but also concerns short-term effects that can be visible as children enter in formal schooling (Kulp, 1999; Pitchford, Papini, Outhwaite, & Gulliford, 2016; Son & Meisels, 2006). In a cross sectional study, Pienaar, Barhorst, and Twisk (2013) observed that visuo motor integration, motor coordination and motor proficiency were related to academic achievement in South African first graders. Recently, Kim, Duran, Cameron, and Grissmer (2017) examined the relationships between three processes (visuo motor integration, attention, and fine motor coordination) and mathematics skills in 5-year-olds (kindergarteners) and 6-year-olds (first graders) that were followed over the course of 2 school years. Fine motor coordination measured when children were at the beginning of kindergarten, contributed significantly to visuo motor integration at the end of kindergarten which was, in turn related to mathematics skills at the end of first grade. These findings suggest that motor proficiency contributes to academic achievement as soon as children begin formal reading and maths learning.

However, despite the above evidence, the nature of the relationship between motor proficiency and early academic achievement is still unclear and the precise mechanisms that link them are debated (Cameron, Cottone, Murrah, & Grissmer, 2016). In most of the studies, the strength of the relationship between motor proficiency and academic achievement has been evaluated with correlational methods but these methods do not indicate if the relationship is direct or indirect or mediated by others factors like cognitive abilities (Cameron et al., 2016; Libertus & Hauf, 2017). Therefore, the main objective of the current study was to obtain a deeper understanding of the relationship between motor proficiency and academic achievement in children. A causal model was tested based on the assumption that motor proficiency influence academic achievement possibly by influencing cognitive ability (Bornstein et al., 2013; Rigoli, Piek, Kane, & Oosterlaan, 2012).

Motor proficiency is a broad concept that refers to the ability to perform various motor skills in a consistent and proficient manner (Bardid, Rudd, Lenoir, Polman, & Barnett, 2015; Rudd et al., 2015). As specified by Adolph and Franchak (2017), it depends on generating, controlling, and exploiting physical forces but also on core psychological functions for adaptive control of movement for goal directed actions. From the actual literature, it is difficult to disentangle which aspects of motor proficiency are more or less related to cognitive abilities at school age. Libertus and Hauf (2017) proposed that connections between motor experiences and cognitive development may exist beyond infancy but are limited to specific domains of cognition, such as spatial cognition for example. In a review aimed to give an overview of studies providing evidence for a relationship between motor and cognitive skills in 4–16 year old typically developing children, van der Fels et al. (2015) found that some categories of motor skills like fine motor skills, bilateral motor coordination and timed performance were more strongly related to cognitive skills like fluid intelligence, short term memory, visual processing compared to balance and agility skills. In contrast, Frick and Möhring (2016) found that balance skills in 6 year-olds were related with spatial and reasoning skills in mathematics one year later. In a large sample of 423 children aged between 8 and 10 years, Geertsen et al. (2016) found that specific motor skills were associated with different cognitive functions. More specifically, visuo motor tracking capacity (fine motor skills) and body coordination (gross motor skills) were associated with spatial working memory, wordlist memory, sustained attention, reaction time, the ability to learn paired associates, and performance in mathematics and reading.

Furthermore, in most of these studies, the level of children's physical activity was not considered while positive relations between physical activity levels and specific cognitive functions such as working memory and selective attention have been shown (Chaddock-Heyman, Hillman, Cohen, & Kramer, 2014; Geertsen et al. 2016). There is also evidence that motor proficiency and physical activity levels are related (Cliff, Okely, Smith, & McKeen, 2009). For example, preschool children with better motor proficiency tend to be engaged more frequently in physical activity (O'Neill et al., 2014) and to have a better physical fitness (Sigmundsson & Haga, 2016). Cognitive abilities in children might be influenced by this combined effect of motor proficiency and physical fitness.

Therefore, in the current study, instead of considering a unique cognitive function as potential mediator of the relationship between motor proficiency and academic achievement, it was decided to examine the influence of three functions taken from the Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV) (Wechsler, 2003) that are perceptual reasoning, working memory and processing speed. These functions were chosen because they have been previously related to motor skills (Piek et al., 2004; Wechsler, 2004).

Thus, in order to examine the relationship between motor proficiency and academic achievement in first graders and verify if this relationship is mediated by cognitive ability, a mediating model was constructed and tested (Fig. 1). To construct this model, it was