Review

Αναζητήσεις στη Φυσική Αγωγή & τον Αθλητισμό
Τόμος 19 (1), 17 – 29
Δημοσιεύτηκε: Μάρτιος 2021

Inquiries in Sport & Physical Education
Volume 19 (1), 17 – 29
Released: March 2021

www.pe.uth.gr/emag

ISSN 1790-3041

The Relationship Between Motor Skills and Executive Functions in Children 1–15 Years Old With and Without Special Educational Needs and/or Disabilities

Aimilia Rouvali & Vassiliki Riga

Department of Educational Sciences and Early Childhood Education, University of Patras

Abstract

From Piaget's cognitive developmental theory to the embodied cognition perspective, there is a consensus among researchers that motor development and skills are intertwined with cognitive development. During the past decade, there has been an increasing interest among the academic world to further examine this relationship and determine the extent to which it is significant. The aim of this paper is to combine and present all the latest data from studies investigating the relationship between gross motor skills and executive functions (EFs) in children 1–15 years old. The results illustrated in the latest available research data indicate that the correlation between these two concepts can vary from weak to strong, depending on the sample (age, abilities, and skills), and the tool for measuring EFs. However, a stronger and more consistent correlation is illustrated between EFs and more complex motor skills. The authors of the article suggest a further investigation of the relationship between EFs and motor skills of the under-researched cohort of children three-to-five years old, as well as the development of appropriate assessment methods for EFs in preschool-aged children in Greece. Thus, in the future it will be more feasible to develop and assess the effectiveness of intervention programmes that will be oriented towards - but not limited to - utilising motor activities as a way of enhancing both the motor development and executive functioning of children.

Keywords: *executive functions, motor skills, cognitive development, motor development, children*

Corresponding address: Vassiliki Riga
Department of Educational Sciences and Early Childhood Education, University of Patras, 26504, Rio, Patras, Greece
Email: vriga@upatras.gr

Ανασκοπική

Η Σχέση Μεταξύ Κινητικών Δεξιοτήτων και Επιτελικών Λειτουργιών σε Παιδιά Ηλικίας 1-15 Ετών Με ή Χωρίς Ειδικές Εκπαιδευτικές Ανάγκες ή/και Αναπηρία

Αιμιλία Ρούβαλη & Βασιλική Ρήγα

Τμήμα Επιστημών της Εκπαίδευσης και της Αγωγής στην Προσχολική Ηλικία, Πανεπιστήμιο Πατρών

Περίληψη

Από την εποχή του Piaget και της θεωρίας για τη γνωστική ανάπτυξη έως την οπτική της ενσώματης νόησης, είναι κοινώς αποδεκτό μεταξύ των ερευνητών πως η κινητική και η γνωστική ανάπτυξη είναι στενά συνδεδεμένες. Τα τελευταία είκοσι χρόνια παρουσιάζεται ένα συνεχώς αυξανόμενο ενδιαφέρον από την ερευνητική κοινότητα για τη μελέτη της σχέσης αυτής και τον προσδιορισμό της σημαντικότητάς της. Το παρόν άρθρο έχει ως στόχο να παρουσιάσει τα τελευταία δεδομένα των ερευνών που εξετάζουν τη σχέση μεταξύ της αδρής κινητικότητας και των επιτελικών λειτουργιών σε παιδιά ηλικίας 1-15 ετών. Τα αποτελέσματα της επισκόπησης των ερευνών υποδηλώνουν πως η συσχέτιση μεταξύ των δύο αυτών εννοιών δύναται να κυμαίνεται από στατιστικά ασήμαντη έως σημαντική, αναλόγως του δείγματος (ηλικία, ικανότητες και δεξιότητες), και της μεθόδου αξιολόγησης των επιτελικών λειτουργιών. Παρατηρείται, όμως, σταθερά στατιστικά σημαντική συσχέτιση μεταξύ των επιτελικών λειτουργιών και των πιο πολύπλοκων κινητικών δεξιοτήτων. Οι συγγραφείς του άρθρου προτείνουν την περαιτέρω διερεύνηση της συσχέτισης των επιτελικών λειτουργιών και της αδρής κινητικότητας σε παιδιά 3-5 ετών, καθώς και την ανάπτυξη κατάλληλων μεθόδων αξιολόγησης των επιτελικών λειτουργιών σε παιδιά που φοιτούν στο νηπιαγωγείο στην Ελλάδα. Με αυτό τον τρόπο καθίσταται δυνατή η ανάπτυξη και αξιολόγηση κινητικών προγραμμάτων παρέμβασης που θα σκοπεύουν τόσο στην κινητική ανάπτυξη, όσο και στην ενίσχυση των επιτελικών λειτουργιών σε παιδιά.

Λέξεις κλειδιά: *επιτελικές λειτουργίες, κινητικές δεξιότητες, γνωστική ανάπτυξη, κινητική ανάπτυξη, παιδιά*

Διεύθυνση επικοινωνίας: Βασιλική Ρήγα
Τμήμα Επιστημών της Εκπαίδευσης και της Αγωγής στην Προσχολική Ηλικία, Πανεπιστήμιο Πατρών, 26504, Ρίο, Πάτρα, Ελλάδα
E–mail: vriga@upatras.gr

Introduction

Motor proficiency, cognitive skills, and executive functions (EFs) constitute fundamental factors in children's development, mental and physical health, as well as school readiness and achievement (Diamond, 2013). They facilitate information processing, as well as the initiation and organisation of thoughts and goal-directed behaviour (Carlson et al., 2016). An increasing number of scholars captures a close relationship between motor skills and cognitive mechanisms (e.g., executive functions), not only in adults (Niemann et al., 2014; Ratey & Loehr, 2011; Wang & Guo, 2020), but also in adolescents (Marchetti et al., 2015; Rigoli et al., 2012) and children (de Sousa et al., 2019; Niederer et al., 2011; Riga, 1995; van der Fels et al., 2015). This relationship is especially apparent in, and significant for, young children. According to Kubicek, Javanic, and Schwarzer (2017), infants that start crawling at around the age of 9 months, perform better at tasks related to visual prediction in comparison to infants of the same age that start crawling at a later stage. On the same note, in a study involving 18-month-old infants, Gottwald and colleagues (2016) claimed the existence of a positive correlation not only between the young participants' motor control and inhibition (moving without touching an object), but also between motor control and working memory. At preschool age, EFs have also been found to be associated with motor skills (Cameron et al., 2012). Cameron and her colleagues (2012) concluded that there was a significant positive correlation between motor skills and how well three- to four-year-old children performed in tasks measuring cognitive inhibition.

The idea that the development of both motor and cognitive skills may be fundamentally intertwined is not novel. On the contrary, it partially stems from the embodied cognition perspective, according to which knowledge and representational ability emerge from the individual's bodily interaction with the physical and social environment (Houwen et al., 2017; Oudgenoeg-Paz et al., 2012; Smith & Gasser, 2005). Following the aforementioned example, 9-month-old infants that crawl have more opportunities to gain knowledge about their surroundings. This enables changes in various visual perception systems, leading to enhanced and differentiated social and mental cognition, which in return influences the way these infants examine and manipulate their environment (Dourou et al., 2017; Houwen et al., 2017; von Hofsten, 2007). The existence of a relationship between motor and cognitive development has also been introduced by Piaget's cognitive developmental theory (1952) and Gibson's theory of ecological psychology (1979).

Yet, motor and cognitive development tends to be studied separately and have been treated as independent phenomena that take place simultaneously (Diamond, 2000). However, should we aim to ensure the optimal development of children, we need to not only be aware of the developmental course and the factors influencing it, but also the way these factors are interrelated. This way, potential risks and protective factors can be identified early on, followed by the appropriate prevention and intervention programmes accordingly. The current article aims to combine and present the latest knowledge around the association of motor skills and EFs in both typically developing children and children with diagnosed special educational needs and/or disabilities (SEND).

Relevant theories and constructs

Executive functions

Despite the existing disagreement among researchers regarding the specific definition and terminology of EFs, there is a general consensus that executive functioning is not a unitary process; rather, it is an umbrella term, commonly used to describe a set of higher-order collective cognitive processes that are responsible for purposeful, goal-directed, adaptive, and flexible behaviour in a demanding environment (novel or complex situations) (Carlson et al., 2016; Diamond, 2013). In contrast to other aspects of cognition that are solidified, EFs are "*fluid cognitive processes that individuals draw upon in circumstances when automaticity is not possible*" (Willoughby et al., 2018, p. 1). Executive functions include three distinguishable, yet related cognitive sub functions: inhibitory control, shifting or cognitive flexibility, and updating, which are developed between early childhood and adolescence (Miyake & Friedman, 2012).

The inhibitory control refers to the ability to overpower predominant responses and conflicting stimuli. The process of inhibition control consists of two distinct factors: the response inhibition (repressing planned actions that are no longer required based on the existing context) and the interference control (cognitively overpowering conflicting stimuli) (Nigg, 2000; van der Fels et al., 2019; Verbruggen & Logan, 2008). Shifting, or cognitive flexi-

bility, describes the ability to shift between multiple tasks, rules, or mental sets to generate appropriate behavioural responses. Finally, updating concerns the ability to sustain, monitor, and rapidly manipulate contents in working memory, whereby specialised systems process verbal and visual information (Diamond, 2013; Miyake & Friedman, 2012).

Recent studies focused on the functions of the dorsolateral prefrontal cortex, the medial frontal, and orbitofrontal areas (the brain areas where EFs are controlled) have proposed a new distinction of EFs based on how the different processes manifest in a variety of contexts; the "*cool*" cognitive parts of EFs and the "*hot*" emotional parts (Nejati et al., 2018; Wu et al., 2017; Zelazo & Carlson, 2012). The former refers to top-down control processes, such as working memory, inhibitory control, and shifting or cognitive flexibility that occur in a nonemotional and analytical environment. The latter, on the other hand, consists of top-down processes elicited in contexts involving motivation and tasks having emotional components (Nigg, 2017; Peterson & Welsh, 2014).

The vast majority of researchers have reached a consensus that executive functions constitute fundamental cognitive skills that are ubiquitous in the lives of young children, potentially indicating a range of outcomes in the school and social environment, and enabling young children to face new and complex situations (McClelland et al., 2013; McClelland & Cameron, 2019; Moffitt et al., 2011). For example, when children play a game, they need to focus their attention, remember the rules and steps, switch their attention to the teacher/caregiver/peer if needed, and exhibit inhibitory control in order to stop the game if requested to do so.

Executive functions not only participate in demanding cognitive tasks like the aforementioned, but also in mastering motor tasks (Diamond, 2000). These links are further supported by longitudinal studies indicating a positive correlation between motors and attentional skills during the performance of tasks measuring working memory (Ludyga et al., 2019). From a behavioural point of view, the link between gross motor skills and executive functions may be explained by the fact that the latter are present in complex motor tasks (Livesey et al., 2006). Sports, which include the execution of complex motor skills, require attention, cognitive inhibition, and memory of complex sequences, which stimulates executive functioning and leads to further development of EFs (Diamond, 2015; Koutsandréou et al., 2016). For instance, in order to successfully participate in any group game (football, basketball, volleyball, etc.), children need to be able not only to maintain goal-directed behaviour, but also to control their actions and inhibit irrelevant or inappropriate ones, and to continuously adapt to the conditions around them. The more specific aspects and the nature of these relations between gross motor skills and executive functions may imply that the latter exhibit various levels of involvement in different complex gross motor skills for different EFs (van der Fels et al., 2019).

Over the last few years, several researchers have examined how various complex motor interventions may impact different aspects of the executive functioning, such as working memory (Alesi et al., 2016; Koutsandréou et al., 2016; Pesce et al., 2016). Koutsandréou and colleagues (2016) claimed that after a 10-week motor intervention the participating nine- to ten-year-old children showed significant improvement in their working memory. Similar positive effects were observed by Alesi and colleagues (2016) following a football intervention. Finally, during the same year, the results from a physical activity intervention developed and evaluated by Pesce and colleagues (2016) came to contradict the previous studies, claiming that physical activity over a six-month period had positive effects on motor skills and cognitive inhibition, but there was no effect on working memory.

In conclusion, it is evident that the development of motor skills is closely correlated with the development of EFs. However, as stated by van der Fels and colleagues (2019) in their review, the lack of relevant studies holds back any conclusions from being drawn regarding which specific executive functions and gross motor skills are correlated.

Motor skills

Even though motor skills constitute a common and well-known concept, at this point we would like to illustrate the definition of motor skills that was utilised in the context of the present paper. More specifically, motor or movement skills are a broad term that describes all the "*goal-directed movement patterns*" (Burton & Miller, 1998, p. 43). Even though motor skills are not usually approached in the context of cognition, motor skills are actually closely linked to cognition, as carrying out physical movements requires, among others, planning, deliberation, timing, and sequencing (Adolph, 2005; McClelland & Cameron, 2019). According to Burton and Miller (1998), motor skills and motor abilities are two distinct parts. Motor abilities outline an individual's general characteristics or capacities that support the performance of skills, and they are less prone to change from training. Motor skills are typically divided into two categories: gross and fine motor skills. In the context of this pa-

per, the focus is shifted mainly to the link between the gross motor skills and EFs, as gross motor skills comprise the ground upon which the fine motor skills are developed, and the existing research on the relationship between fine motor skills and EFs is limited and includes the element of academic achievement (Oberer et al., 2017).

It is universally acknowledged that gross motor skills illustrate the involvement of large body muscles in balance, limb, and trunk movements (Bishop, 2014). They constitute the fundamental skills that young children acquire and develop, which enable them to develop more complex and fine movements and skills (McClelland & Cameron, 2019). Gross motor skills are significant, not only for the physical, but the overall healthy development of children as well. Initially, as a means of social development and participation, especially in early childhood (e.g., playing games with peers) (Bar-Haim & Bart, 2006). Furthermore, gross motor skills are also linked to a number of other domains such as perception, language, cognition, and executive functioning (Barnett et al., 2009; van der Fels et al., 2019). The significant connection between motor and cognitive skills is apparent in children with motor skill impairments, as will be further discussed below (Piek et al., 2004; Rigoli et al., 2012).

Review of latest relevant literature

Researchers have been investigating the links between motor and cognitive functions for decades. Recent scientific findings of both behavioural and neuroimaging studies have come to further support Piaget's innovative proposal (Ridler et al., 2006; Rigoli et al., 2012). More recently, researchers have been shifting their attention to the embodied cognition approach, which positions cognitive functioning within a sensorimotor context (Houwen et al., 2017; Oudgenoeg-Paz et al., 2012). For Koziol, Budding, and Chidekel (2012), both the cerebellum and the sensorimotor interaction with the environment are equally significant for the regulation of one's behaviour.

Recent data from brain research support the theorised association between the two domains (Diamond, 2000). From a neuropsychological point of view, data indicate that regions important to motor performance and executive functioning overlap (Diamond, 2000; Leisman et al., 2016). Neural networks such as the cerebellum, prefrontal cortex, the basal ganglia, and other connecting structures are not only underlying executive functions, but also heavily participate in gross motor tasks, and are co-activated during motor and cognitive tasks (Leisman et al., 2016). These relations are supported by longitudinal studies as well (Ludyga et al., 2019). In addition to that, according to Howard, Okely, and Ellis (2015), both motor and cognitive development undergoes a maturation and integration period during preschool years. Another possible explanation for the interrelations between motor and cognitive skills is that they share higher order cognitive processes such as planning, goal-orientation, and strategy use (Oberer et al., 2017). Based on research findings, it is not surprising that children with diagnosed neurodevelopmental disorders tend to face significant difficulties with their motor and cognitive development (Riga et al., 2020; Diamond, 2000). Over the past years, the assumptions regarding the association between motor skills and EFs have been empirically investigated in all age groups.

Evidence from typically developing children

A growing number of academics have focused their research interest on infancy. Research on EF (working memory) proposed that infants that acquire the ability to walk earlier, tend to perform better in working memory tasks later in their lives (Poranen-Clark et al., 2015). A recent study on early motor skills has illustrated that gross motor ability at two years of age can predict inhibition control at three years, while early motor abilities (one and two years of age) can predict not only working memory but also inhibition control at two years of age (Wu et al., 2017). In a similar tone, a number of other studies verify the assumption that motor proficiency is not just related to the development of cognitive skills but may also act as a "*control parameter*" for future development (Piek et al., 2008; Poranen-Clark et al., 2015; von Hofsten, 2007; Zysset et al., 2018).

A recent study on five- to six-year-old children found a positive correlation between motor skill performance and EFs (Stöckel & Hughes, 2016). Another study on the same age group proposed that several motor scores (qualitative and quantitative) were correlated to working memory and verbal fluency, a relationship which remained significant even after controlling for attention. Results from studies that included older children as well (four- to sixteen-year-old) using cross-sectional data have shown correlation between more demanding motor skills and executive functions (van der Fels et al., 2015). In a similar sampled study (typically developing chil-

dren six to fourteen years old), several weak but significant links were reported between motor skills and inhibition, working memory, and the cognitive flexibility assessed using the Pearson correlation coefficient (absolute values ranging from 0.02 to 0.22) (Piek et al., 2004). Even after considering the variables of age, gender, and inattention, Piek and her colleagues (2004) concluded that working memory and inhibition continued to present significant correlation to motor performance of the sample. Similarly, Livesey and colleagues (2006) found that overall motor performance was moderately-to-strongly related to inhibition in typically developing young children (five to six years old). Finally, the same intensity of correlations ranging from weak to moderate between motor performance and inhibition were found in a normative sample of adolescents (Rigoli et al., 2012). On the opposite side, a study involving five- to six-year-old children highlighted that motor ability and EFs presented a link only on one working memory task (Wassenberg et al., 2005).

Evidence from children with SEND

It has been suggested that the relationship between motor and cognitive skills might be more apparent in children with developmental disorders. Research has illustrated that children with motor coordination difficulties also exhibit additional difficulties in EFs (Bernardi et al., 2018; Leonard & Hill, 2015). In a two-year follow-up study, Bernardi and colleagues (2018) concluded that children exhibiting poor motor coordination (either diagnosed with Developmental Coordination Disorder, or not) exhibited persistent difficulties in their executive functions, mainly associated with the non-verbal domains of EFs. Their results came in complete agreement with previous relevant research (Michel et al., 2011). In 2018, Michel, Molitor, and Schneider presented the results of a one-year follow-up investigation on the relationship between motor coordination difficulties and poor executive functioning in four- to six-year-old children (Michel et al., 2018). In their study, they initially recruited a sample of 208 four- to six-year-old children from mainstream and special needs. After being tested with the M-ABC-2, all the children that scored below the 10^{th} percentile (n = 48) were included in the motor coordination impairment group and were later paired with a child from the rest of the sample as a comparison measure. One year later, the sample was tested again. The data collected from several tasks (i.e., the GoNogo task, the standard Flanker task, and part 1 of the HTKS task) indicated that a year after the initial measurement and without the presence of an intervention programme, half of the young participants in the impairment group were able to catch up with their typically developing peers in regard to their executive functioning, while the rest continued to "*perform worse*" (Michel et al., 2018, p. 36). Furthermore, Houwen and colleagues (2016) highlighted once more the overlap of these two developmental domains in their study where children who face cognitive difficulties were more likely to experience motor difficulties as well.

The correlation between motor development and EFs has also been supported by studies on children with attention deficit hyperactivity disorder (ADHD) (Fliers et al., 2012). Recruiting a sample of 50 children with diagnosed ADHD, Ziereis and Jansen (2016) examined the correlation between cognitive and motor abilities in this cohort. The researchers found significant links between motor skills and working memory, introducing the hypothesis that motor training could improve executive functioning in children with ADHD. The hypothesis was later tested and proven valid by several relative studies (Benzing et al., 2018; Den Heijer et al., 2017; Grassmann et al., 2017). Children with diagnosed ADHD often have gross motor skills problems (difficulties with balance, rapid movements, and with consistency and timing of movements). Similar deficits can be identified in children with dyslexia (Marchand-Krynski et al., 2017).

Finally, children and adults within the autism spectrum often experience disturbances, not only in gross and fine motor skills (Kopp et al., 2010), but also in their general coordination, with hypotonia and apraxia being very common among them (Ament et al., 2015; Whyatt & Craig, 2012). In 2016, a group of researchers examined EFs in infants at with various levels of risk for ASD (based on family history), and the potential links between motor skills and EFs (St. John et al., 2016). Infants that had a sibling or a first degree relative diagnosed with autism spectrum disorder were considered high risk, and infants with no history of autism in their immediate family were considered low risk. Motor skills (both fine and gross) and cognitive ability were directly measured at two time points (12 and 24 months). The results indicated that even though no group differences were observed at 12 months, motor skills were associated with EF performance on reversal trials at 24 months. According to researchers, "*findings suggest that high risk siblings demonstrate altered EF development and that motor skills may play an important role in this process*" (St. John et al., 2016, p. 1016).

Discussion

The available literature on the relationship between motor skills and executive functioning present a few issues that warrant further investigation. Initially, most of the studies on the matter have examined the relationship between the two constructs focused on five-year-old children and older (with a few exceptions of research on infants). Even though the preschool years have been highlighted as a crucial developmental period for both motor and cognitive skills, empirical research involving three to five-year-old children is rather rare (Niederer et al., 2011).

Another important issue to consider is the significant contradictions among the results of different studies. The inconsistency of evidence stems from various reasons. Should we examine more thoroughly various studies on the matter, it appears that when confounding variables are examined, the statistical significance of the relationship between the motor skills and EFs is weakened (e.g., Piek et al., 2008; Rigoli et al., 2012; Roebers & Kauer, 2009). For instance, in a study, which was focused on seven-year olds who attended mainstream primary school, weak-to-moderate but significant correlations were reported between motor skills and EFs. However, additional checks took place controlling for the variables age and processing speed, leading to a decrease in the amount of significant correlations (Roebers & Kauer, 2009). The researchers endeavoured to explain the contradicting results above by introducing two new concepts (the nominal task difficulty and functional task difficulty) as variables influencing the link between motor performance and EFs. The former referred to the difficulty of the task, and the latter to the skills required by the child participating in the task. More specifically, Roebers and Kauer (2009) claimed that the young participants had already reached, at least to some extent, a level of automaticity, which enabled them to perform the easy gross motor tasks with limited demands on EFs. This resulted in the weak and non-significant links with EFs. However, in the instance that they had to face more demanding (complex) gross motor tasks, and thus utilise the EFs, the performance correlated significantly with EFs. Rigoli and colleagues (2012) agreed with the crucial role of the child's developmental level, but they also proposed that correlation between motor skills and EFs may be influenced by existing motor coordination difficulties.

Moreover, a significant inconsistency among the studies that could account for the conflicting results is the way EFs were measured (performance-based measures versus observation ratings by parents/carers and teachers) (Toplak et al., 2013). According to Toplak and colleagues (2013), these two distinct measures do not assess the same construct. On one hand, the performance-based measures of EFs are implemented under optimal performance situations and within very structured conditions, often providing unclear data on how motor performance may be related to observations of EFs in an everyday context. On the other hand, parents' and teachers' rating measures occur under typical performance situations and evaluate the individual's manifestations of EFs in unstructured everyday conditions, but they are more prone to bias. '*The former measures are "supervisory", and the latter involve "executive control"*' (Toplak et al., 2013, p. 140). Thus, it has been suggested that both performance-based measures and ratings should be used in a complimentary manner (Houwen et al., 2017).

Furthermore, the significant variable of the cultural context has been ignored in many of the studies. The way EFs are perceived and evaluated differs significantly between Western and Eastern cultures, which could have a valuable impact on the results, mainly when parents' and teachers' rating are used as a means of evaluating EFs. In a study concerning the relationship between EFs and school achievement in six- to eleven-year-old children from four different countries (Sweden, Spain, Iran, and China), Thorell and colleagues (2013) suggested the existence of cultural bias in how the assessments were completed by parents or teachers (i.e., Chinese boys received lower rating than girls to the extent that they were illustrated as having EFs' deficits, while Iranian girls received lower rating than boys. No similar variation in EFs due to sex being observed in Sweden or Spain). According to the researchers, 'perhaps executive functioning deficits are exacerbated in China because the Chinese culture has such a strong emphasize [sic] on self-regulatory skills' (Thorell et al., 2013, p. 635). The cultural bias effect is not a novel methodological issue. In a 2011 study regarding ADHD symptoms in children, Hinshaw and colleagues pinpointed the same phenomenon. According to their study, American teachers showed more tolerance regarding what type of behaviour they considered disruptive, while Chinese teachers tended to be stricter, resulting in two significantly different ratings for the same behaviour (Hinshaw et al., 2011). American teachers showed more tolerance regarding what type of behaviour they considered disruptive, while Chinese teachers tended to be stricter, resulting in two significantly different ratings for the same behaviour (Hinshaw et al., 2011). According to Thorell and colleagues (2013), executive functioning ratings are prone to bias, especially

from a cross-cultural point of view, which highlights the need for continuous research for more sensitive and valid tools for measuring EFs.

Finally, an emerging concept and possible implication deriving from the existence of a relationship between gross motor skills and EFs, as well as the nature of this relationship, is the use of motor training as an indirect way of enhancing EFs. As it has already been mentioned, this notion was presented by Ziereis and Jansen (2016), and it referred to the use of motor training as a means of improving EFs in children with ADHD. This hypothesis was also tested and proven valid by several researchers in the field (Benzing et al., 2018; Den Heijer et al., 2017; Grassmann et al., 2017).

As it has been highlighted, the relationship between gross motor skills and EFs is apparent in all children. Research on children with or without SEND, as well as on children in various age groups (from preschoolers to teenagers) has pinpointed the existence of a weak to strong correlation between these two concepts, especially between EFs and more complex motor skills. This relationship has inspired an increasing number of researchers into utilising motor training activities as a means of enhancing EFs in children. However, most of these studies are limited to children attending primary education and beyond, leaving the preschool age a rather undeveloped area.

Conclusion

The relationship between motor and cognitive development has been an area of interest for more than 70 years. The available literature in both neurophysiological and behavioural level verifies this relationship, with contradicting results regarding its significance. Based on the studies presented above, the correlation between these two concepts can vary from weak to strong, depending on the sample (age, abilities, and skills), and the method of measuring EFs.

In the present paper the authors not only highlighted the existing gaps in this area of research, but they also suggested future directions and implications. Initially, most of the studies outlined above presented a significant lack of consistency not only regarding the assessment methods used, but also the sample, and the targeted motor skills and EF. Thus, the results regarding the relationship between motor skills and EFs were often contradicting, not allowing generalisations to be made and conclusion to be drawn. Additionally, the authors pinpointed the limited research on the matter concerning children three-to-five years old. Based on these points, the authors of this article claim that there is significant need for more thorough and in-depth investigation of the relationship between gross motor skills and EFs through studies that present consistency in their methodologies and statistical analyses. Furthermore, it is of great importance for future studies to be focused on the relations between gross motor skills and EFs in children three-to-five years old, as it is universally acknowledged that preschool age is a rather significant developmental stage that can have a valuable impact on later life. The consistency among the studies, as well as the more thorough examination of the preschool age group will allow researchers to decode the true relationship between EFs and motor skills in this age group (including methods to validly assess EFs). As a result, it will be easier for researchers to design, and for educational staff to implement, appropriate prevention and intervention programmes. Should we consider the extent to which these awaiting to be discovered and utilised intervention and prevention programmes could support children with and without SEND, it is without a doubt that more attention and consideration should be given on this relationship, especially regarding young children three-to-five years old.

Implications for Physical Education

Nowadays, there is a significant shift in a more academic way of learning, even in preschool education, resulting in the diminishment of the importance of physical education (PE). The research presented in this paper highlights the importance of PE curriculum for children with and without SEND, not only as a means of enhancing the development of gross motor skills, but also as a way to improve and support cognitive development.

Implications for Quality of Life

The importance of EFs in children's development and quality of life has been long proven and acknowledged. The relationship between gross motor skills and EFs has created possibilities regarding the utilisation of PE as a way of enhancing EFs, and through that, of supporting children with and without SEND in their cognitive development, resulting in better quality of life.

References

Adolph, K. E. (2005). Learning to learn in the development of action. In J. J. Rieser, J. J. Lockman, & C. A. Nelson (Eds.), *Minnesota Symposia on Child Psychology* (pp. 91-122). US: Lawrence Erlbaum.

Alesi, M., Bianco, A., Luppina, G., Palma, A., & Pepi, A. (2016). Improving children's coordinative skills and executive functions: The effects of a football exercise program. *Perceptual and Motor Skills, 122*(1), 27–46. https://doi.org/10.1177/0031512515627527

Ament, K., Mejia, A., Buhlman, R., Erklin, S., Caffo, B., Mostofsky, S., & Wodka, E. (2015). Evidence for Specificity of Motor Impairments in Catching and Balance in Children with Autism. *Journal of Autism and Developmental Disorders, 45*, 742–751. https://doi.org/10.1007/s10803-014-2229-0

Bar-Haim, Y., & Bart, O. (2006). Motor function and social participation in kindergarten children. *Social Development, 15*(2), 296–310. https://doi.org/10.1111/j.1467-9507.2006.00342.x

Barnett, L. M., van Beurden, E., Morgan, P. J., Brooks, L. O., & Beard, J. R. (2009). Childhood motor skill proficiency as a predictor of adolescent physical activity. *Journal of Adolescent Health, 44*(3), 252–259. https://doi.org/10.1016/j.jadohealth.2008.07.004

Benzing, V., Chang, Y. K., & Schmidt, M. (2018). Acute physical activity enhances executive functions in children with ADHD. *Scientific Reports, 8*(12382). https://doi.org/10.1038/s41598-018-30067-8

Bernardi, M., Leonard, H. C., Hill, E. L., Botting, N., & Henry, L. A. (2018). Executive functions in children with developmental coordination disorder: A 2-year follow-up study. *Developmental Medicine and Child Neurology, 60*(3), 306–313. https://doi.org/10.1111/dmcn.13640

Bishop, M. R. (2014). Motor. In D. Granpeesheh, J. Tarbox, A. C. Najdowski, & J. Kornack (Eds.), *Evidence-based treatment for children with autism: The CARD model. A volume in practical resources for the mental health professional* (pp. 261–272). Academic Press. https://doi.org/10.1016/b978-0-12-411603-0.00014-8

Burton, A. W., & Miller, D. E. (1998). *Movement skill assessment*. Champaign, IL: Human Kinetics.

Carlson, S. M., Faja, S., & Beck, D. M. (2016). Incorporating early development into the measurement of executive function: The need for a continuum of measures across development. In J. A. Griffin, P. McCardle, & L. S. Freund (Eds.), *Executive function in preschool-age children: Integrating measurement, neurodevelopment, and translational research* (pp. 45–64). US: American Psychological Association. https://doi.org/10.1037/14797-003

De Santana, J. J. R. A., & Galera, C. (2014). Visual-spatial and verbal-spatial binding in working memory. *Psychology and Neuroscience, 7*(3), 399–406. https://doi.org/10.3922/j.psns.2014.048

de Sousa, F. A., Medeiros, A. R., Del Rosso, S., Stults-Kolehmainen, M., & Boullosa, D. A. (2019). The influence of exercise and physical fitness status on attention: a systematic review. *International Review of Sport and Exercise Psychology, 12*(1), 202–234. https://doi.org/10.1080/1750984X.2018.1455889

Den Heijer, A. E., Groen, Y., Tucha, L., Fuermaier, A. B. M., Koerts, J., Lange, K. W., Thome, J., & Tucha, O. (2017). Sweat it out? The effects of physical exercise on cognition and behavior in children and adults with ADHD: A systematic literature review. *Journal of Neural Transmission, 124*(Suppl 1), 3-26. https://doi.org/10.1007/s00702-016-1593-7

Diamond, A. (2000). Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. *Child Development, 71(*1), 44–56. https://doi.org/10.1111/1467-8624.00117

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*, 135-168. https://doi.org/10.1146/annurev-psych-113011-143750

Diamond, A. (2015). Effects of physical exercise on executive functions: Going beyond simply moving to moving with thought. *Annals of Sports Medicine and Research, 2*(1), 1011. Retrieved from http://www.pubmed.ncbi.nlm.nih.gov

Dourou, E., Komessariou, A., Riga, V., & Lavidas, K. (2017). Assessment of gross and fine motor skills in preschool children using the Peabody Developmental Motor Scales Instrument. *European Psychomotricity Journal, 9*(1), 89-113.

Fliers, E. A., Vasquez, A. A., Poelmans, G., Rommelse, N., Altink, M., Buschgens, C., Asherson, P., Banaschewski, T., Ebstein, R., Gill, M., Miranda, A., Mulas, F., Oades, R. D., Roeyers, H., Rothenberger, A., Sergeant, J., Sonuga-Barke, E., Steinhausen, H. C., Faraone, S. V., Franke, B. (2012). Genome-wide association study of motor coordination problems in ADHD identifies genes for brain and muscle function. *World Journal of Biological Psychiatry, 13*(3), 211–222. https://doi.org/10.3109/15622975.2011.560279

Gibson, J. J. (1979). *The ecological approach to visual perception*. NJ: Lawrence Erlbaum.

Gottwald, J. M., Achermann, S., Marciszko, C., Lindskog, M., & Gredebäck, G. (2016). An embodied account of early executive-function development: Prospective motor control in infancy is related to inhibition and working memory. *Psychological Science, 27*(12), 1600-1610. https://doi.org/10.1177/0956797616667447

Grassmann, V., Alves, M. V., Santos-Galduróz, R. F., & Galduróz, J. C. F. (2017). Possible cognitive benefits of acute physical exercise in children with ADHD: A systematic review. *Journal of Attention Disorders, 21*(5), 367-371. https://doi.org/10.1177/1087054714526041

Hinshaw, S. P., Scheffler, R. M., Fulton, B. D., Aase, H., Banaschewski, T., Cheng, W., Mattos, P., Holte, A., Levy, F., Sadeh, A., Sergeant, J. A., Taylor, E., & Weiss, M. D. (2011). International variation in treatment procedures for ADHD: social context and recent trends. *Psychiatric Services, 62*(5), 459-464. https://doi.org/10.1176/ps.62.5.pss6205_0459

Houwen, S., van der Veer, G., Visser, J., & Cantell, M. (2017). The relationship between motor performance and parent-rated executive functioning in 3- to 5-year-old children: What is the role of confounding variables? *Human Movement Science, 53*, 24–36. https://doi.org/10.1016/j.humov.2016.12.009

Houwen, S., Visser, L., van der Putten, A., & Vlaskamp, C. (2016). The interrelationships between motor, cognitive, and language development in children with and without intellectual and developmental disabilities. *Research in Developmental Disabilities, 53-54*, 19-31. https://doi.org/10.1016/j.ridd.2016.01.012

Howard, S. J., Okely, A. D., & Ellis, Y. G. (2015). Evaluation of a differentiation model of preschoolers' executive functions. *Frontiers in Psychology, 6*(285). https://doi.org/10.3389/fpsyg.2015.00285

Kopp, S., Beckung, E., & Gillberg, C. (2010). Developmental coordination disorder and other motor control problems in girls with autism spectrum disorder and/or attention-deficit/hyperactivity disorder. *Research in Developmental Disabilities, 31*(2), 350-361. https://doi.org/10.1016/j.ridd.2009.09.017

Koutsandréou, F., Wegner, M., Niemann, C., & Budde, H. (2016). Effects of motor versus cardiovascular exercise training on children's working memory. *Medicine and Science in Sports and Exercise, 48*(6), 1144-1152. https://doi.org/10.1249/MSS.0000000000000869

Koziol, L. F., Budding, D. E., & Chidekel, D. (2012). From movement to thought: Executive function, embodied cognition, and the cerebellum. *Cerebellum, 11*, 505-525. https://doi.org/10.1007/s12311-011-0321-y

Kubicek, C., Jovanovic, B., & Schwarzer, G. (2017). The relation between crawling and 9-month-old infants' visual prediction abilities in spatial object processing. *Journal of Experimental Child Psychology, 158*, 64-76. https://doi.org/10.1016/j.jecp.2016.12.009

Leisman, G., Moustafa, A., & Shafir, T. (2016). Thinking, walking, talking: Integratory motor and cognitive brain function. *Frontiers in Public Health, 4*(94). https://doi.org/10.3389/fpubh.2016.00094

Leonard, H. C., & Hill, E. L. (2015). Executive difficulties in developmental coordination disorder: Methodological issues and future directions. *Current Developmental Disorders Reports, 2*, 141-149. https://doi.org/10.1007/s40474-015-0044-8

Livesey, D., Keen, J., Rouse, J., & White, F. (2006). The relationship between measures of executive function, motor performance and externalising behaviour in 5- and 6-year-old children. *Human Movement Science, 25*(1), 50-64. https://doi.org/10.1016/j.humov.2005.10.008

Ludyga, S., Mücke, M., Kamijo, K., Andrä, C., Pühse, U., Gerber, M., & Herrmann, C. (2019). The role of motor competences in predicting working memory maintenance and preparatory processing. *Child Development, 91*(3), 799-813. https://doi.org/10.1111/cdev.13227

Marchand-Krynski, M. È., Morin-Moncet, O., Bélanger, A. M., Beauchamp, M. H., & Leonard, G. (2017). Shared and differentiated motor skill impairments in children with dyslexia and/or attention deficit disorder: From simple to complex sequential coordination. *PLoS ONE 12*(5), e0177490. https://doi.org/10.1371/journal.pone.0177490

Marchetti, R., Forte, R., Borzacchini, M., Vazou, S., Tomporowski, P. D., & Pesce, C. (2015). Physical and motor fitness, sport skills and executive function in adolescents: A moderated prediction model. *Psychology, 6*(14), 1915-1929. https://doi.org/10.4236/psych.2015.614189

McClelland, M. M., Acock, A. C., Piccinin, A., Rhea, S. A., & Stallings, M. C. (2013). Relations between preschool attention span-persistence and age 25 educational outcomes. *Early Childhood Research Quarterly, 28*(2), 314-324. https://doi.org/10.1016/j.ecresq.2012.07.008

McClelland, M. M., & Cameron, C. E. (2019). Developing together: The role of executive function and motor skills in children's early academic lives. *Early Childhood Research Quarterly, 46*, 142-151. https://doi.org/10.1016/j.ecresq.2018.03.014

Michel, E., Molitor, S., & Schneider, W. (2018). Differential changes in the development of motor coordination and executive functions in children with motor coordination impairments. *Child Neuropsychology, 24*(1), 20-45. https://doi.org/10.1080/09297049.2016.1223282

Michel, E., Roethlisberger, M., Neuenschwander, R., & Roebers, C. M. (2011). Development of cognitive skills in children with motor coordination impairments at 12-month follow-up. *Child Neuropsychology, 17*(2), 151-172. https://doi.org/10.1080/09297049.2010.525501

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science, 21*(1), 8-14. https://doi.org/10.1177/0963721411429458

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H. L., Houts, R., Poulton, R., Roberts, B. W., Ross, S., Sears, M. R., Thomson, W. M., & Caspi, A. (2011). A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences of the United States of America, 108*(7), 2693-2698. https://doi.org/10.1073/pnas.1010076108

Nejati, V., Salehinejad, M. A., & Nitsche, M. A. (2018). Interaction of the left dorsolateral prefrontal cortex (l-DLPFC) and right orbitofrontal cortex (OFC) in hot and cold executive functions: Evidence from transcranial direct current stimulation (tDCS). *Neuroscience, 369*, 109-123. https://doi.org/10.1016/j.neuroscience.2017.10.042

Niederer, I., Kriemler, S., Gut, J., Hartmann, T., Schindler, C., Barral, J., & Puder, J. J. (2011). Relationship of aerobic fitness and motor skills with memory and attention in preschoolers (Ballabeina): A cross-sectional and longitudinal study. *BMC Pediatrics, 11*(34). https://doi.org/10.1186/1471-2431-11-34

Niemann, C., Godde, B., Staudinger, U. M., & Voelcker-Rehage, C. (2014). Exercise-induced changes in basal ganglia volume and cognition in older adults. *Neuroscience, 281*(5), 147-163. https://doi.org/10.1016/j.neuroscience.2014.09.033

Nigg, J. T. (2000). On inhibition/disinhibition in developmental psychopathology: Views from cognitive and personality psychology and a working inhibition taxonomy. *Psychological Bulletin, 126*(2), 220-246. https://doi.org/10.1037/0033-2909.126.2.220

Nigg, J. T. (2017). Annual research review: On the relations among self-regulation, self-control, executive functioning, effortful control, cognitive control, impulsivity, risk-taking, and inhibition for developmental psychopathology. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 58*(4), 361-383. https://doi.org/10.1111/jcpp.12675

Oberer, N., Gashaj, V., & Roebers, C. M. (2017). Motor skills in kindergarten: Internal structure, cognitive correlates and relationships to background variables. *Human Movement Science, 52*, 170-180. https://doi.org/10.1016/j.humov.2017.02.002

Oudgenoeg-Paz, O., Volman, M. C. J. M., & Leseman, P. P. M. (2012). Attainment of sitting and walking predicts development of productive vocabulary between ages 16 and 28 months. *Infant Behavior and Development, 35*(4), 733-736. https://doi.org/10.1016/j.infbeh.2012.07.010

Pesce, C., Masci, I., Marchetti, R., Vazou, S., Sääkslahti, A., & Tomporowski, P. D. (2016). Deliberate play and preparation jointly benefit motor and cognitive development: Mediated and moderated effects. *Frontiers in Psychology, 7*, 349. https://doi.org/10.3389/fpsyg.2016.00349

Peterson, E., & Welsh, M. C. (2014). The development of hot and cool executive functions in childhood and adolescence: Are we getting warmer? In S. Goldstein, J. Springer, & A. Naglieri (Eds.), *Handbook of executive functioning* (pp. 45-65). Springer. https://doi.org/10.1007/978-1-4614-8106-5

Piaget, J. (1952). *The origins of intelligence in children*. NY: International Universities Press.

Piek, J. P., Dawson, L., Smith, L. M., & Gasson, N. (2008). The role of early fine and gross motor development on later motor and cognitive ability. *Human Movement Science, 27*(5), 668–681. https://doi.org/10.1016/j.humov.2007.11.002

Piek, J. P., Dyck, M. J., Nieman, A., Anderson, M., Hay, D., Smith, L. M., McCoy, M., & Hallmayer, J. (2004). The relationship between motor coordination, executive functioning and attention in school aged children. *Archives of Clinical Neuropsychology, 19*(8), 1063-1076. https://doi.org/10.1016/j.acn.2003.12.007

Poranen-Clark, T., von Bonsdorff, M. B., Lahti, J., Räikkönen, K., Osmond, C., Rantanen, T., Kajantie, E., & Eriksson, J. G. (2015). Infant motor development and cognitive performance in early old age: the Helsinki Birth Cohort Study. *Age, 37*(3), 9785. https://doi.org/10.1007/s11357-015-9785-x

Ratey, J. J., & Loehr, J. E. (2011). The positive impact of physical activity on cognition during adulthood: A review of underlying mechanisms, evidence and recommendations. *Reviews in the Neurosciences, 22*(2), 171-185. https://doi.org/10.1515/RNS.2011.017

Ridler, K., Veijola, J. M., Tanskanen, P., Miettunen, J., Chitnis, X., Suckling, J., Murray, G. K., Haapea, M., Jones, P. B., Isohanni, M. K., & Bullmore, E. T. (2006). Fronto-cerebellar systems are associated with infant motor and adult executive functions in healthy adults but not in schizophrenia. *Proceedings of the National Academy of Sciences of the United States of America, 103*(42), 15651-15656. https://doi.org/10.1073/pnas.0602639103

Riga, V. (1995). *Expression corporelle, facteur d' apprentissage?* Thèse de Doctorat nouveau régime. Strasbourg: USHS.

Riga, V., Misirli, A., Komessariou, A. (2020). Assessment of motor development of preschool children with special education needs. *European Journal of Physical Education and Sport Science, 6*(7), 17-34. http://dx.doi.org/10.46827/ejpe.v6i7.3303

Rigoli, D., Piek, J. P., Kane, R., & Oosterlaan, J. (2012). An examination of the relationship between motor coordination and executive functions in adolescents. *Developmental Medicine and Child Neurology, 54*(11), 1025-1031. https://doi.org/10.1111/j.1469-8749.2012.04403.x

Roebers, C. M., & Kauer, M. (2009). Motor and cognitive control in a normative sample of 7-year-olds. *Developmental Science, 12*(1), 175-181. https://doi.org/10.1111/j.1467-7687.2008.00755.x

Siegler, R., DeLoache, J., Eisenberg, N., Saffran, J., & Leaper, C. (2020). *How children develop*. New York: Worth Publishers.

Smith, L., & Gasser, M. (2005). The development of embodied cognition: Six lessons from babies. *Artificial Life, 11*(1-2), 13-29. https://doi.org/10.1162/1064546053278973

St. John, T., Estes, A. M., Dager, S. R., Kostopoulos, P., Wolff, J. J., Pandey, J., Elison, J. T., Paterson, S. J., Schultz, R. T., Botteron, K., Hazlett, H., & Piven, J. (2016). Emerging executive functioning and motor development in infants at high and low risk for autism spectrum disorder. *Frontiers in Psychology, 7,* 1016. https://doi.org/10.3389/fpsyg.2016.01016

Stöckel, T., Hughes, C.M., (2016). The relation between measures of cognitive and motor functioning in 5- to 6-year-old children. *Psychological Research, 80*(4), 543-554. https://doi.org/10.1007/s00426-015-0662-0

Thorell, L. B., Veleiro, A., Siu, A. F. Y., & Mohammadi, H. (2013). Examining the relation between ratings of executive functioning and academic achievement: Findings from a cross-cultural study. *Child Neuropsychology, 19*(6), 630-638. https://doi.org/10.1080/09297049.2012.727792

Toplak, M. E., West, R. F., & Stanovich, K. E. (2013). Practitioner Review: Do performance-based measures and ratings of executive function assess the same construct? *Journal of Child Psychology and Psychiatry and Allied Disciplines, 54*(2), 131-143. https://doi.org/10.1111/jcpp.12001

van der Fels, I. M. J., Smith, J., de Bruijn, A. G. M., Bosker, R. J., Königs, M., Oosterlaan, J., Visscher, C., & Hartman, E. (2019). Relations between gross motor skills and executive functions, controlling for the role of information processing and lapses of attention in 8-10-year-old children. *PLoS ONE, 14*(10), e0224219. https://doi.org/10.1371/journal.pone.0224219

van der Fels, I. M. J., te Wierike, S. C. M., Hartman, E., Elferink-Gemser, M. T., Smith, J., & Visscher, C. (2015). The relationship between motor skills and cognitive skills in 4-16-year-old typically developing children: A systematic review. *Journal of Science and Medicine in Sport, 18*(6), 697-703. https://doi.org/10.1016/j.jsams.2014.09.007

Verbruggen, F., & Logan, G. D. (2008). Response inhibition in the stop-signal paradigm. *Trends in Cognitive Sciences, 12*(11), 418-424. https://doi.org/10.1016/j.tics.2008.07.005

von Hofsten, C. (2007). Action in development. *Developmental Science, 10*(1), 54-60. https://doi.org/10.1111/j.1467-7687.2007.00564.x

Wang, B., & Guo, W. (2020). Exercise mode and attentional networks in older adults: A cross-sectional study. *Peer Journal- Life and Environment, 8*(e8364). https://doi.org/10.7717/peerj.8364

Wassenberg, R., Kessels, A. G. H., Kalff, A. C., Hurks, P. P. M., Jolles, J., Feron, F. J. M., Hendriksen, J. G. M., Kroes, M., Beeren, M., & Vles, J. S. H. (2005). Relation between cognitive and motor performance in 5- To 6-year-old children: Results from a large-scale cross-sectional study. *Child Development, 76*(5), 1092-1103. https://doi.org/10.1111/j.1467-8624.2005.00899.x

Whyatt, C. P., & Craig, C. M. (2012). Motor skills in children aged 7-10 years, diagnosed with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 42*(9), 1799-1809. https://doi.org/10.1007/s10803-011-1421-8

Willoughby, M. T., Piper, B., Kwayumba, D., & McCune, M. (2018). Measuring executive function skills in young children in Kenya. *Child Neuropsychology, 25*(1), 1-20. https://doi.org/10.1080/09297049.2018.1486395

Wu, M., Liang, X., Lu, S., & Wang, Z. (2017). Infant motor and cognitive abilities and subsequent executive function. *Infant Behavior and Development, 49*, 204-213. https://doi.org/10.1016/j.infbeh.2017.09.005

Zelazo, P. D., & Carlson, S. M. (2012). Hot and cool executive function in childhood and adolescence: Development and plasticity. *Child Development Perspectives, 6*(4), 354-360. https://doi.org/10.1111/j.1750-8606.2012.00246.x

Ziereis, S., & Jansen, P. (2016). Correlation of motor abilities and executive functions in children with ADHD. *Applied Neuropsychology: Child, 5*(2), 138-148. https://doi.org/10.1080/21622965.2015.1038746

Zysset, A. E., Kakebeeke, T. H., Messerli-Bürgy, N., Meyer, A. H., Stülb, K., Leeger-Aschmann, C. S., Schmutz, E. A., Arhab, A., Puder, J. J., Kriemler, S., Munsch, S., & Jenni, O. G. (2018). Predictors of executive functions in preschoolers: Findings from the SPLASHY study. *Frontiers in Psychology, 9*, 2060. https://doi.org/10.3389/fpsyg.2018.02060