DISSERTATION SUMMARY

IMPORTANCE OF MOTOR SKILLS IN EARLY CHILDHOOD

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List of publications that the dissertation is based upon

Study	Publication	Status	Impact Factor
1	**Gandotra, A.,** Csaba, S., Sattar, Y., Cserényi, V., Bizonics, R., Cserjesi, R., & Kotyuk, E. (2021). A Meta-analysis of the Relationship between Motor Skills and Executive Functions in Typically-developing Children. *Journal of Cognition and Development*, 1-28	Accepted, published online	1.82
2	**Gandotra, A.,** Kotyuk, E., Bizonics, R., Khan, I., Petánszki, M., Kiss, L., Paulina, L., & Cserjesi, R. (2022). An exploratory study of the relationship between motor skills and indicators of cognitive and socio-emotional development in preschoolers. *European Journal of Developmental Psychology*, 1-16.	Accepted, published online	2.88
3	**Gandotra, A**., Cserjesi, R., Bizonics, R., & Kotyuk, E. (2021). Age differences in executive functions among Hungarian preschoolers. *European Journal of Developmental Psychology*, *18*(5), 695-710.	Accepted, published online	2.08
4	**Gandotra, A.,** Kotyuk, E., Szekely, A., Kasos, K., Csirmaz, L., & Cserjesi, R. (2020). Fundamental movement skills in children with autism spectrum disorder: A systematic review. *Research in Autism Spectrum Disorders*, *78*, 101632.	Accepted, published online	2.08

List of publications that are not based upon the topic of dissertation

Study	Publication	Status	Impact Factor
1	**Gandotra, A.,** Mehrotra, S., & Bharath, S. (2017). Psychological recovery and its correlates in adults seeking outpatient psychiatric services: An exploratory study from an Indian tertiary care setting. *Asian journal of psychiatry*, *29*, 77-82.	Accepted, published online	3.54
2	Mehrotra, S., **Gandotra, A.,** Sudhir, P. M., Thirthalli, J., & Rao, G. N. (2017). Why urban Indians are interested in an internet-based self-care app for depression? a brief pilot survey. *International Journal of Community Medicine and Public Health*, *4*(6), 2197-2201.	Accepted, published online	1.23
3	Mehrotra, S., Sudhir, P. M., Thirthalli, J., Rao, G. N., Srikanth, T. K., & **Gandotra, A. (**2017). Profile of seekers of an internet-based self-help program for depression in India: observations and implications. *International Journal of Community Medicine and Public Health*, *4*(9), 3202-3211.	Accepted, published online	1.23
4	Mehrotra, S., Kumar, S., Sudhir, P., Rao, G. N., Thirthalli, J., & **Gandotra, A**. (2017). Unguided mental health self-help apps: Reflections on challenges through a clinician's lens. *Indian Journal of Psychological Medicine*, *39*(5), 707.	Accepted, published online	1.072

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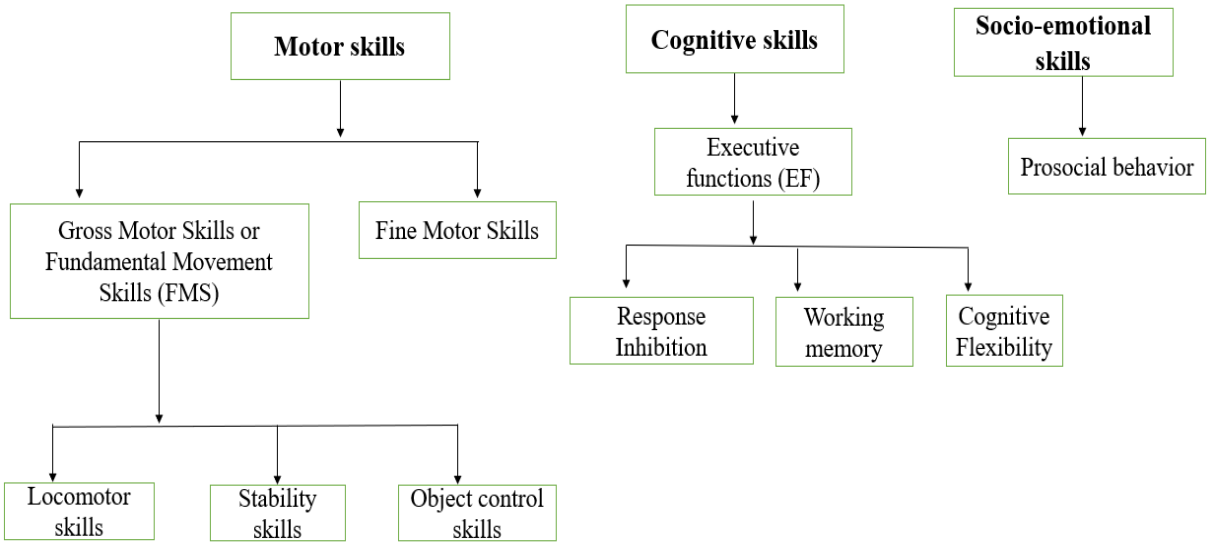
1. GENERAL INTRODUCTION

Movement is a significant aspect of development as it facilitates child's learning and growth. During early childhood (defined as ages 3 to 7 years for the purpose of this dissertation), motor skills develop rapidly and lay an important foundation for the physical, cognitive and language development (Clark, 1994). Motor skills are also crucial for children social functioning and adaptive behaviour. There is also a growing body of evidence suggesting that impairments in motor skills may have the potential to be an earlier behavioral maker for many neurodevelopmental disorders (NDD) (see review Micai et al., 2020). Despite its significance, movement is an overlooked aspect of development in the discipline of child psychology. In view of this, the present dissertation was undertaken to develop a deeper understanding of the important of motor skills by investigating its relationship with other developmental domains namely; cognitive and socio-emotional development.

1.1 Constructs that are used in the dissertation

Figure1.
Schematic diagram of the constructs used in the dissertation



Motor skills during early childhood can be broadly classified into two different groups (Figure 1.) i.e., gross motor skills and fine motor skills (Magill & Anderson, 2010).

Gross motor skills refer to the ability to effectively move through space using the large, force-producing muscles of the body (Haywood & Getchell, 2009). A specific set of gross motor skills are *Fundamental movement skills* (FMS). These are large movements that involve different body parts such as the feet, legs, trunk, hands, arms and head (Hulteen et al., 2018). FMS can be broadly classified into three groups i.e., locomotor skills, stability skills (or balance), and manipulative (or object control) skills. *Locomotor skills* are those that engage the body in movement in different directions. *Balance skills* are those that enhance body balance when in situ or in motion. *Manipulative skills* involve handling and controlling objects with the hand or foot (Haywood & Getchell, 2009).

Fine motor skills, refer to the precise movements of small muscle groups in the fingers, hands, and wrists to efficiently manipulate objects such as tying shoelaces, flipping pages of books, cutting with scissors, and making shapes from folding paper (Clark & Whitall, 1989).

Executive Functions. Executive functions (EFs) are an umbrella term that refers to a set of higher order cognitive processes that enables individuals to interact with their environment in an adaptive manner (Diamond, 2013). Currently, several authors have established that executive functions in preschool children comprises of three interrelated (Figure.1) yet distinct components – namely, response inhibition (RI), working memory (WM), and cognitive flexibility (CF) (or set shifting) in preschool children (Diamond, 2013; Miyake et al., 2000).

Response inhibition or inhibitory control refers to the ability to suppress an automatic response in favour of a more appropriate subordinate response, is the first component to emerge and is considered to be the foundation of EF (Miyake et al., 2000). *Working memory* is defined as the ability to briefly hold information in mind and mentally work on it to achieve a goal

(Garon et al., 2008). *Cognitive flexibility* (also known as set shifting) is the last EF component to develop as it builds on inhibitory control and working memory, is defined as the ability to rapidly switch between mental sets (Miyake et al., 2000).

Socio-emotional skills: With respect to socio-emotional skills, we used pro-social behavior as its indicator since it has been relatively less studied in conjunction with motor skills. *Prosocial behavior* refers to the voluntary behavior performed by an individual to benefit others and is a key element in the social adjustment of the child (Eisenberg & Fabes, 1990). It develops rapidly during early childhood and is typically demonstrated by preschoolers in the form of cooperation, sharing, helping, and comforting acts (Svetlova et al., 2010; Warneken & Tomasello, 2007).

1.1.Theoretical framework:

The current dissertation is based upon several theoretical perspectives which underscores the significance of motor skills by emphasizing its functional interconnectedness with other developmental domains.

Piaget's theory of cognitive development (1936) is one the earliest theory that suggests that the early onset of locomotor experiences provides children with increased opportunities to explore and interact with their environment, which in turn enhances their cognitive skills. These ideas were further reinforced in the *embodied cognition perspective*, in which cognition is considered to take place in the context of the sensory–motor interactions of the individual's body with their physical, as well as with their social environment (Barsalou, 1999; Gibbs, 2005; Smith & Gasser, 2005).

In keeping with these ideas, more recent theoretical accounts based on the concepts of reciprocity and automaticity have offered explanations of the relationship between the development of motor skills and EFs (Kim, Duran, Cameron, & Grissmer, 2018). *Reciprocity* occurs when motor skills and EFs develop and improve alongside each other (McClelland &

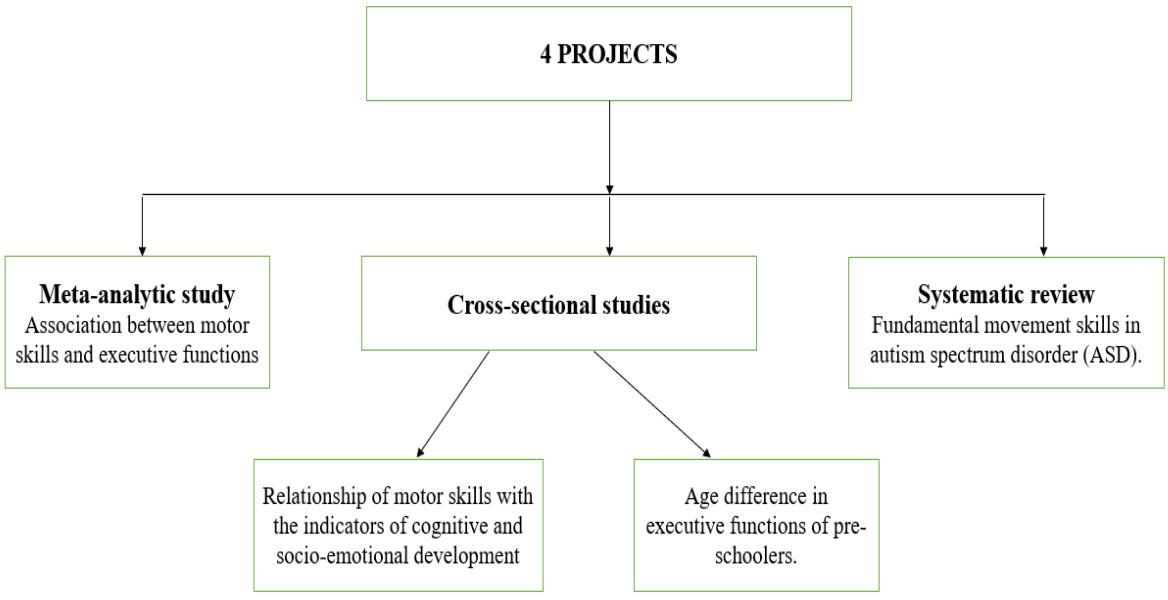
Cameron, 2019), while a*utomaticity* refers to the competition for attentional resources between motor and cognitive tasks. When a new motor task is performed, there is a greater need for cognitive attentional resources. However, practicing motor tasks leads to automaticity, meaning that fewer cognitive attentional resources are required for their successful performance (Floyer-Lea & Matthews, 2004). At the same time, if EFs are no longer involved in the performance of an automated motor task, it becomes easier to simultaneously perform a second task that does require EFs (Floyer-Lea & Matthews, 2004).

Collectively, these theoretical perspectives suggest that motor skills are functionally intertwined with other developmental domains and that it cannot be viewed as a separate entity.

2. RESEARCH PROJECTS

Figure 2.

Schematic presentation of the research projects



A total of four studies (Figure 2) were undertaken to examine the importance of motor skills in early childhood. Out of the four studies, the first study was a meta-analytic study, the next two were cross-sectional studies and the last study was a systematic review.

2.1 Study I: A meta-analysis of the relationship between motor skills and executive functions in typically developing children.

Summary of the study: The aim of this study was to provide empirical evidence for the relationship between motor skills and EFs in typically developing children. Traditionally, motor skills and cognitive skills have been viewed as separate entities. However, in recent years there is a large body of evidence that supports the relationship between motor skills and executive functions. One explanation stem from neurobiological studies, which have demonstrated the parallel activation of the prefrontal cortex (responsible for EFs), the cerebellum (responsible for coordinating voluntary movements), and the basal ganglia (responsible for the planning and execution of movements) during the performance of complex motor and EFs tasks. A second explanation of the relationship between motor skills and EFs comes from behavioral studies involving children with developmental disorders, who are characterized by high levels of comorbidity between cognitive and motor symptoms. Children with motor coordination difficulties such as DCD, for example, have been found to exhibit particular difficulties in the performance of EFs. Conversely, motor impairments have been identified in children diagnosed with cognitive disorders (Houwen et al., 2016).

In light of these preliminary evidence, we investigated the relationship between motor skills and EFs at global as well as specific levels of analysis. An in-depth understanding of the nature of the relationship between motor skills and EFs can be valuable from both a theoretical and a practical point of view. It can contribute to our currently limited knowledge of which motor skills and EFs are strongly associated with one another. Additionally, this information can benefit to childcare practitioners when designing comprehensive training and intervention programs aimed at improving motor and cognitive functioning in children.

Table 1.

Effect Size for Overall Relationship between Global Domains of Motor Skills and Executive Functions

Overall	K	N	r	95% CI	Q (df)	I^2(%)
	32	4,866	.18***	.127 – .247	127.25(31)***	75.63

Note. *p < .05. **p < .01.***p < .001

Table 2.

Effect Size Between Different Components of Motor Skills and Executive Functions

Between motor skills & EF components	K	N	r	95% CI	Q (df)	I^2(%)
Balance						
Response inhibition	9	1160	.20***	.098 - .301	20.94(8)**	61.79
Working memory	8	946	.18**	.052 - .298	24.90(7) ***	71.90
Cognitive flexibility	8	1005	.12*	.014 - .230	20.34(7)**	65.58
Manual dexterity						
Response inhibition	16	1872	.19***	.100 - .280	58.86(15)***	74.51
Working memory	17	2263	.21***	.104 - .324	114.53(16)***	86.03
Cognitive flexibility	12	1573	.17**	.052 - .278	58.01(11)***	81.04
Locomotor skills						
Response inhibition	8	1529	.07	-.112 - .262	79.75(7)***	91.22
Working memory	7	1487	.19**	.047 - .328	39.39(6)***	84.78
Cognitive flexibility	7	1487	.06	-.092 - .227	48.34(6)***	87.58
Object control skills						
Response inhibition	11	1857	.08	-.034 - .202	55.41(10)***	81.95
Working memory	8	1679	.08	-.019 - .189	26.90(7)***	73.98
Cognitive flexibility	9	1779	.06	-.052 - .186	44.15(8)***	81.89

Note. *p < .05. **p < .01. ***p < .001

The analysis was carried out on 4,866 children between the ages of 3 and 12 years, taken from 32 studies. The results (Table 1) revealed a significant positive association between motor skills and EFs at the global level. The effect size was considered to be "small" in size, however the association was found to be statistically significant ($z = 5.95$, $p = 0.000$). These findings confirm the theoretical assumption of motor-EFs link and supports the general idea that both motor and executive functioning are served by overlapping neural network.

Regarding the specific associations between the different components of motor skills and EFs, several significant associations of small effect sizes were found (Table 2). The motor skills that showed the strongest correlation with working memory ($r = .217$) and cognitive flexibility ($r = .168$) was manual dexterity skills. These findings suggest that certain components of motor skills are more difficult (i.e., less automated) and therefore require greater use of executive functions compared to other motor skills which are relatively easy (i.e., more automated) and less cognitively demanding. Object control skills and locomotor skills were least related to the executive function. A possible explanation of these findings is that these tasks are comparatively well practiced and familiar to children, which in turn may lead to an automatic response without much involvement of executive functions.

2.1. Study II: An exploratory study of the relationship between motor skills and indicators of cognitive and socioemotional development in preschoolers.

Summary of the study: The purpose of this study was to explore the relationship of motor skills with the indicators of cognitive and socio-emotional development. Many of the existing studies on this topic have been conducted on school going children and the extent to which the results can be generalized to preschoolers is not clear. Moreover, the studies that did involve preschoolers did not include both gross motor and fine motor skills simultaneously and selectively focused on only one or two components of EFs. Therefore, more research is needed

to gain a better understanding of the possible relationship between motor skills and the core components of executive functioning in preschool children.

Alongside cognition, motor skills also play a crucial role in a child's social and emotional functioning (Cairney et al., 2013; Cummins et al., 2005; Piek et al., 2015). Much of the existing work on the developmental origins of prosocial behaviour in preschoolers has focused on the child's early socialization processes (Eivers et al., 2012; Hay, 1994), cognitive maturity (Aguilar-Pardo et al., 2013), and emotional regulation (Laible et al., 2014), while the role of motor skills has been largely ignored. To date, the only study that has examined the direct link between gross motor, fine motor skills, and helping behaviour has been conducted on 16-month-old infants (Köster et al., 2019). The results of this study showed that the qualitative changes in infants' social abilities that are brought by their accompanied increased competence in motor skills supported their helpful behaviour. However, more research is needed to explore the possible relationship between motor skills and prosocial behaviour in preschool children, as the current evidence base is limited.

Table 3.
Correlation between Motor Skills and Executive Functions

	Response Inhibition	Working memory	Cognitive flexibility	Gross motor skills	Fine motor skills
Response inhibition	1	.510**	.486**	.461**	.667**
Working memory	.510**	1	.346**	486**	.494**
Cognitive flexibility	.486**	.346**	1	.479**	.398**
Gross motor skills	.461**	.486**	. 479**	1	.540**
Fine motor skills	.667**	.494**	.398**	.540**	1

Note. **: Correlation is significant at the $p \leq .01$ level.

Table 4.

Correlation Between Motor Skills and Prosocial Behaviour

	Gross motor skills	Fine motor skills	Prosocial behaviour
Gross motor skills	1	.540**	.709**
Fine motor skills	.540**	1	.607**
Prosocial behaviour	.709**	.607**	1

Note. **: Correlation is significant at the $p < .01$ level.

Table 5

Multiple Linear Regression Models for Response Inhibition, Working Memory, Cognitive Flexibility and Prosocial Behaviour Based on the Following Predictors: Gross Motor and Fine Motor Skills.

	Predictor	B	T	Sig.	B	Model R^2	Model F	Model sig.
Response inhibition	Gross motor skills	.40	2.475	.015	.20			
	Fine motor skills	.81	6.658	< .001	.55	.45	44.1	< .001
Working memory	Gross motor skills	.07	2.457	.016	.24			
	Fine motor skills	.07	3.249	.002	.32	.23	16.2	< .001
Cognitive flexibility	Gross motor skills	.32	4.374	< .001	.40			
	Fine motor skills	.16	2.936	.004	.27	.33	26.7	< .001
Prosocial behaviour	Gross motor skills	.78	7.244	< .001	.53			
	Fine motor skills	.36	4.424	< .001	.33	.56	68.5	< .001

The results revealed positive correlation of moderate strength between motor skills and EFs (Table 3). Concerning the correlations with prosocial behaviour, significant positive correlation of medium to high magnitude was found for both gross motor and fine motor skills (Table 4).

Further, the results of multiple linear regressions (Table 5) demonstrated that all four models were significant, with RI and prosocial behaviour best predicted by fine motor and gross motor skills respectively.

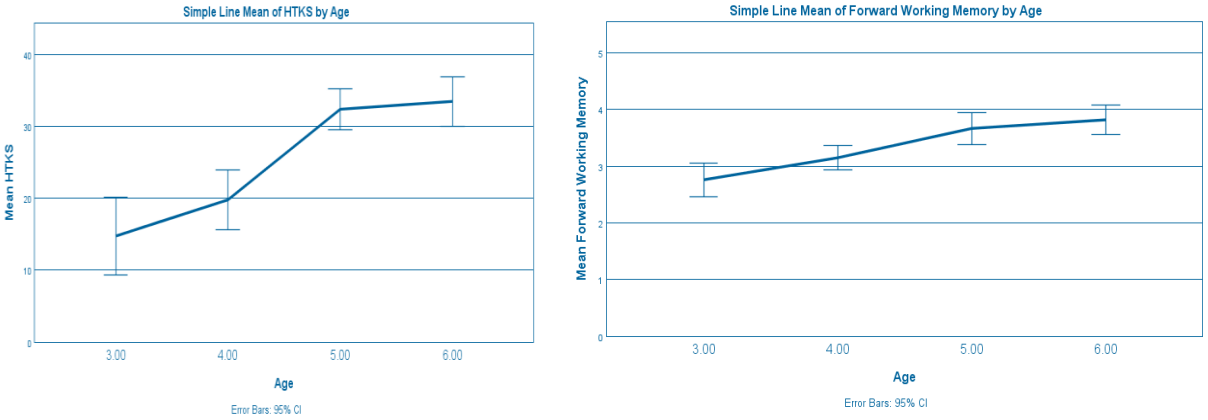
2.2.Study III: Age differences in executive functions among Hungarian preschoolers

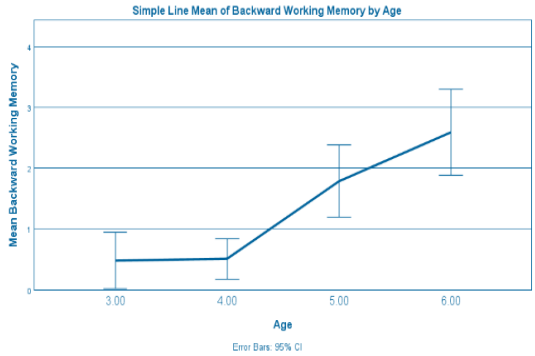
Summary of the study: The aim of the study was to investigate the age-related effects in executive functions, an important construct of the dissertation among Hungarian preschoolers. EF are particularly crucial during early childhood as they are associated with a myriad of positive outcomes including school readiness, academic success, socioemotional competence, and mental health. These benefits as well as the rapid brain maturational processes that takes place during this developmental period makes it an ideal time to thoroughly investigate the nature and factors influencing the development of EF. Although there are numerous studies on EF improvement as a function of age in multiple countries, including the USA (Best & Miller, 2010; Carlson, 2005; Davidson et al., 2006), Canada (Garon et al., 2008; Zelazo et al., 2003), and the Netherlands (Huizinga et al., 2006), there are very few studies based in Eastern European countries. Moreover, the preschool education system in Eastern European countries, and especially Hungary, has several distinctive characteristics compared to the USA and most Western European countries, which suggests the need for a thorough examination of the development of EF among Hungarian preschoolers. For instance, children in Hungary start preschool education at 3 years of age and spend at least 4 hours per day in kindergarten (Hungarian Government, 2011). As opposed to rote learning and subject knowledge, the educational curriculum of kindergartens in Hungary (Ministry of Culture and Education, 1997)

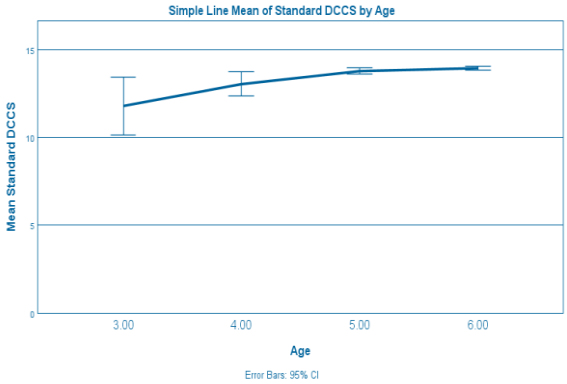
places a strong emphasis on fostering children's imagination and ability to think flexibly by introducing them to a variety of activities such as music, art, movement, and handicrafts. This kind of creative curriculum, which gives children equal exposure to the arts and the sciences, in a preschool environment that is characterized by social connectedness as an important child rearing practice (Brayfield & Korintus, 2011) has been found to have a positive outcome on children's literacy skills, such as reading and writing (Podlozny, 2000). However, its impact on children's executive functions is not yet known. In light of this, the present study was undertaken uses a sample of Hungarian preschoolers to investigate age-related difference in EFs in a sample of Hungarian preschoolers.

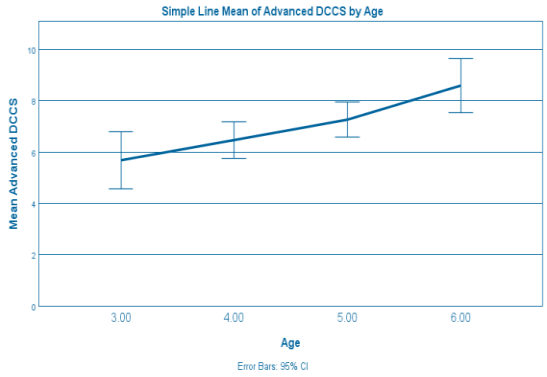
Figure 3.

Performance on EF tests as a function of age.









The findings showed a clear trend towards better performance with an increase in age in all the EF tests. In particular, performance across all the EF tests was found to be pronounced at the age of 5 years (Figure 3).

Unlike previous studies, most of the 3-year-olds were able to sort the cards according to the new rule in the post-switch phase in the standard DCCS test (M = 11.8), although not as efficiently as children aged 4 (M = 13.04) and above.

2.3.Study IV: Fundamental movement skills in children with autism spectrum disorder: A systematic review

Summary of the study: The objective of this study was to identify impairments in fundamental movement skills (FMS) as a motor marker in the diagnosis of autism spectrum disorder (ASD) by systematically reviewing the studies in this area. This need was necessitated by the increasing prevalence and significant costs associated with ASD. An in depth understanding of the biomarkers and symptoms associated with ASD can lead to early detection and

subsequently a better prognosis of this disorder. Motor skills have received a renewed interest in children with ASD due to growing evidence that suggests that impairments in motor skills precede, and even exacerbate, social- communicative symptoms in ASD (Harris, 2017; Leary & Hill, 1996; MacDonald, Lord, & Ulrich, 2014). With this in mind, the goal of the systematic review was to determine the prevalence of the impairments in FMS in children with ASD by comparing their performance on standardized movement assessment batteries with that of typically developing children and children with other neurodevelopment disorders.

The results of the 24 studies showed that impairments in FMS are highly prevalent across the ASD spectrum and that children with ASD exhibited greater impairments in FMS competencies especially object control and locomotor skills compared to typically developing children and those with other developmental disorders. Moreover, these impairments in FMS appear to emerge early in life and persist throughout late childhood years in the majority of children with ASD. Children in the ASD group were found to have greater impairments, even after controlling for IQ scores (Hilton et al., 2007; Staples & Reid, 2010; Whyatt & Craig, 2012). They also demonstrated significant impairments in overall FMS composite across all the clinical groups i.e., children with attention deficit hyperactivity disorder (ADHD), those with non-motor delay (NMD) and with speech delays (Green et al., 2002; Hauck & Dewey, 2001; Van Waelvelde et al., 2010). Within the ASD group, children at the severe end of the spectrum exhibited greater impairments in movement skills (Iwanaga et al., 2000; Matson et al., 2010). Across the different FMS competencies, specific areas of impairment were observed in object control and locomotor skills (Green et al., 2002; Pan et al., 2009).

3. GENERAL DISCUSSION

The purpose of the dissertation was to develop a better understanding of the importance of motor skills in early childhood by gaining deeper insights into the interrelatedness of motor skills with other developmental domains. In view of this, four studies were carried out.

Concerning the first objective of the dissertation about the association of motor skills with cognitive development, our meta-analytic study found evidence although small in size (r = .18) for the relationship between motor skills (balance manual dexterity, locomotor skills, and object control skills) and EFs (response inhibition, working memory, and cognitive flexibility). These findings confirm the theoretical notion of reciprocal relationships between motor skills and EFs and support the general idea that both motor skills and executive functioning are subserved by overlapping neural networks (Diamond, 2000; Ito, 2008; Leisman, Moustafa, & Shafir, 2016; Sergeant, 2000). Amongst the different components of motor skills, balance and manual dexterity were found to have strongest independent association with all the EF components indicating that these motor skills are less automatized in children and thus require extensive implementation of higher-order cognitive strategies (Best et al., 2009). These findings are important in the context of intervention programs which are aimed at promoting motor skills and EFs in children, as they support the idea that interventions in one domain may facilitate the development of both motor skills and EFs in children (Westendrop et al., 2014).

Regarding the relationship of motor skills with the indicator of socio-emotional development, our cross-sectional study demonstrated that prosocial behavior was related more strongly to gross motor than to fine motor skills. These findings suggest that having gross motor skills may facilitate prosocial behavior in preschoolers by providing them with opportunities to engage in social interactions with their peers (Bar-Haim & Bart, 2006; Zimmer-Gembeck et al., 2005). For instance, children with better motor skills are more likely to participate in active play with

their peers, which in turn promotes and stimulates social interaction and helps these children develop a positive attitude toward their peers, which is a key component of prosocial behavior (Caputi et al., 2012; Layous et al., 2012; Pellegrini & Smith, 1998).

The next research objective which was about examining the developmental trajectories of executive functions amongst Hungarian preschoolers, our dissertation demonstrated that all the three EF components improved as a function of age with the highest performance shift occurring around 5 years of age. These findings can be corroborated with previous studies (Best & Miller, 2010; Carlson, 2005; Davidson et al., 2006; Garon et al., 2008; Huizinga et al., 2006; Zelazo et al., 2003). However, unlike other studies, an interesting finding of our dissertation was that most of the 3-year-olds were able to sort the cards according to the new rule in the post-switch phase of the standard DCCS test, although not as efficiently as children aged 4 and above. These findings suggest that besides brain maturation processes such as increased myelination, synaptic pruning, and the formation of neural networks in the prefrontal cortex (Casey et al., 2005; Kagan et al., 2005; Thompson & Nelson, 2001), superior performance on executive functions tasks by younger participants was a result of their early exposure to preschool education. Compared to the USA and other western countries, children in Hungary start preschool education at 3 years of age and spend at least 4 hours per day in kindergarten (Hungarian Government, 2011). Early exposure to the academic structure of the kindergarten, which entails repeated practise in areas such as memory skills, deductive reasoning, and different learning strategies, can nurture a child's ability to make use of strategies and skills to efficiently solve problems, which may later be reflected in their improved performance on all EF tasks. These findings improve our understanding of how environmental influences such as early childhood education contribute to the development of certain EF component and suggest that environmental influences, in the form of early childhood education, have the potential to serve as a pathway for promoting EF skills.

Lastly, our dissertation also showed that impairments in motor skills especially fundamental movement skills (FMS) are fairly prevalent in majority of children autism spectrum disorder (ASD). Compared to their typically developing peers, a larger number of children in the ASD group were found to have greater impairments across all the categories of FMS (i.e., object control, locomotor skills, and balance skills or overall FMS composite), even after controlling for IQ scores, indicating that cognitive abilities alone cannot explain movement skills difficulties among children with ASD (Hilton et al., 2007**;** Staples & Reid, 2010**;** Whyatt & Craig, 2012). Children with ASD also demonstrated significant impairments in overall FMS composite across all the clinical groups indicating that impairments in FMS are specific to ASD. Across the different FMS competencies, specific areas of impairment were observed in object control and locomotor skills (Green et al., 2002**;** Pan et al., 2009). These findings suggest that children with ASD have significant underlying difficulty in performing tasks that rely heavily on perceptual-action coupling strategies, such as ball catching (Haswell, Izawa, Dowell, Mostofsky, & Shadmehr, 2009; Izawa et al., 2012) and tasks that requires coordinated movements between arms and legs, such as jumping and leaping. Within the ASD group, almost all the children regardless of their specific diagnosis (of autism, AS and PDD-NOS) demonstrated impairments in FMS compared to the normative sample. However, children at the severe end of the spectrum exhibited greater impairments in movement skills (Ghaziuddin & Butler, 1998; Iwanaga et al., 2000; Matson et al., 2010). These differences can be attributed to the lower levels of cognitive functioning in children with autism (Baird et al., 2006), which appears to result in decreased or delayed neural pruning during motor activity (Akshoomoff, Pierce, & Courchesne, 2002; Ming et al., 2007), thereby leading to severe movement impairments in this group as compared to children at the milder end of the spectrum. These findings suggests that FMS have the potential to be an early motor marker in ASD and strongly recommends clinicians to consider the evaluation of movement skills as a routine

investigation in children with ASD. It also highlights that movement skills especially object control and locomotor skills, should be targeted as an important focus of early intervention.

4. STRENGTHS AND IMPLICATIONS

- The purview of the dissertation is broad as it tries to provide us with an in-depth understanding of the nature of the relationship of motor skills with other developmental domains, namely, cognitive and socio-emotional development.
- It enhances our understanding of the multilevel nature of the relationship between motor skills and EFs in typically developing children. This knowledge in turn can be valuable to child care practitioners when designing intervention programs aimed at improving motor skills and/or EFs in children.
- It also draws our attention to the potential influence of early childhood education, via child-rearing beliefs and practises, on the promotion of EF skills. It specifically emphasises the inclusion of creative activities such as music, art, movement and handicrafts in the educational curriculum of kindergartens for the promotion of executive functions especially cognitive flexibility.
- The dissertation also demonstrates that FMS has the potential to be an early motor marker in children with ASD, and that practitioners should therefore be encouraged to consider movement skill evaluations as a routine investigation for children with ASD.
- It also lays the groundwork for future research to investigate the role of motor skills in various neurodevelopmental disorders.
- Finally, the cross-sectional studies that are included in the dissertation utilized standardized and age-appropriate measures to collect the data on the various study variables i.e., fine motor skills, gross motor skills, executive functions (response inhibition, working memory and cognitive flexibility), and prosocial behaviours.

5. LIMITATIONS AND FUTURE DIRECTION

- Due to the exploratory nature of the study, it is important to interpret the findings on the association between motor skills with the indicators of cognitive and socio-emotional development with precaution.
- It cannot be ruled out that the relationship between motor skills and executive functions may have been influenced by the choice of tests used. For instance, the motor component involved in each of the three EFs tests employed in the study, might have confounded the nature and the strength of this relationship. It is therefore recommended for future studies to replicate the current findings by employing different measures of EFs.
- The present findings on the association between motor skills and indicators of cognitive development are based on a cross-sectional investigation and causal relationships cannot be inferred. Studies with a longitudinal research design are therefore required to confirm the underlying neural mechanism related to motor skills and executive functions.
- The findings relating to socio-emotional development is limited to only prosocial behaviour and does not generalize to its other elements such as self-awareness and emotion regulation. It would be therefore highly suggested for the future studies to reflect more light on these elements in conjunction with motor skills.
- Although our study shows that environmental influences in the form of early childhood education have the potential to serve as a pathway for promoting EF skills. However, the mechanism by which early childhood education has been assumed to influence EFs informs future research to carry out studies regarding international comparisons on child rearing for obtaining a more authentic representation of children's self-regulation.

- Due to the time-bound nature of the study and logistic reasons, the coverage of empirical studies was limited to typically developing children. In future studies, it would be worth comparing the strength of the relationship between motor skills and EFs in typically and atypically developing children, and the level of evidence for it, so as to ascertain the underlying causes of the relationship.

6. CONCLUSION

Our dissertation fills an important gap in the literature by demonstrating the importance of motor skills as critical for healthy child development. It contributes to a better understanding of the interrelation between motor skills with other components, namely cognitive and socio-emotional aspects of development especially in preschool aged children. These findings can inform and guide researchers, practitioners and policymakers on best practices and emphasizes the importance and need for promoting motor skills during early child development. Additionally, these findings encourage child care practitioners to routinely assess motor skills in children with neurodevelopmental disorders especially ASD.

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