The Importance and Training of Executive Functions among Children and Children with Autism Spectrum Disorder

Jingyi Qi *

Department of Psychology Neuroscience and Behaviour, McMaster University, Hamilton, L8S 4M6, Canada

* Corresponding Author Email: qij17@mcmaster.ca

Abstract. Executive function is a set of higher-order cognitive processes in which people control their thoughts and behaviors to accomplish goals. This paper explores whether executive functions are similar important for children and children with autism spectrum disorder, and whether existing training methods are efficient. Executive function is important for children because they can use the function to improve their academic and social performance. When children lack executive functions, they are vulnerable to mental disorders including the autism spectrum disorder. To reduce the risk of mental disorders, children should be provided with executive function training, which usually includes behavioral, movement-based and mindfulness training methods. Behavioral training can effectively help children with attention deficiency. Movement-based training is supposed to strengthen children's muscles, in particular the brain development, and enhance children's inhibitory control and attention. Mindfulness training aims at removing judgmental experiences at a given moment in terms of feelings, thoughts, and behaviors. It can reduce stress and anxiety, as well as improve children's cognitive control. Executive functions are more rampant among preschool children. Children with autism spectrum disorder need executive function training as it can improve their working memory, cognitive flexibility and response inhibition. However, executive function training can be highly individualized and require qualified trainers, and traditional executive function training methods may lack effectiveness, which requires future research to continue to develop and focus on advanced technologies to improve the effectiveness of executive function training. This paper can provide some reference for follow-up research.

Keywords: Executive functions; Children; Autism spectrum disorder; Executive function training.

1. Introduction

All Executive function (EF) is an umbrella term for higher cognitive processes essential for purposeful navigation through life situations. Executive functions can be defined as a set of higher-order cognitive processes that allow us to control our thoughts and behaviors to achieve a goal [1]. These cognitive functions have four major components: working memory, response inhibition, cognitive flexibility and planning, which enable an individual to deal effectively with the complex demands of life situations by regulating thoughts, emotions, and behavioral responses. Brain imaging studies have demonstrated that the pre-frontal region of the brain is implicated in executive functions, as lesions in the pre-frontal cortex cause disturbances in these functions [2]. Executive functions are important for children as they reliably predict social competency, literacy, reading and academic performance. Conversely, impairment in EF is evidenced in neurodevelopmental disorders, such as autism spectrum disorder (ASD) [3]. This essay aims to describe the importance of executive functions for children and the types of training used for enhancing executive functions. Following the overview of executive functions, the importance of EF and different types of training will be discussed in light of empirical evidence.

2. Overview of Executive Functions

This section will highlight the meaning and essence of executive functions. Executive functions are a group of cognitive processes that enable individuals to deal with and adapt to environmental demands by regulating behaviour, emotion, and thoughts [4]. It helps children in self-regulation and

is associated with numerous cognitive outcomes. Further, Autism Spectrum disorder (ASD) will be discussed that shows impairment in EF. Lastly, the training methods for enhancing Executive functions are highlighted in this section.

2.1 Executive Function Meaning and Factors

Executive functions allow us to adapt to the demands of novel situations by regulating our responses. Three components of executive functions: working memory, cognitive flexibility/ attention shifting and inhibitory control were distinguished. The first component, working memory, is an active system that stores and manipulates incoming information simultaneously. The Second component is response inhibition, which can be described as an ability to minimize or suppress impulsive behaviors. It enables individuals to analyze and choose the most appropriate behaviour than impulsive acting. Another component is cognitive flexibility, described as the ability of an individual to quickly adapt to the changes in the demands of the situation. Lastly, planning refers to thinking about the task and preparing a roadmap to achieve those goals. All these functions enable the individual to adapt to novel life situations to achieve the desired goals.

2.2 The Importance and Effect of Executive Function (EF)

From the tender age, it has been noted that execution is essential in the growth and well-being of minors until reaching the major ages. Its importance cuts across the activities they engage in, as they help them understand more, counter issues with objective solutions, and be positioned to implement the solutions. From a general perspective, it helps one outgrow their age in thinking and executing daily activities.

It is the backbone of the functionality of the body that is considered to be pivotal in undertaking daily activities such as organizing, emotional controls, planning, remembering activities, and prioritizing what to do or what not to do is essential to normal functionality [5]. These are associated with developing skills, including teamwork, decision-making, critical thinking, goal-directed behaviour, relationships, and stress reduction. It helps children follow instructions, avoid distractions, persist in problem-solving, managing time, and control rash reactions in school and home settings [2]. Thus, it can be seen that EF is associated with beneficial outcomes for children.

Empirical evidence suggests that executive function is associated with academic performance among children at school. For example, Cortés-Pascual et al. [6] conducted a meta-analysis of 21 studies and reported that executive functions are predictors of language as well as mathematical performance. Thus, how a person undertakes daily activities is certain whether the functions are inculcated in him. Impairment in the executive function of the body means dis-functionality of the specific organs assigned to the specific function. In this case, how the body operates is designed to coordinate with each other. Generally, such functions can be nurtured, and one is taught and adaptation of the same is obtained over time.

2.3 Executive Function in Typical and Autistic Children

Once a skill is availed to a child at a tender age, it will be easy for the child to adapt and use it per the intended direction. The EF is crucial in the growth of children as it helps them understand and has cognitive ideas for handling specific tasks, including planning, problem-solving, regulation of behaviour and organization [2]. Therefore, it is a pivotal tool in examining how easily or hard a child can handle and tackle certain issues. Bearing in mind that such skills can are taught and nurtured in learning institutions, students who may be seen to have underlying problems should not be exempted but should as well be considered. We can have an example of a student with a DDC (Dopa-Decarboxylase) condition; such can be treated as a special case since their ultimate brain function is not certain.

Autism spectrum disorder (ASD), a condition attached to how a person communicates, responds, and interacts, is associated with a developmental disability. Children with autism spectrum disorder display profound impairment in executive functioning skills, including self-regulation, planning,

analysis, organization of ideas and social competence. A study by Robinson et al. [7] showed significant impairment in executive functions such as planning, response inhibition, generativity, self-monitoring, and mental flexibility in children with ASD compared to typical children. Consequently, signaling the overall impairment in executive functions among children with ASD. Furthermore, brain imaging studies suggest that the disability is associated with the brain, such as the pre-frontal cortex, orbitofrontal cortex and temporal regions [8]. Hence, The EF in such children will be hard to administer. However, with research, it has been recommended that continuity in exposing and interacting with them enables them to get such skills

3. Executive Function Training

Executive functioning skills are not readily present at the time of birth. However, children develop these skills through their life experiences. These executive functions develop in childhood and are matured in adulthood. Thus, these functions can be improved through training [9]. The training of executive functions has been associated with neuroplasticity. According to neuroplasticity, the brain can reorganize its neural connections through practice and reinforcement, strengthening the older connections and forming new connections [10]. Further, the results of fMRI studies also suggest that higher executive functions during childhood, such as self-regulation is associated with favorable outcomes as an adult and can be improved via training [11]. Therefore, the findings based on the existing literature imply that training can enhance executive functions.

3.1 Types of Training

For a child to adopt a specific skill or acquire knowledge in a specified field, it is essential that training should be conducted. The training will be helpful for the continuity of usage of the skill, being creative, as well as increasing the ease of decision-making in fields that may be needed [9]. Further, training in executive functions at in early age can facilitate the development and application of these skills in adolescent and adult life [9]. Three major types of training, namely, behavioral, mindfulness-based and movement-based training, will be described in the upcoming sections.

3.1.1 Behavioral training

Behavioral training is one the most widely used training programs for enhancing executive functioning skills among children. A study reveals that this form of training best works on children or people conditioned with attention deficiency. It indicates that they cannot concentrate on a specific activity for a long time. Therefore, adopting behavioral training helps children better remembering the activity easily [12].

Eventually, with behavioral training, the target market will easily remember what they were going through. The condition with which the training takes place is also a factor in determining how easily or hand he will acknowledge the skill. Generally, a harsh and unfriendly environment will produce a negative result. On the contrary, a positive and reinforcing environment can facilitate training by learning the desired skills through practice. Still, training while focusing on a specific behaviour can favor EF. The ultimate need for this strategy is consistency and being determined as to what is to be achieved.

3.1.2 Movement-Based training

Movement-based training for executive function is aimed at strengthening specific body muscles. It is essential in strengthening specific muscles. Notably, movement engages the entire body, therefore, can be categorized as an exercise that is essential for children as well as the older ages. Considering a condition like Minimal Residual Disease (MRD), fighting the same requires multiple exercises, which will aid in relieving the issues. Therefore, it is usually essential for the intended persons to exercise the same.

Having in mind that Movement-based training involves the entire body, it is reasonably true that brain development can as well as be enhanced through movement training. Movement-based training

can include techniques ranging from physical exercise to dance and aerobic exercises. Therefore, this form of training cuts across the young and the elderly. Aerobic exercises are crucial in developing EF as some hormones are released, and happy hormones are generated in the body, facilitating growth and mental health. Along similar lines, Chou et al. [13] conducted a study to evaluate the effectiveness of movement-based interventions on executive functions. Their study participants were 40 obese children who participated in movement games three times a week for eight weeks. The intervention results showed that movement-based games enhance inhibitory control and attention among the participants. Thereby signaling that movement-based games and training can improve executive functions. Also, better EFs can be seen or expected when one is well-rested, physically fit and has social support. Overall, everyone needs to train using this activity for its beneficial factors.

3.1.3 Mindfulness training

Mindfulness training focuses on the thoughts, feelings, and behaviors at the present moment by being non-judgmental of the experiences. This is a form of training that involves theoretical engagement as a learning tool. In this case, the target market is set in a way that engages past and present activities to determine what will happen in the future. Mindfulness training can enhance executive functions as it facilitates top-down processing, such as sustained attention and cognitive flexibility, and reduces the impact of bottom-up processes, including stress and anxiety [14]. Hence, mindfulness training can be used for the training of executive functions.

It is also pivotal in strengthening the EFs as one will be in opposition to determining what will happen in the future based on past occurrences. Janz et al. [15] conducted a study to evaluate the effectiveness of mindfulness-based programs on executive functioning among children from 1-2 grades. In this study a total of fifty-five students participated in the study. They were given a mindfulness program called CalmSpace for two terms. The analysis of the intervention demonstrated that implementing the mindfulness-based program resulted in improvements in executive functions among young children. Likewise, Schonert-Reichl et al. [16] used a socio-emotional learning program that included mindfulness among elementary school students. The findings illustrated an improvement in executive functions such as cognitive control. Therefore, mindfulness-based training is effective for enhancing executive functions among children. However, most research studies have been conducted with older children and adolescents, and small effect sizes are reported. Further, specialized training is required to deliver these mindfulness training programs for children, and parental involvement is also necessary [17]. Nonetheless, there is growing evidence for the effectiveness of mindfulness training in enhancing executive functioning among younger children.

3.2 Training Effects in Typical and Autistic Children

Research evidence suggests that the training interventions to enhance executive functioning are equally effective for typical and autistic children.

3.2.1 Training effects on typical children

Executive Functions have been observed to be more rampant during the preschool period. In such period's children are in the vigor to know multiple things and the readiness to learn. Therefore, early training in executive functions is beneficial. For example, a study by Melby-Lervåg & Hulme [18] among children between the ages of 4 to 6 presented a high magnitude of acquiring the skills, unlike the older ones. Besides the convenience and effectiveness of administering the skills, it is said that the student-to-teacher ratio can be a factor that ought to be considered while training. For instance, A teacher with a huge number of students will have a hard time teaching/training the children, unlike the parent-to-child interaction [19]. Therefore, the ratio of teachers to students must be taken into consideration while planning training programs at school.

3.2.2 Training effects on children with autism

Generally, autistic children will require professional training that will help them acquire part of the skills, if not as a whole. This may be hard for child-to-parent engagement as some parents may

not be aware of handling them and how to communicate with them, especially if both parents do not have any background of autism. As initially explained, this relates to the DDC condition, where professionals are needed to handle such children. Also, autistic children can be viewed to exhibit such conditions as CAS (Childhood Apraxia of Speech), where speech is vulnerable, thus advisable for professional training. Nonetheless, research evidence suggests that training in executive functions is beneficial for children with ASD. For instance, in their study, Ji et al. [20] evaluated the effectiveness of physical exercise and virtual training among children with ASD. The training took place six weeks for three sessions of one hour each week. The results of the study showed significant improvement in major components of executive functions, including working memory, cognitive flexibility and response inhibition.

3.3 Limitations

Research evidence suggests that training can enhance executive functioning skills among typical and autistic children. Numerous training methods can be empirically shown to be effective for training in executive functioning, including behavioural, movement-based and mindfulness-based training. However, each of these training methods must be highly individualized as per the needs and requirements of the individual. For instance, mindfulness-based therapy can work best with older children. Conversely, physical exercises can be effective for young children with ASD [20]. Furthermore, implementing all the training methods requires well-trained and qualified trainers instead of classroom teachers [17]. Moreover, due to the advancement in technology now, virtual, and cognitive stimulation game-based therapy is also widely used and shown to be effective in enhancing executive function by targeting the pre-frontal region of the brain [21]. As a result of which, these traditional training methods may lack effectiveness. Nonetheless, the empirical evidence supports the efficacy of the training methods to improve executive functioning, and it is emphasized that training in childhood can help in applying these skills throughout the lifespan

4. Summary

In conclusion, this essay aims to describe executive functions, their importance and the training method used to improve executive functioning among children. Executive functions (EF) are a set of higher cognitive processes that enable people to deal with and adapt to novel situations by controlling our thoughts and behaviors to achieve the desired goal. These are associated with numerous outcomes for children ranging from better academic performance to social competence. On the other hand, impaired Executive functioning skills are related to disorders such as autism spectrum disorder (ASD) and Attention-Deficit Hyperactivity Disorder (ADHD). It is empirically validated that training in executive functions in childhood can facilitate the use of these skills in adulthood and aids in dealing with the day-to-day demands of life. Further, the research evidence suggests that behavioral, mindfulness-based and movement-based training methods are efficacious in improving Executive functions in both typical and autistic children. However, each of these training methods must be tailored and used as per the needs of the individual and must be delivered by trained expert professionals. Overall, it can be concluded that executive functions are a crucial set of processes necessary for successful navigation in life and can improve through training programs. Future investigation should be focusing on more efficient methods of executive function training for children to improve their abilities through better executive functions.

References

[1] Zelazo Philip David, Carlson Stephanie M. Hot and cool executive function in childhood and adolescence: Development and plasticity. Child development perspectives, 2012, 6(4): 354-360.

[2] Diamond Adele. Executive functions. Annual review of psychology, 2013, 64, 135.

[3] Danforth Jeffrey S., Connor Daniel F., Doerfler Leonard A. The development of comorbid conduct problems in children with ADHD: An example of an integrative developmental psychopathology perspective. Journal of attention disorders, 2016, 20(3): 214-229.

[4] Savina Elena. Self-regulation in preschool and early elementary classrooms: Why it is important and how to promote it. Early Childhood Education Journal, 2021, 49(3): 493-501.

[5] Traverso Laura, Viterbori Paola, Usai Maria Carmen. Improving executive function in childhood: evaluation of a training intervention for 5-year-old children. Frontiers in psychology, 2015, 6: 525.

[6] Cortés-Pascual Alejandra, Moyano-Muñoz Nieves, Quílez-Robres Alberto. The Relationship Between Executive Functions and Academic Performance in Primary Education: Review and Meta-Analysis. Frontiers in Psychology, 2019, 10, 1582.

[7] Robinson Sally, Goddard Lorna, Dritschel Barbara, Wisley Mary Wisley et al. Executive functions in children with autism spectrum disorders. Brain and cognition, 2009, 71(3): 362-368.

[8] Ha Sungji, Sohn In-Jung, Kim Namwook, Sim Hyeon Jeong, Cheon Keun-Ah. Characteristics of brains in autism spectrum disorder: structure, function and connectivity across the lifespan." Experimental neurobiology, 2015, 24(4): 273.

[9] Diamond Adele, Daphne S. Ling. Review of the evidence on, and fundamental questions about, efforts to improve executive functions, including working memory. Cognitive and Working Memory Training: Perspectives from Psychology, Neuroscience, and Human Development, 2020, 143–431.

[10] Han Kihwan, Chapman Sandra B., Krawczyk Daniel C. Neuroplasticity of cognitive control networks following cognitive training for chronic traumatic brain injury. NeuroImage: Clinical, 2018, 18: 262-278.

[11] Posner Michael I., Rothbart Mary K., Tang Yiyuan. Developing self-regulation in early childhood. Trends in neuroscience and education, 2013, 2(3-4): 107-110.

[12] Miranda Ana, Presentación M. Jesús, Siegenthaler Rebeca, Jara Pilar. Effects of a psychosocial intervention on the executive functioning in children with ADHD. Journal of learning disabilities, 2013, 46(4): 363-376.

[13] Chou Chien-Chih, Chen Kuan-Chou, Huang Mei-Yao, Tu Hsin-Yu, Huang Chung-Ju. Can movement games enhance executive function in overweight children? A randomized controlled trial. Journal of Teaching in Physical Education, 2019, 39(4): 527-535.

[14] Zelazo Philip David, Lyons Kristen E. The potential benefits of mindfulness training in early childhood: A developmental social cognitive neuroscience perspective. Child development perspectives, 2012, 6(2): 154-160.

[15] Janz Philip, Dawe Sharon, Wyllie Melissa. Mindfulness-based program embedded within the existing curriculum improves executive functioning and behavior in young children: A waitlist-controlled trial. Frontiers in Psychology, 2019, 10: 2052.

[16] Schonert-Reichl Kimberly A., Oberle Eva, Lawlor Molly Stewart, Abbott David et al. Enhancing cognitive and social–emotional development through a simple-to-administer mindfulness-based school program for elementary school children: A randomized controlled trial. Developmental psychology, 2015, 51(1): 52.

[17] Maynard Brandy R., Solis Michael R., Miller Veronica L., Brendel Kristen E. Mindfulness-based interventions for improving cognition, academic achievement, behavior, and socioemotional functioning of primary and secondary school students. Campbell systematic reviews, 2017, 13(1): 1-144.

[18] Melby-Lervåg Monica, Hulme Charles. Is working memory training effective? A meta-analytic review. Developmental psychology, 2013, 49(2): 270.

[19] Domitrovich Celene E., Cortes Rebecca C., Greenberg Mark T. Improving young children's social and emotional competence: A randomized trial of the preschool "PATHS" curriculum. The Journal of primary prevention, 2007, 28(2): 67-91.

[20] Ji Chaoxin, Yang Jun, Lin Lin, Chen Song. Executive Function Improvement for Children with Autism Spectrum Disorder: A Comparative Study between Virtual Training and Physical Exercise Methods. Children, 2022, 9(4): 507.

[21] Spencer-Smith Megan, Quach Jon, Mensah Fiona, Roberts Gehan et al. Anderson. The Effectiveness of Working Memory Training for Children with Low Working Memory. Pediatrics, 2020, 146(6).