European Journal of Education Studies
ISSN: 2501 - 1111
ISSN-L: 2501 - 1111
Available online at: www.oapub.org/edu

DOI: 10.46827/ejes.v10i10.5052 Volume 10 | Issue 10 | 2023

THE RELATIONSHIP BETWEEN MOTOR ACTIVITY AND EXECUTIVE FUNCTIONS IN THE TEACHING-LEARNING PROCESS: CASE OF 6 - 7 AGED TUNISIAN PUPILS

Mounira Ben Sidhom[i],
Nizar Souissi
Research Unit of the National Sports Observatory (ONS):
Physical activity: Sport & Health,
Tunis, Tunisia

Abstract:
Considering that the cognitive and motor dimensions of human beings grow together and that primary school age is one of the most important stages of children's cognitive and motor development, the aim of this study was to investigate the relationship between executive functions and motor activity in the teaching-learning process. Primary school students (N = 40; 6.3 years) participated in this study. They were divided into two groups: an experimental group (20 students) and a control group (20 students). The first group followed a 12-week motors activity program with 5 sessions of 40 minutes per week and the second a regular math sessions program. The results of the experimental group show a clear improvement in most of the study variables. Also, these results highlight the value of actively involving the student in the task and the importance of using active methods in the teaching-learning process.

Keywords: math class, children, motricity, working memory, inhibitory control

1. Introduction

Successful functioning throughout life (e.g., in school, social interactions, and physical and mental health) requires well-developed executive functions (EFs) (Vandenbroucke et al., 2018). The term "EFs" refers to a multifaceted concept that has been defined in a variety of ways. Nonetheless, there are some common components in these definitions that highlight the important qualities of EFs.

In summary, EFs are cognitive processes that influence actions, ideas, and emotions from the top down (Zelazo, 2012). Second, EFs are only activated in instances where conscious, goal-directed conduct is required, not in situations where automatic or intuitive conduct is required, so employing EFs necessitates attempt and effort (Huizinga,

[i]Correspondence: email stapssidhommounira@gmail.com

2006). Third, EFs refer to a collection of related but distinct cognitive processes, making it a multidimensional, rather than unitary, concept (Vandenbroucke et al., 2018).

Based on recent studies, EFs are related to different brain regions (McKenna et al., 2017). Takeuchi et al. (2012) used the terms hot and cool executive functions, stating that hot executive functions include affective decision-making or decision-making about events that have emotionally significant consequences and are associated with the orbital regions of the prefrontal cortex; cool executive functions include working memory, planning, and problem-solving and are related to the dorsolateral regions of the prefrontal cortex (Takeuchi et al., 2012). This viewpoint is supported by an increasing corpus of neurophysiological and neuroimaging evidence (Hanakawa, 2012). Neuroimaging techniques have revealed that some motor and cognitive regions critical for motor performance and cognition, such as the cerebellum, dorsolateral prefrontal cortex, and linking structures (including the basal ganglia), are co-activated, so evidence of the relationship between motor and cognitive development can also be found in behavioral studies (Donnelly et al., 2016).

In this regard, Piaget believed that motor and cognitive skills are intertwined. Piaget's hypothesis was based on the premise that children learn from observable object motor activities (Piaget and Cook, 1952). Payne and Isaacs (2017) stated that cognitive and motor development interact with each other and inhibit or help each other throughout life.

However, research on the relationship between cognitive and motor development is limited to specific cognitive domains (Libertus and Hauf, 2017), such as working memory (Van der Fels et al., 2020), language (Muhoozi et al., 2018), etc. motor development is important in young children to aid in developmental functions such as perceptual and cognitive abilities (Aye et al., 2017).

Different perspectives on the relationship between motor skills and cognitive skills in children have existed in the past.

On the one hand, motor and cognitive skills have long been thought of as distinct processes that develop separately and involve different brain regions (Van der Fels, 2015). In this regard, and rejecting the relationship with the study of different dimension effects of human development, especially cognitive and motor development, several studies have been conducted (Veldman et al., 2019).

2. Literature Review

The following body of information makes up the literature review, which has a direct bearing on the study.

2.1. Executive Functions

EF is a commonly cited construct in cognitive, educational developmental, and neuropsychology fields. However, EF remains a controversial topic in research due to the wide range of definitions, theories, and measures associated with it (Baggetta and

Alexander, 2016; Soto et al., 2020; Laurey et al., 2022). Studies on the conceptualization and operationalization of this construct are incongruent and guidance for clinicians and researchers aiming to assess EF is insufficient due to measurement variability (Baggetta and Alexander, 2016; Wallisch et al., 2018). Children's EF remains up for debate, especially in terms of their number, nature, degree of separation, developmental trajectories, and milestones along with the ecological and construct validity of their measures.

2.2. Development of Executive Functions

The development of EF depends on the PFC maturation and its networks, including neural fiber's myelinization. EF shows prolonged development concerning the extensive maturation of the cortical networks that underlie them. EF development, although protracted, emerges rapidly, as early as the first months of life (Diamond and Goldman-Rakic, 1989; Diamond, 2013, 2020). Neuroimaging has revealed structural and functional changes in brain regions underpinning EF during middle age and older adulthood, that are highly likely to affect performance in these age groups (Petrican et al., 2017). A recent study by (Ferguson et al., 2021) examined EF in a large, community-based sample aged from 10 to 86 years old, demonstrating that planning ability and WM capacity continue to develop throughout adolescence as well as in early adulthood.

2.2.1. Working Memory

Early in life, infants and young children are able to hold information in their minds for quite a long time (Diamond, 1995; Nelson et al., 2012). In tasks such as A-not-B, infants of 9 to 12 months can update their WM contents (Diamond, 1985; Bell and Cuevas, 2016). However, memorization and mental manipulation (e.g., reordering visual representations of objects by size) are much more delayed and take longer to develop (Davidson et al., 2006; Cowan et al., 2011). WM in children improves with age due to enhanced interference inhibition (Hale et al., 1997). Children's performance improves throughout childhood and full capacity of WM may be reached by late adolescence (Gathercole et al., 2004). With aging, WM declines primarily due to a decrease in inhibitory control, making older adults more vulnerable to proactive and retroactive interferences (Solesio-Jofre et al., 2012) as well as distractions (Rutman et al., 2010).

2.2.2. Inhibitory Control

Executive functions refer to the cognitive processes necessary for goal-directed cognition and behavior, which develop across childhood. They can be defined as a set of high-level cognitive processes that govern goal-directed actions and adaptive responses to new and/or complex situations (Miyake et al., 2000). These cognitive control processes are called upon when we have to concentrate on a task, memorize and manipulate information, adapt to new environments or rules, and more generally when habits or automatisms are not sufficient to achieve these goals (Diamond, 2013). We invoke these cognitive functions: planning/organizing, updating working memory, cognitive flexibility, and inhibitory control.

We are going to develop only this last executive function that we have found useful to investigate in this study.

Inhibitory control is the ability to prevent oneself from producing an automatic response, to stop the production of an ongoing response, and to rule out stimuli irrelevant to the current activity. It is an active mechanism of suppression (Posner & Rothbart, 1998).

Indeed, this executive function allows the temporary suppression of an automatic, habitual, and dominant response. It prevents the entry of parasitic information and focuses on that which is necessary to act and think. It acts as a filter in working memory. For Harnishfeger (1995), there are two kinds of inhibition: motor (which concerns motor aspects) and conceptual (which has the function of blocking irrelevant information to achieve a goal). It is considered to be a determining factor in cognitive development in childhood (Dempster, 1992).

2.3. Relationship between Motor Development and Cognitive Development of the Child

In psychology, it is shown that the learning period in children aged 6 to 12 is the longest time in childhood when the child will be able to learn and develop in primary school. The child's development is broken down into three or four major areas: motor development, cognitive development, and finally, emotional and social development even if it is very artificial and questionable because every individual can only conceive of himself as a whole. In the school context, several studies assert that the development of the child's motor skills will have an impact on the development of his other affective abilities through the autonomy that the control of his motor skills confers, by exploring and adapting to the environment that his motor skills allow, and by playing with his peers and friends (Haywood & Getchell, 2001).

Indeed, several components of this development (body schema, spatial and temporal structuring, etc.) are even considered as important prerequisites for school learning (De Lievre & Staes, 2000; Lauzon, 1990; Rigal, 1996). In this sense, Grissmer, Grimm, Steele, Aiyer, and Murrah (2010) and Diamond's (2000) neuroimaging studies suggest that cortical areas (cerebellum, NGC) associated with motor learning and those associated with cognitive activities (prefrontal cortex) are co-active in some motor and cognitive tasks.

On the one hand, several cognitive activities use control and modulation functions that are found in the cerebellum and the central grey nuclei (NGC) that develop during the acquisition of basic motor skills.

On the other hand, the neural structures that are set up during motor development, between the prefrontal cortex and the motor areas, are also used in cognitive learning. Furthermore, in cognitive psychology, Pailhous and Bonnard (1989) set out three reasons for the links between cognitive research and motor skills: the first is related to the fact that movement itself can be the object of cognitive processes, and the second is that, for a number of authors, motor skills appear to be the source of ideas (Piaget, 1947), or through its role in socialization processes, of personality (Wallon, 1959). The third, finally, stems from the fact that the integrated motor performance is the place of integration of the processes that ensure its organization and control section.

3. Material and Methods

3.1. Procedure

Our procedure would be of a quasi-experimental type and based on a motor activity game. Our intervention program was spread over 12 weeks, with 5 sessions of 40 minutes per week. The control group followed conventional learning, respecting the same hourly volume as the experimental group.

In fact, for all tests, the child is interviewed individually in a bright and quiet room of his school in which he is sitting comfortably at a table facing the examiner. The tests and retests were taken at 8 a.m. in the same classroom. It should be noted that after one day of the end of the learning program, the cognitive tests were taken again for the two groups.

The procedures and methods used in the study conform to the ethical guidelines defined by the World Medical Association's Declaration of Helsinki and its subsequent revisions. The study protocol was approved by The Regional Committee for Medical Research Ethics. We obtained written consent from each child's parents for all testing.

3.2. The Cognitive Function Assessment Tests

A. Stroop Fruits

The test "Stroop fruits" is a simplified version of the original Stroop test (Stroop, 1935), adapted from Archibald and Kerns (1999) and Monette and Bigras (2008). This is an inhibition test for children of preschool age to the extent that it excludes the component of reading that is not yet automatized at this age level. The effect of interference, which must be inhibited, results from a competition between the name of a color and the prototypical color of two fruits (banana, strawberry).

The task consists of three conditions. In the first, the experimenter shows the child a sheet of A4 paper with twenty colored rectangles, half of which are red, and the other half are yellow. The child has 45 seconds to name the color of as many rectangles as possible. In the second condition, the rectangles are replaced with images of bananas and strawberries in their prototypical color (yellow and red).

The child must give the color of the fruits, still as fast as possible. In the last, interference condition, half of the fruits appear in prototypical color, while the others are presented in non-prototypical colors, namely red bananas or yellow strawberries.

The child must name the colors of the fruit by correcting those perceptual errors; for this, he is asked to give the color of the fruits "in real life."

A score of interference evaluates the inhibition capacities, based on the following formula:

Interference [%] = 100 x ((Mean Cond 1 & 2 - Cond 3) / (Mean Cond 1 & 2))

where:
Mean Cond 1 & 2 = mean number of correct responses in conditions 1 and 2,
Cond 3 = correct responses in condition 3which expresses the amount of interference in percent caused by the non-prototypical colors (a high interference score reflecting inhibition difficulties).

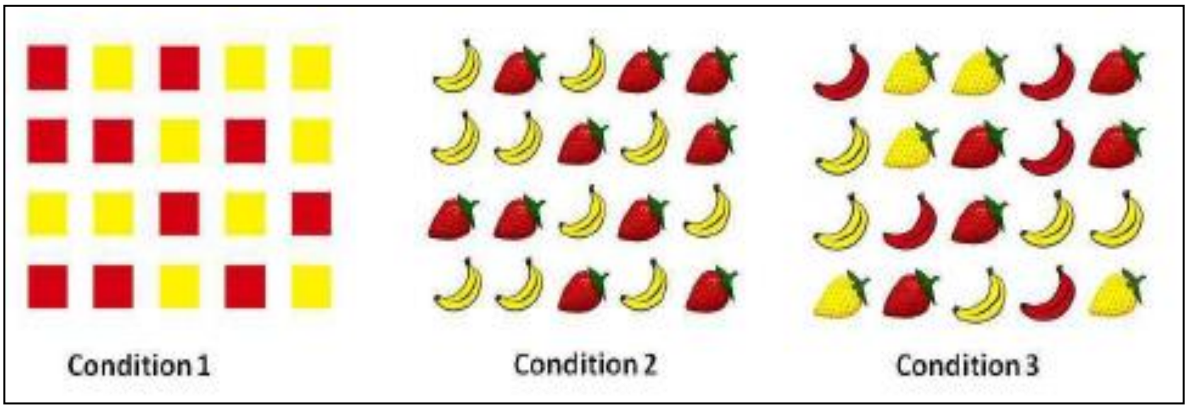

Figure 1: Three conditions of the Stroop fruits test

B. Digit Span (Working Memory Test)
The test of "Digit span in direct order" belongs to the WISC-IV (Wechsler Intelligence Scale for Children-IV) (Wechsler, 2003), a battery for the assessment of cognitive functioning of children between 6 and 16 years and often used in school and clinic. The test assesses updating by means of a series of digits to remember. The task is to immediately repeat a sequence of numbers (from 1 to 10) set by the experimenter. The test starts with a sequence of two numbers and, if the child succeeds, continues in an ascending order of difficulty. The test stops when the child fails all items of the same level of difficulty. The score taken into account is the number of items correctly repeated.

In the test of "Digit span in indirect order", from the WISC-IV, the child is requested to repeat a sequence of numbers (from 1 to 10) set by the experimenter, but in the reverse order.

3.3. Data Analysis
The statistical tests were carried out using the Statistica software (StatSoft, France). The data were reported as a mean standard deviation. Once the normality hypothesis was confirmed by the Shapiro-Wilk test, parametric tests were performed. For each of the analyses, when the ANOVA showed a significant effect, a post-hoc Tukey test was applied to compare the experimental data two to two. All observed differences are considered statistically significant for a probability threshold below (p0.05).

We also calculated the delta variation (Δ) between the test and the pre-test with the formula [Δ = test-retest] and the percentage of the delta variation (Δ%) with the formula [Δ% = ((retest-test) / test) × 100].

4. Results

At the beginning, before the experiment, the two groups were homogeneous for all parameters (no significant difference between them before the new learning method). Afterward, the experimental group showed significant differences between the before and after training for all tested parameters, which led to significant differences being recorded between the control group and the experimental group at the after. It's obvious that the progress (Δ = before − after) recorded by the experimental group is significantly different from the control group in all settings. All the used data in this test assessment are obtained from the analysis of the answers of all the participants.

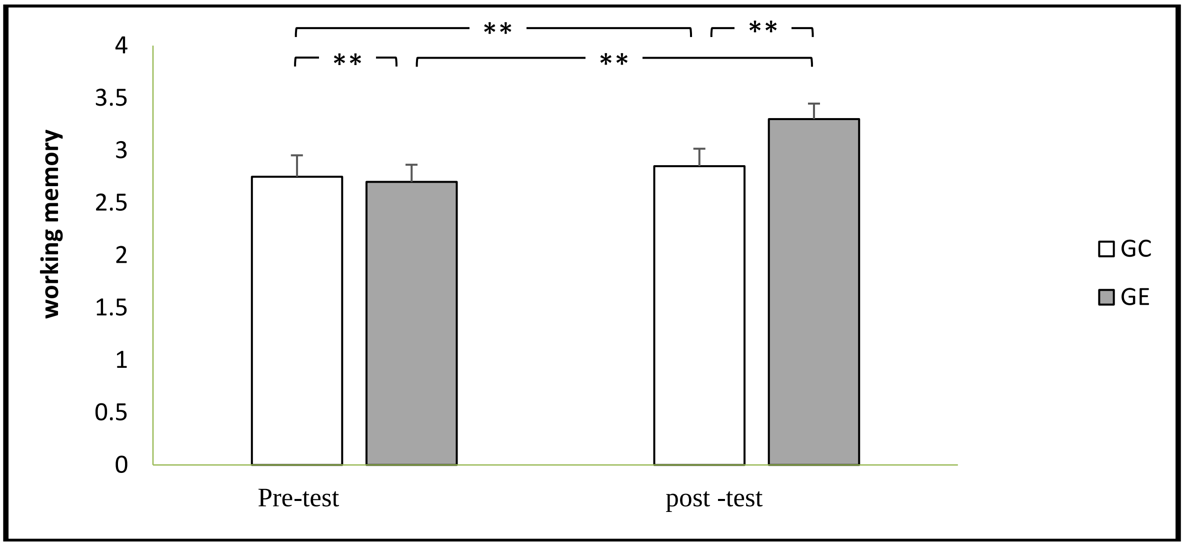

Figure 2: Working memory scores of EG and CG at Pre- and Post-Test

Concerning working memory as measured by the Digit spanscore, the repeated measures ANOVA revealed significant main effects for performance ($F_{(1,44)} = 36.58$, $p < 0.001$, $\eta^2_p = 0.45$) and group ($F_{(1,44)} = 9.54$, $p < 0.01$, $\eta^2_p = 0.17$). There was also a significant (group × performance) interaction effect ($F_{(1,44)} = 12.41$, $p < 0.001$, $\eta^2_p = 0.22$). Post-hoc testing revealed better performance for the EG, but not CG, participants at post-testing when compared to pre-testing ($p < 0.01$). In addition, post-hoc testing showed significantly higher digit span scores for the EG compared with the CG participants at post-testing ($p < 0.01$).

The results of the present study confirm that the practice of motor activity has a positive effect on the inhibitory capacity in children: indeed, the analyses have shown a significant difference at p <0.01 for variables relating to the two groups. However, the comparison of intra-group interference scores, showed that there was no significant difference except for the variable interference error at p <0.05 in favor of the experimental group.

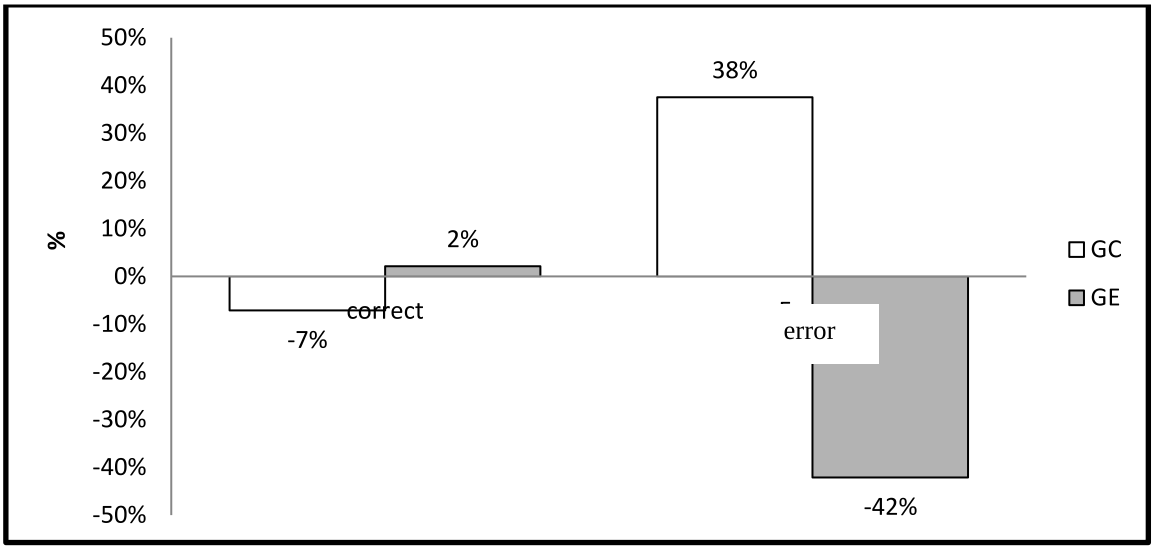

Figure 3: (Δ%) STROOP 1 « color » of EG and CG at Pre- and Post-testing

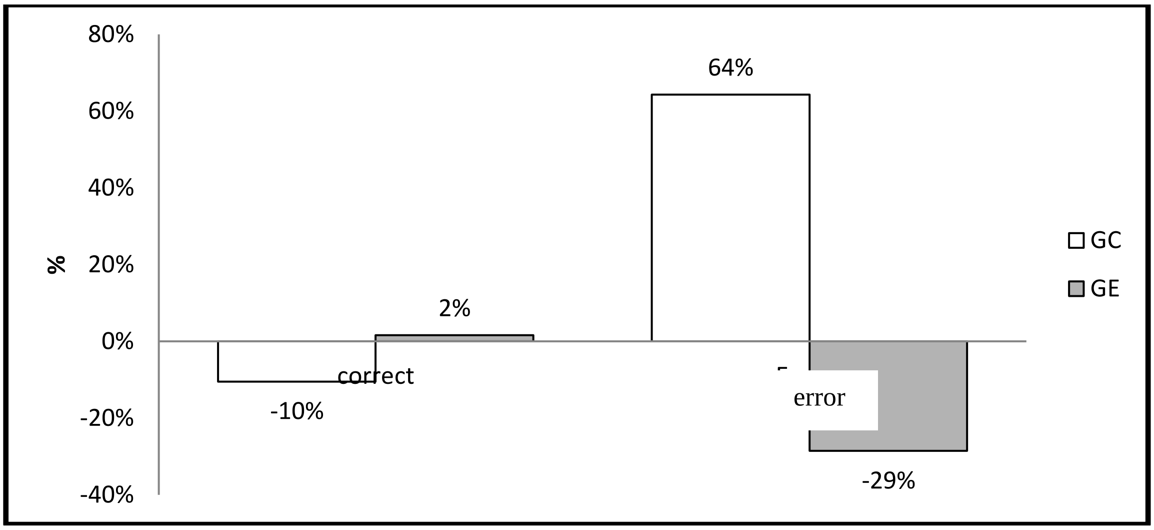

Figure 4: (Δ%) STROOP 2 « color's fruits » of EG and CG at Pre- and Post-testing

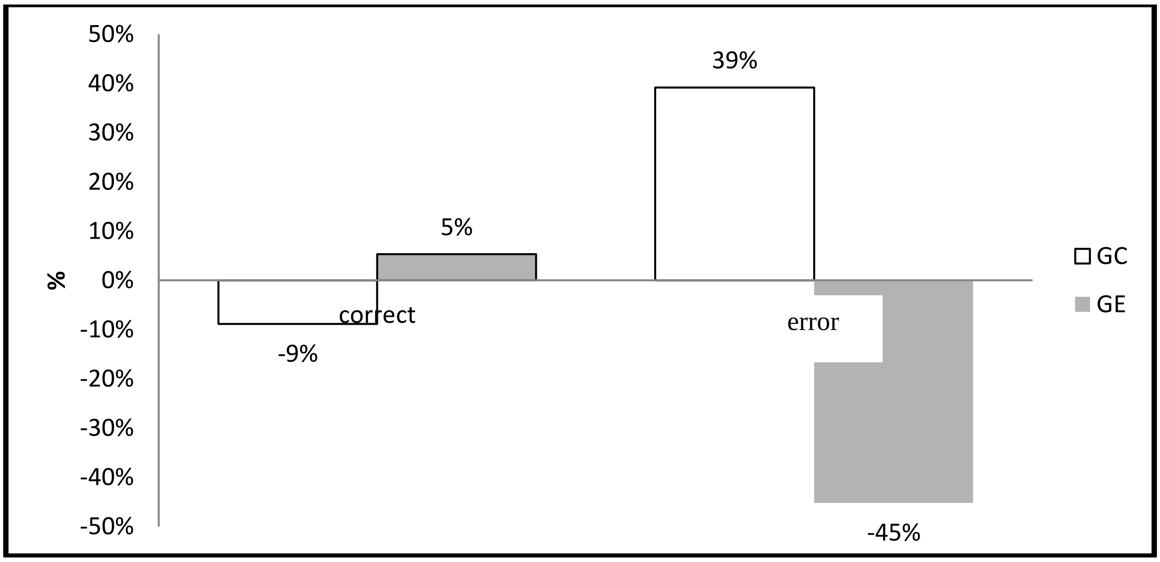

Figure 5: (Δ%) STROOP 3 « Interference » of EG and CG at Pre- and Post-testing

This result confirms the improvement of the inhibitory control following the practice of motor activity against the control group which was not mentioned as a significant in the Stroop effect (interference score). Moreover, the analysis of the delta percentage showed that the experimental group benefited from a more considerable decrease in terms of error or / and time during the facilitation and interference scores

5. Discussion

We aimed, in this study, to examine the effects of motor activity program on inhibition, working memory, among children aged 6–7 years. Our data supported our hypothesis that participating in a 12-week motor activity program during school-based math classes vs the control group. Positive changes in inhibition were demonstrated through improvements in corrected and error scores on the Stroop Test for EG, but not CG participants. Working memory as measured by the Digit span score was also enhanced after the motor activity program but not for participants in the control group. These findings are in line with previous reports that creative education in math classes training significantly influenced EF in children (Yetti et al., 2019). A very recent study has also reported that motricity improved inhibitory control and working memory in primary school children (Rudd et al., 2021).

In childhood, especially in late childhood, motor skills undergo dynamic development (Myer et al., 2015), and cognitive functions, especially executive functions (EFs), are identifiable and mature at different rates (Anderson, 2002). There is considerable debate regarding which cognitive skills represent EFs, but Diamond (2013) has asserted that they include three types of brain functions: working memory, inhibitory control, and cognitive flexibility. EF skills develop during childhood in parallel with the development of neural synapses, myelination, and the recruitment and consolidation of neural networks for specific cognitive tasks (Stevens et al., 2009). These functions are multidimensional and include a broad variety of skills such as attentional control, cognitive flexibility, inhibition, and strategic planning (Reader et al., 1994). EFs play an important role in determining the cognitive and academic functioning that supports learning and scholarly achievement (McClelland & Cameron, 2012; Raver et al., 2011; Ursache et al., 2012).

On the other hand, poor EF skills may put children at risk for ineffective environmental interactions leading to significant and lasting cognitive, academic, and social difficulties (Biederman et al., 2004; Clark et al., 2002; Ellis et al., 2004; Tapert et al., 2002). Indeed, students with poor working memory are more likely to experience difficulties following instructions for an activity, performing mental calculations, and retaining relevant information for other academic work (Cosnefroy, 2010). As EFs involve cognitive processes responsible for organizing and controlling goal-directed behavior, they are directly relevant to success in school and life in general (Kulinna et al., 2018).

Previous researchers have noted that cognitive skills develop in parallel with motor skills (Diamond, 2000; Hillman et al., 2005; Metcalf et al., 2011). Physical activity

(PA) has been specifically associated with children's EF (Sibley & Etnier, 2003). In this context, a previous study showed that PA improved EF in children aged 6–7 years old (Abdelkarim et al., 2017). Indeed, PA may exert beneficial effects on working memory (Kamijo et al., 2011), inhibition and cognitive flexibility (Hillman et al., 2014).

6. Recommendations

The research findings, although of a limited validity and generalization due to the small size of the sample, showed that motor game can play an important role in the learning of cognitive concepts and also offered for cross thematic and interdisciplinary teaching in school learning activities.

7. Conclusion

This study is one of the rare works that have been interested in studying the effect of the practice of specific activity on the cognitive functioning of the child.

According to the results of this study, it seems that motor and cognitive developments are related, in many cases, motor development could predict the development of cognitive skills. Given the importance of cognitive development and executive functions in childhood, it seems that by helping to develop their motor skills, executive functions will also be strengthened. As we have seen in the present study, object control skills were able to predict inhibition and organization. On the other hand, motor activity predicted working memory. However, it should be noted that the relationship between the development of cognitive and motor skills is probably stronger and more significant in some aspects, while in others, motor skills are unpredictable. The reason for this seems to depend on factors such as the age of the study participants and their living environment, which subsequently affects the type of physical activity and other environmental factors. However, for a more accurate insight, more research is needed, especially on the components of executive functions that have received little research.

Acknowledgements

The authors express their sincerest gratitude to the editors and blind reviewers who have shared their expertise and guidance for the opportunity laid through this paper. The authors would also like to thank the principal of the school, all the children who participated in this study, and the university teacher who participated in the design of our intervention program.

Conflict of Interest Statement

The authors declare no conflicts of interest.

About the Author(s)
Mounira Ben Sidhom is a doctor in didactics of disciplines, Research Unit of the National Sports Observatory (ONS): Physical activity: Sport & Health, Tunis, Tunisia. Higher Institute of Education and Continuous Training, Virtual University, Montplaisir 2019, Tunisia.
Nizar Souissi is a professor in sport sciences, Department of Health, Exercise Science Research Center Human Performance and Recreation, University of Arkansas, Fayetteville, AR 72701, USA. Research Unit of the National Sports Observatory (ONS): Physical activity: Sport & Health, Tunis, Tunisia.

References

Abdelkarim, O., Ammar, A., Chtourou, H., Wagner, M., Knisel, E., Hökelmann, A., & Bös, K. (2017). Relationship between motor and cognitive learning abilities among primary school-aged children. *Alexandria Journal of Medicine, 53*(4), 325-331.

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology,* 8(2), 71-82.

Aye, T., Oo, K. S., Khin, M. T., Kuramoto-Ahuja, T., & Maruyama, H. (2017). Reliability of the test of gross motor development second edition (TGMD-2) for Kindergarten children in Myanmar. *Journal of Physical Therapy Science, 29*(10), 1726-1731.

Biederman, J., Monuteaux, M. C., Doyle, A. E., Seidman, L. J., Wilens, T. E., Ferrero, F., . . Faraone, S. V. (2004). Impact of executive function deficits and attention-deficit/hyperactivity disorder (ADHD) on academic outcomes in children. *Journal of consulting and clinical psychology, 72*(5), 757.

Clark, C., Prior, M., & Kinsella, G. (2002). The relationship between executive function abilities, adaptive behaviour, and academic achievement in children with externalising behaviour problems. *Journal of Child Psychology and Psychiatry, 43*(6), 785-796.

Cosnefroy, L. (2010). L'apprentissage autorégulé: perspectives en formation d'adultes. *Savoirs*(1), 9-50.

Cowan, N., AuBuchon, A. M., Gilchrist, A. L., Ricker, T. J., & Saults, J. S. (2011). Age differences in visual working memory capacity: Not based on encoding limitations. *Developmental science, 14*(5), 1066-1074.

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia, 44*(11), 2037-2078.

De Lièvre, B., & Staes, L. (2000). *La psychomotricité au service de l'enfant: notions et applications pédagogiques*: De Boeck.

Diamond, A. (1995). Evidence of robust recognition memory early in life even when assessed by reaching behavior. *Journal of experimental child psychology, 59*(3), 419-456.

Diamond, A. (2000). Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. *Child development, 71*(1), 44-56.

Diamond, A. (2013). Executive functions. *Annual review of psychology, 64*, 135-168.

Diamond, A., & Goldman-Rakic, P. S. (1989). Comparison of human infants and rhesus monkeys on Piaget's AB task: Evidence for dependence on dorsolateral prefrontal cortex. *Experimental brain research, 74*, 24-40.

Ellis, L. K., Rothbart, M. K., & Posner, M. I. (2004). Individual differences in executive attention predict self-regulation and adolescent psychosocial behaviors. *Annals of the New York Academy of Sciences,* 1021(1), 337-340.

Ferguson, H. J., Brunsdon, V. E., & Bradford, E. E. (2021). The developmental trajectories of executive function from adolescence to old age. *Scientific reports, 11*(1), 1382.

Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental psychology, 40*(2), 177.

Grissmer, D., Grimm, K. J., Aiyer, S. M., Murrah, W. M., & Steele, J. S. (2010). Fine motor skills and early comprehension of the world: two new school readiness indicators. *Developmental psychology, 46*(5), 1008.

Hale, S., Bronik, M. D., & Fry, A. F. (1997). Verbal and spatial working memory in school-age children: developmental differences in susceptibility to interference. *Developmental psychology, 33*(2), 364.

Hanakawa, T. (2011). Rostral premotor cortex as a gateway between motor and cognitive networks. *Neuroscience research, 70*(2), 144-154.

Haywood, K. M., & Getchell, N. (2001). Learning activities for life span motor development. *(No Title)*.

Hillman, C. H., Castelli, D. M., & Buck, S. M. (2005). Aerobic fitness and neurocognitive function in healthy preadolescent children. *Medicine and science in sports and exercise, 37*(11), 1967.

Hillman, C. H., Pontifex, M. B., Castelli, D. M., Khan, N. A., Raine, L. B., Scudder, M. R., Kamijo, K. (2014). Effects of the FITKids randomized controlled trial on executive control and brain function. *Pediatrics, 134*(4), e1063-e1071.

Huizinga, M., Dolan, C. V., & Van der Molen, M. W. (2006). Age-related change in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia, 44*(11), 2017-2036.

Kamijo, K., Pontifex, M. B., O'Leary, K. C., Scudder, M. R., Wu, C. T., Castelli, D. M., & Hillman, C. H. (2011). The effects of an afterschool physical activity program on working memory in preadolescent children. *Developmental science, 14*(5), 1046-1058.

Kulinna, P. H., Stylianou, M., Dyson, B., Banville, D., Dryden, C., & Colby, R. (2018). The effect of an authentic acute physical education session of dance on elementary students' selective attention. *BioMed Research International, 2018*.

Libertus, K., & Hauf, P. (2017). Motor skills and their foundational role for perceptual, social, and cognitive development (Vol. 8, pp. 301): Frontiers Media SA.

McClelland, M. M., & Cameron, C. E. (2012). Self-regulation in early childhood: Improving conceptual clarity and developing ecologically valid measures. *Child development perspectives, 6*(2), 136-142.

McKenna, R., Rushe, T., & Woodcock, K. A. (2017). Informing the structure of executive function in children: a meta-analysis of functional neuroimaging data. *Frontiers in human neuroscience,* 11, 154.

Metcalf, B. S., Hosking, J., Jeffery, A., Voss, L., Henley, W., & Wilkin, T. (2011). Fatness leads to inactivity, but inactivity does not lead to fatness: a longitudinal study in children (EarlyBird 45). *Archives of disease in childhood, 96*(10), 942-947.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive psychology, 41*(1), 49-100.

Monette, S., & Bigras, M. (2008). La mesure des fonctions exécutives chez les enfants d'âge préscolaire. *Canadian Psychology/Psychologie Canadienne, 49*(4), 323.

Muhoozi, G. K., Atukunda, P., Diep, L. M., Mwadime, R., Kaaya, A. N., Skaare, A. B., . . . Iversen, P. O. (2018). Nutrition, hygiene, and stimulation education to improve growth, cognitive, language, and motor development among infants in Uganda: A cluster-randomized trial. *Maternal & child nutrition, 14*(2), e12527.

Myer, G. D., Faigenbaum, A. D., Edwards, N. M., Clark, J. F., Best, T. M., & Sallis, R. E. (2015). Sixty minutes of what? A developing brain perspective for activating children with an integrative exercise approach. *British journal of sports medicine, 49*(23), 1510-1516.

Pailhous, J., & Bonnard, M. (1989). Programmation et contrôle du mouvement. *Traité de psychologie cognitive, 1*.

Payne, V. G., & Isaacs, L. D. (2017). *Human motor development: A lifespan approach*: Routledge.

Petrican, R., Taylor, M. J., & Grady, C. L. (2017). Trajectories of brain system maturation from childhood to older adulthood: implications for lifespan cognitive functioning. *Neuroimage, 163*, 125-149.

Piaget, J. (1947). Psychologie de l'Intelligence Armand-Colin.

Piaget, J., & Cook, M. (1952). The origins of intelligence in children (p. 419). *New York, NY, US: WW Norton & Co*.

posner, M., & Rothbart, M. (1998). Attention, self–regulation and consciousness. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences, 353*(1377), 1915-1927.

Raver, C. C., Jones, S. M., Li-Grining, C., Zhai, F., Bub, K., & Pressler, E. (2011). CSRP's impact on low-income preschoolers' preacademic skills: self-regulation as a mediating mechanism. *Child development*, *82*(1), 362-378.

Reader, M. J., Harris, E. L., Schuerholz, L. J., & Denckla, M. B. (1994). Attention deficit hyperactivity disorder and executive dysfunction. *Developmental neuropsychology, 10*(4), 493-512.

Rigal, R. (1996). *Motricité humaine: fondements et applications pédagogiques. 2, Développementmoteur*: Presses universitaires du Québec.

Rudd, J., Buszard, T., Spittle, S., O'Callaghan, L., & Oppici, L. (2021). Comparing the efficacy (RCT) of learning a dance choreography and practicing creative dance on improving executive functions and motor competence in 6–7 years old children. *Psychology of Sport and Exercise, 53*, 101846.

Rutman, A. M., Clapp, W. C., Chadick, J. Z., & Gazzaley, A. (2010). Early top–down control of visual processing predicts working memory performance. *Journal of cognitive neuroscience, 22*(6), 1224-1234.

Sibley, B. A., & Etnier, J. L. (2003). The relationship between physical activity and cognition in children: a meta-analysis. *Pediatric exercise science, 15*(3), 243-256.

Solesio-Jofre, E., Lorenzo-López, L., Gutiérrez, R., López-Frutos, J. M., Ruiz-Vargas, J. M., & Maestú, F. (2012). Age-related effects in working memory recognition modulated by retroactive interference. *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences, 67*(6), 565-572.

Stevens, M. C., Skudlarski, P., Pearlson, G. D., & Calhoun, V. D. (2009). Age-related cognitive gains are mediated by the effects of white matter development on brain network integration. *Neuroimage, 48*(4), 738-746.

Takeuchi, H., Taki, Y., Sassa, Y., Hashizume, H., Sekiguchi, A., Fukushima, A., & Kawashima, R. (2013). Brain structures associated with executive functions during everyday events in a non-clinical sample. *Brain Structure and Function, 218*, 1017-1032.

Tapert, S. F., Baratta, M. V., Abrantes, A. M., & Brown, S. A. (2002). Attention dysfunction predicts substance involvement in community youths. *Journal of the American Academy of Child & Adolescent Psychiatry, 41*(6), 680-686.

Ursache, A., Blair, C., & Raver, C. C. (2012). The promotion of self-regulation as a means of enhancing school readiness and early achievement in children at risk for school failure. *Child development perspectives, 6*(2), 122-128.

van der Fels, I. M., de Bruijn, A., Renken, R., Königs, M., Meijer, A., Oosterlaan, J., . . . Smith, J. (2020). Relationships between gross motor skills, cardiovascular fitness, and visuospatial working memory-related brain activation in 8-to 10-year-old children. *Cognitive, Affective, & Behavioral Neuroscience, 20*, 842-858.

Van der Fels, I. M., Te Wierike, S. C., 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.

Vandenbroucke, L., Spilt, J., Verschueren, K., Piccinin, C., & Baeyens, D. (2018). The classroom as a developmental context for cognitive development: A meta-analysis on the importance of teacher–student interactions for children's executive functions. *Review of Educational Research, 88*(1), 125-164.

Veldman, S. L., Santos, R., Jones, R. A., Sousa-Sá, E., & Okely, A. D. (2019). Associations between gross motor skills and cognitive development in toddlers. *Early human development, 132*, 39-44.

Wechsler, D. (2003). Wechsler intelligence scale for children–Fourth Edition (WISC-IV). *(No Title)*.

Yetti, E., Syarah, E. S., Pramitasari, M., Syarfina, S., & Susanti, D. (2019). *The influence of the dance creativity on executive functions of early childhood.* Paper presented at the International Conference on Arts and Design Education (ICADE 2018).

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.