Research Article https://doi.org/10.12973/eu-jer.12.1.359

European Journal of Educational Research
Volume 12, Issue 1, 359 - 369.
ISSN: 2165-8714
https://www.eu-jer.com/

Examining the Associations Between Calibration Accuracy and Executive Functions in Physical Education

Evdoxia Samara* University of Thessaly, GREECE

Athanasios Kolovelonis University of Thessaly, GREECE

Marios Goudas University of Thessaly, GREECE

Received: July 14, 2022 ▪ Revised: November 21, 2022 ▪ Accepted: December 26, 2022

Abstract: This study examined students' calibration of performance in a sport skill in relation to their performance in an executive functions test. A total of 265 students in the fourth, fifth, and sixth grades participated in the study. The students took an executive functions test, and then they were tested on a basketball shooting test, after having provided a personal estimation regarding their performance. Based on students' actual and estimated performance, the bias index was calculated to classify students into three categories; accurates, underestimators and overestimators, while the accuracy index (absolute values of the bias index) was also calculated. The results showed a positive but small magnitude relation between students' scores in the executive functions test and their performance calibration, while accurate scored higher on the executive function test compared to over estimators and under estimators. These results are similar to those of previous studies with elementary school children that employed cognitive tasks and were discussed with reference to theoretical and empirical implications.

Keywords: *Calibration accuracy, executive functions, physical education, sports performance.*

To cite this article: Samara, E., Kolovelonis, A., & Goudas, M. (2023). Examining the associations between calibration accuracy and executive functions in physical education. *European Journal of Educational Research, 12*(1), 359-369. https://doi.org/10.12973/eu-jer.12.1.359

Introduction

Physical education at the elementary level aims to help students mastering new skills (Ennis, 2011). Thus, research in physical education is examining factors associated with students' learning and performance, including cognitive and metacognitive ones (Goudas et al., 2013). In this line, the present study focused on the associations between metacognitive aspects of performance such as performance calibration and cognitive process such as executive functions in the field of physical education.

Theorists agree that there are conceptual similarities between executive functions and metacognition and research has demonstrated a relationship between these concepts (Effeney et al., 2013; Roebers & Feurer, 2016). Although executive functions and metacognition are considered to overlap in theory, the literature is limited regarding their interrelations (Roebers & Feurer, 2016). Therefore, this study examined the relationships between executive functions and calibration of performance in a sport skill in the context of physical education.

Executive Functions

Executive functions encompass higher-order cognitive processes that are involved in goal-directed behaviors and in the regulation of knowledge and behaviors. These are usually activated in new and complicated conditions (Diamond, 2013, 2015). Executive functions are essential when there is a need to concentrate and pay attention and they are involved the selection and the successful monitoring of behaviors that facilitate the achievement of specific goals (Eslinger, 1996). Executive functions may also involve scheduling or decision-making, correcting potential errors or troubleshooting. They also refer to situations which demand new sequences of actions and conditions requiring overcoming a standard reaction or resisting in a temptation (Diamond, 2013).

The three core executive functions are: inhibition, working memory, and cognitive flexibility (Diamond, 2015). Inhibitory control enables selective monitor, focusing on specific aspects of the task and suppressing attention to an

* **Corresponding author:**
Samara Evdoxia, University of Thessaly, Department of Physical Education & Sport Science, Volos, Greece. ✉ evdosamara@uth.gr

unrelated stimulus. Working memory involves retaining information in the mind and working with it mentally. Finally, cognitive flexibility refers to meeting different requirements or applying different rules in different settings.

Executive functions develop gradually and can be improved throughout a person's lifetime (Diamond & Ling, 2016). Although the abilities to be cognitively flexible, setting goals and dealing with information appear early in life, they come to a relative maturity around the age of 12 (Anderson, 2002). It is difficult to clarify whether there is a unique sequence of stages through which executive functions are developed or whether there are environments or life experiences that can help individuals to develop their executive functions through various sequences. Some students may require more attention and help compared to their classmates in order to obtain and evolve these skills. Providing students with the appropriate support to develop these skills in educational programs may be a priority of teachers.

Executive functions have attracted research interest because they are considered important for health, quality of life, and success in school and life (Diamond & Ling, 2016). Physical activity is considered one of the means for promoting students' executive functions (de Greeff et al., 2018). Indeed, a recent study showed positive associations between motor ability and executive functions, which in turn were positively associated with students' attendance at school (Gu et al., 2019). Moreover, executive functions mediated the association between motor ability and academic success (Schmidt et al., 2017). Executive functions can be developed through appropriately designed programs or interventions (Diamond & Lee, 2011). A recent review including a variety of physical activity programs has suggested that physical activity can enhance executive functions (Vazou et al., 2019).

It has also been found that school-aged children improved executive functions and academic performance after the inclusion of cognitive physical education breaks (Egger et al., 2019). Regardless of the time period, these interventions had a positive effect on the assessment of students' cognitive abilities (Moreau et al., 2017; Veldman et al., 2020). Physical activity interventions to improve performance should focus on improving executive functions (Visier-Alfonso et al., 2021). Therefore, even short physical activity modules are suggested to be in the students' daily curriculum as this can help them to participate more actively in learning.

Calibration of Performance

Calibration refers to the degree of the fit between individuals' judgements of performance and their actual performance (Keren, 1991). Therefore, calibration is the difference between one's estimated performance and actual performance on specific tasks. By adopting the above definition, one could claim that calibration is part of the individual's metacognitive processes. It has been maintained that metacognition has different facets, i.e., metacognitive knowledge, metacognitive skills, and metacognitive experiences (Efklides, 2008; Flavell, 1979; Veenman et al., 2006). It could be argued that calibration of performance is part of students' metacognitive experiences that "are what the person is aware of and what she or he feels when coming across a task and processing the information related to it" (Efklides, 2008, p. 279). Metacognitive experiences are considered as the interface between the person and the task. Further, Efklides (2008, p. 279) delineated that "The online task-specific knowledge comprises task information that we are attending to, and ideas or thoughts that we are aware of as we deal with a task... It also comprises metacognitive knowledge that we retrieve from memory in order to process the task; for example, metacognitive knowledge about tasks and procedures that we used in the past, comparison of the current with other tasks about their similarities or differences, and so forth". According to this definition, calibration of performance could be part of the students' online task-specific knowledge. It should also be noted that, in the present study, calibration of performance is referred to students' estimations of success *before* actual performance. As regards the degree of fit between judgements of performance and actual performance, this comparison can result in three categories referring to accuracy and inaccuracy: accurate, underestimation, overestimation. Calibration bias refers to the degree to which a person is under or over confident in estimated performance. Well-calibrated people can estimate their performance more accurately.

Regarding the development of metacognition in children, the metacognitive phenomena emerge in their early forms in young ages, as early as in preschool and early school years (e.g., Dermitzaki et al., 2009; Zhang & Whitebread, 2017), and they expand thereafter during schooling. Children become gradually aware of their personal knowledge, tasks' characteristics, or the strategies to use to monitor their progress (Veenman & Spaans, 2005). It has been asserted that the different facets of metacognition do not develop in the same pace. Metacognitive knowledge increasingly developes in the first school years, but the development of metacognitive skills is usually expected to set in after the age of 11–12 years (e.g., Veenman & Spaans, 2005), whereas the use of more sophisticated strategies is expected during adolescence and early adulthood. Previous research findings suggest that elementary school students are limited in metacognitive knowledge and incorrectly declare themselves ready for memory and knowledge projects (Brown, 1978; Flavell, 1978; Flavell & Wellman, 1977). Further, some metacognitive skills (e.g., control skills and evaluation) mature later on than others such as planning (Veenman et al., 2006).

Given the developmental limitations, previous studies examined students' self-estimation of competence and performance using various types of tasks. It has been attested that, younger children from different cultural environments, despite the cognitive abilities of their age, usually overestimate their capabilities, including physical and motor abilities (e.g., Franchak, 2019). Calibration has been examined in physical education as it relates to students' motivation to learn and practice. In most studies, the students overestimated their actual performance (e.g., Kolovelonis, 2019a, 2019b; Kolovelonis et al., 2012) although the tasks' characteristics (e.g., shooting position; Kolovelonis & Goudas, 2018), seem to affect calibration accuracy. Previous research has attested that, well-calibrated students can discern the points of performance that are still lagging behind (Efklides, 2014) and set realistic goals for improvement. Also, well-calibrated students are more receptive to pursuing tasks related to cognitive, motivational, or self-regulatory processes that affect their learning (Chen & Bembenutty, 2018). Several studies in academic settings have reported that students are usually inaccurate (Chen, 2003; Hacker & Bol, 2004) and overestimate their performance (Eme et al., 2006; Follmer, 2021; Hacker et al., 2008). In addition, well-calibrated students have greater potential for self-regulation and more developed monitoring ability (Bol & Hacker, 2012; Zimmerman & Moylan, 2009). In particular, students who overestimate their potential by setting high goals, tend to reduce their effort, in case of failure, (Efklides & Misailidi, 2010), while students who underestimate their performance may be reluctant to try difficult tasks (Schunk & Pajares, 2004). Researchers are interested in the accurate calibration of students as it is related to motivation, learning and performance (Schunk & Pajares, 2009). According to previous research, calibration accuracy is related to higher performance and can be improved through feedback and practice (Kolovelonis et al., 2013, 2020).

Associations Between Executive Functions and Metacognitive Aspects

Metacognition and executive functions share theoretical and conceptual similarities. As summarized by Roebers (2017) and Roebers and Feurer (2016), they are theorized as higher-order cognitive processes that allow individuals to function and adapt effectively to new and demanding tasks. Executive functions and metacognition are not automated responses but are considered to be initiated and controlled by the individual. Further these involve sub-procedures (e.g., shifting, updating, and inhibition for executive functions, monitoring and control for metacognition). Further, both concepts are related to the ability of individuals to monitor and control their thinking and behavior.

However, studies with early elementary children that examined the relationship of executive functions with metacognitive aspects have indicated relations of low magnitude. The metacognitive aspects examined in these studies are monitoring and control while only one study (Destan & Roebers, 2015) assessed accuracy of performance prediction (i.e., calibration). Roebers et al. (2012) employing a spelling test, assessed second graders' metacognitive monitoring (e.g., "how sure are you that the word was spelled correctly") and control (e.g., "Cross out words that have been spelled incorrectly"). They reported correlations ranging from 0.01 to 0.26 between executive functions (inhibition, flexibility and mental fluency) and metacognitive monitoring and control. Correlations of similar magnitude between executive functions and metacognitive control were reported by Spiess et al. (2016), who utilized a similar procedure with eight-year-old children. Similarly, Bryce et al. (2015) reported generally low respective correlations for a sample of five and seven-year-old children who undertook a toy-building task, although these relationships were higher for the five-year old children. Finally, Bellon et al. (2019) reported correlations less than .20 between calibration confidence and inhibition, shifting and updating among seven and eight-year-old children who took an arithmetic test with addition and multiplication problems. In a study that in addition to metacognitive monitoring and control assessed calibration, Destan and Roebers (2015), six-year-old children estimated their subsequent performance on a Japanese character paired associate learning task. The accuracy of this estimation (i.e., calibration accuracy) correlated with a composite score of inhibition, working memory, and cognitive flexibility only .17. Overall, in late kindergarten and early elementary children, metacognitive aspects are loosely related to executive functions. Besides, only one study (Destan & Roebers, 2015) has examined the metacognitive aspect of performance estimation (calibration) in relation to executive functions.

The Current Study

The present study focused on the relations between executive functions and metacognitive aspects of performance (i.e., performance calibration) in physical education. Calibration is especially important because students' ability to accurately estimate their performance influences their efforts and strategic behaviors in learning and mastering skills. Moreover, executive functions are considered higher-order cognitive processes critical for success in school and life (Diamond & Ling, 2016). Although theoretical evidence has proposed that these two concepts are associated, little empirical evidence exists in this field. Thus, the purpose of this study was to add to the limited literature regarding the relationship between metacognitive aspects and executive functions in elementary children. In particular, this study examined calibration accuracy in relation to executive functions, as related research is scarce. Moreover, as the studies on executive functions and metacognitive aspects have utilized cognitive tasks, the current one employed a motor-task to widen the respective research. Based on previous respective studies (Bellon et al., 2019; Destan & Roebers, 2015; Roebers et al., 2012), a significant but small correlation were expected between executive functions and calibration of performance.

Methodology

Research Design

This is a correlational study on the association between a task-based metacognitive measure and executive function. The design involved a basketball shooting test, prediction of performance and a measure of executive function tapping fluency, inhibition and flexibility.

Participants

Participants in this study were 265 Greek students aged 10-12 years (*M*age = 11.32, *SD* = 0.77, 137 boys and 128 girls) from three elementary schools located at a medium-sized city in central Greece. These students attended five sixth grade (83 students, 44 boys), six fifth grade (89 students, 46 boys) and six fourth grade (93 students, 47 boys) physical education classes.

Measures

Design Fluency Test

The Design Fluency Test (DF, Delis et al., 2001) was used to measure students' executive functions. This is part of the Delis-Kaplan Executive Function System, which is a standardized test battery with satisfactory psychometric properties including test-retest reliability and convergent and discriminant validity (Delis et al., 2004). This test represents a method of executive functioning assessment commonly used in research settings. Children were asked to rapidly generate novel patterns within a structured visual task. The test has three conditions and students had one minute in each condition of the test to draw as many different designs as possible, trying to avoid repeating prior designs.

The first condition (i.e., Filled Dots) requires connecting filled dots. The second condition (i.e., Empty Dots), requires connecting empty dots without using filled dots, while the third condition (i.e., Switch) requires switching between connecting filled and empty dots. In each condition, participants should generate novel designs using exactly four lines in a series of matrices. This test evaluates fluency in generating visual patterns (first condition), inhibition (second condition), and cognitive flexibility (third condition). Three scores (one for each condition of the test), as well as a total score of the three Design Fluency Test conditions were calculated.

Calibration of Basketball Shooting Performance

Basketball shooting performance was measured with a modified shooting accuracy test showing a satisfactory test-retest reliability .92 (Pojskić et al., 2011). Students had to perform, without time limit, 10 shots in front of the basket from a distance of 2.5m. Students' score in this test was their number of successful shots. Before the basketball shooting test, students responded to the following question: "How many of your shots out of 10 will be successful from this position in the following test?" Students' answers in this question were their scores in the estimation of their shooting performance.

Based on students actual and estimated performance, the indexes of calibration bias and accuracy were calculated. Indeed, the calibration bias score was calculated as students' estimated performance score minus their actual performance in the basketball shooting test. The bias index describes the direction of the calibration. A positive bias means that the student's performance has been overestimated, while a negative bias is the opposite. Absolute values of the calibration bias represent the accuracy index. Scores close to zero in the accuracy index indicate a higher calibration accuracy (Schraw, 2009).

Procedure

For conducting this study an ethical approval was granted by the University Ethics Review Committee and the Institute of Educational Policy. Permission was also granted by school principals and physical education teachers. Students' participation was voluntary, while a parental written consent was compulsory prior to participation. The procedure was explained to the students, while it was made clear that answers and performances would remain confidential. Then, students completed the design fluency test in their classrooms. A week later, the experiment took place in the schools' outdoor basketball court, after describing the procedure.

Statistical Analyses

Statistical analyses considered the nature of the calibration bias and accuracy (Griffin et al., 2013; Stankov et al., 2012). Thus, calibration accuracy was used in correlational analyses. The calibration bias served to classify students as accurates, underestimators, and overestimators. These groups were then compared in terms of their executive function scores.

Frequencies of accurates (score: exactly the number of shots), underestimators (negative scores: the real number of shots was higher than predicted), and overestimators (positive scores: the real number of shots was lower than predicted) were calculated. Chi-square tests were used for examining potential differences in the frequencies of these groups. Differences between accurates, underestimators, and overestimators in the executive function test were examined through multivariate and univariate analysis of variance followed by post hoc tests. Effect sizes of Cohen's *d* were calculated (Cohen, 1988).

Findings / Results

Preliminary Analyses

A principal components analysis with varimax rotation was performed on the scores of the three conditions of the design fluency test. The Kaiser-Meyer-Olkin (.65) and the Bartlett test of sphericity, χ^2 (6) = 177.8, $p < .001$, confirmed the sampling adequacy and the appropriateness of the correlation matrix for this analysis. One principal component with eigenvalue > 1 resulted explaining 49.4 of the variance. Therefore, in subsequent analyses, both the scores of the three test conditions and their total score were used. The ANOVA test showed nonsignificant differences between boys and girls on the total Design Fluency Test score, F (1, 263) = .10, p = .75, while the MANOVA test showed that their difference on the three Design Fluency Test conditions was marginally significant, F (3, 261) = 2.80, p = .042. An ANOVA showed nonsignificant differences between three Grades on the total Design Fluency Test score, F (2, 262) = 1.73, p = .18 while the MANOVA test showed that they did not differ on the three Design Fluency Test conditions, F (6, 520) = 1.46, p = .19. Thus, the subsequent analyses were run for the total of the participants. Additionally, the dependent variables for the subsequent ANOVA and MANOVA tests (i.e., scores on the three test conditions of the Design Fluency Test and the respective total score had minimal skewness (range .02 - .32) and kurtosis (range .10 - .52).

Main Analyses

Means and standard deviations of students' scores in the three conditions of the executive function test and in the total score separately for grade and gender are reported in Table 1. For examining the relationship between the calibration accuracy and executive functions, a correlation analysis was used (Table 2). Small correlations emerged between calibration accuracy and executive function test scores.

Table 1. Means and Standard Deviations of Students' Score in Each Condition and in the Total of the Executive Functions Test Separately for Each Grade and Gender

	Total		4th Grade		5th Grade		6th Grade		Boys		Girls	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Basketball Shooting Performance	4.29	1.99	3.52	1.84	4.44	1.75	5.01	2.10	4.90	1.96	3.65	1.81
Estimation	5.06	2.43	5.26	2.92	5.11	2.18	4.78	2.04	5.73	2.28	4.34	3.38
Accuracy	2.19	1.76	2.82	2.16	1.89	1.55	1.82	1.21	2.28	1.71	2.10	1.81
Bias	0.77	2.71	1.74	3.10	0.67	2.35	-0.23	2.18	0.83	2.73	0.70	2.69
DF- Condition 1	7.26	3.17	7.08	2.89	7.63	3.30	7.07	3.32	7.43	3.43	7.08	2.86
DF- Condition 2	7.99	3.12	7.54	3.22	8.16	2.80	8.33	3.31	8.06	3.32	7.92	2.90
DF- Condition 3	4.90	2.96	4.40	2.86	5.08	2.65	5.28	3.31	4.53	3.11	5.30	2.74
DF- Total	20.15	7.40	19.01	7.13	20.87	7.27	20.67	7.77	20.01	7.96	20.30	6.79

Note: DF= Design Fluency Test

Based on the bias index, 11.7% of students (31 students) were accurate, 35.1% (93 students) were underestimators and 53.2% (141 students) were overestimators. Chi-square was used to examine differences in frequencies between the three groups. The results revealed statistically significant differences between the three groups χ^2 (2) = 68.86, p < .001. The means and standard deviations of students' scores in the executive function test separately for accurate, underestimators and overestimators are presented in Table 3.

Table 2. Correlation Between the Variables of the Study

	1	2	3	4	5
1. Basketball Shooting Performance	-				
2. Calibration Accuracy	-.24**	-			
3. DF- Condition 1	.10	-.02	-		
4. DF- Condition 2	.23**	-.17**	.58**	-	
5. DF- Condition 3	.17**	-.12	.36**	.43**	-
6. DF- Total	.21**	-.13*	.82**	.84**	.74**

Note: DF= Design Fluency Test, *p < .05, **p < .001

Prior running a MANOVA, with Group (i.e., the three bias groups) as independent variable and the three test condition scores as dependent variables, the Box M test (F (12, 35717) = .83, p > .05) confirmed that the observed covariance matrices of the dependent variables were equal across groups. The results showed nonsignificant differences between accurates, underestimators and overestimators, F (6, 520) = 1.44, p = .199.

Table 3. Descriptive Statistics for the Design Fluency Test Scores Separately for Accurates, Underestimators and Overestimators

	DF - Condition 1		DF-Condition 2		DF-Condition 3		Total Score in DF Test	
	M	SD	M	SD	M	SD	M	SD
Accurates	7.48	3.00	8.68	3.00	5.55	3.33	21.71	7.35
Underestimators	7.56	3.47	8.48	3.15	5.20	3.01	21.25	7.70
Overestimators	7.01	2.99	7.52	3.07	4.56	2.80	19.09	7.10

Note: DF= Design Fluency Test

For examining potential differences in the total score in the executive functions test between the three bias groups (accurates, underestimators and overestimators) a one-way ANOVA was conducted. The Shapiro –Wilk test confirmed the normal distribution of the dependent variable within each Group (accurates: .96, df = 12, p = .35, underestimators: .98, df = 93, p = .32, overestimators: .99, df = 141, p = .13). A marginally statistically significant difference between groups, F (2, 262) = 3.20, p = .042, was found. LSD post hoc analysis showed that underestimators (M = 21.25) compared to overestimators (M = 19.09) had a higher score in the total executive functions test score (p = .029, d = .29). Accurates had higher values in the total executive functions test score compared to underestimators and overestimators and underestimators had higher score than overestimators, however these differences did not reach significance.

Discussion

This study examined the relationship between students' calibration of their performance in a physical education task with their executive functions. The results showed a generally low relation between students' executive functions and performance calibration. Moreover, accurates had the highest scores in the total score in the Design Fluency Test compared to underestimators and overestimators while underestimators had higher score than overestimators. The results are discussed next with reference to previous findings and the theoretical and the empirical implications for improving learning and performance in physical education.

The magnitude of the relationship between calibration of performance and executive functions was small. Similar results have been provided in studies with elementary and kindergarten children that employed cognitive tasks (Bellon et al., 2019; Destan & Roebers, 2015; Roebers, et al., 2012). Thus, although performance calibration, as a metacognitive aspect, and executive functions share theoretical and conceptual similarities, the results of the present study as well as those of previous ones do not fully support this relationship empirically. Roebers (2017) has provided two possible explanations for these results. The first one is methodological: metacognitive aspects such as calibration are assessed in task-specific context, whereas, executive functions are assessed through tests that are decontextualized. The second possible explanation is theoretical: children at this age may have limited ability to form an awareness of performance which will activate control processes. The results of the present and of several related studies attest that elementary school children usually overestimate their performance in cognitive (Chen, 2003; Hacker & Bol, 2004; Hacker et al., 2008) and in physical (Kolovelonis & Goudas, 2018, 2019; Kolovelonis et al., 2012) tasks. Similarly, in the present study, more than 50% of the participants overestimated their performance.

The consistent finding of the overestimation of performance in young children might denote an adaptive value for them (Bjorklund, 1997; Schwebel & Plumert, 1999). It seems to protect children from becoming discouraged in the face of difficulties or avoiding challenging tasks and, at the same time, it allows them to feel efficacious persisting even when they face a failure. One explanation that has been offered to explain students' overestimation is that younger children are not yet capable of accurately estimating their future performance, however, such an explanation has been challenged by recent data (see Xia et al., 2022). Another explanation proposed that young students may had a difficulty to distinguish between their wishes and expectations, that is, they make predictions based on wishful thinking resulting in overestimation (Lipko-Speed, 2013). Nevertheless, it has been suggested that wishful thinking is context-dependent and thus it can be used for explaining overconfidence on some but not other tasks (Lipko et al., 2009; Schneider, 1998). Beyond the above lines of explanations, new data offer further alternative and more complicated accounts of this phenomenon. Xia et al. (2022) reported that children from both Dutch and Chinese cultures persevered in overestimating themselves on both a motor and a memory task, despite receiving accurate performance feedback. The explanation the authors offered was that, despite children's abilities to remember their previous performance and despite the given feedback, children may fail to take full advantage of the available feedback to make accurate predictions. It seems that a general positive bias regarding judgments of attributes and abilities may exist. That is, children attended to, processed, and interpreted information in a selective way to preserve their optimistic views for themselves.

Although the magnitude of the relationships between executive functions and performance calibration was generally small, both concepts are important for learning and performance in physical education. Executive functions and metacognition are also linked to self-regulated learning. Executive functions serve as specific but relevant cognitive processes, mediated by metacognition, which enables a flexible use of learning strategies to facilitate the attainment of learning objectives. Both concepts are higher-order factors associated with behavioral regulation, share common characteristics, and have similar developmental trajectories associated with common areas of the brain (Roebers & Feurer, 2016). Metacognition is involved in executive functions because subjective experiences (e.g., cognition) allow behavior to be controlled. Calibration, representing a metacognitive process providing information about one's knowledge state and strategies at a cognitive level, is relevant in this context.

Self-regulated learning is based on goal setting, monitoring, evaluation and regulation of learning (Stolp & Zabrucky, 2009). Calibration is also a factor for effective self-regulation as it provides students with internal feedback that can use to control their learning and performance (Bol et al., 2012; Dunlosky & Rawson, 2012). As a result, self-regulated students are more aware of what they know and what they do not, and thus it is expected to be more accurate in estimating their performance (Zimmerman, 2000).

It is known that executive functions promote and engage strategy use as related with metacognitive (Roebers, 2017) self-regulation skills (Blair & Diamond, 2008; Roebers, 2017) and processes in physical activities. Children's executive functions and learning outcomes seem to show common developmental progress. Students with significant age-related cognitive abilities achieve high learning achievements. Conversely, students with high learning performance tend to participate in and complete demanding tasks, thus enhancing their cognitive abilities (Fuhs et al., 2014), even when physical activity modules are short (Gallotta et al., 2012; Jager et al., 2014; Pesce et al., 2009).

Based on the above, it appears that the executive functions allow the smooth adaptation and success of students in their schools (Fuhs et al., 2014; Welsh et al., 2010), while their participation in organized and demanding school activities and the achievement of significant learning outcomes significantly enhance their cognitive abilities. Thus, the interdependence of executive functions and learning achievements paves the way for the creation of educational activities and programs suitable for reinforcement within the school space.

Conclusion

The study showed a small relation between students' performance calibration and their executive functions in physical education. Moreover, the majority of the students overestimated their performance, while students with a higher score on the executive functions were better calibrated regarding their sports performance.

Recommendations

The present findings can provide the basis for important implications regarding students' calibration accuracy and executive functions in physical education. Physical education teachers should design and implement appropriate interventions to enhance students' executive functions. Enhanced executive functions may help students to involve in self-regulated learning, increase their metacognitive awareness including the calibration of their sport performance. Moreover, interventions focusing on improving students' performance calibration (e.g., Kolovelonis et al., 2020) may also involve appropriate content and process for triggering students' executive functions.

Considering that in the present study students' executive functions were measured with only one test, future research should involve multiple tests for measuring executive functions. Future research could also focus on students' self-regulatory practice in respect with the development of their executive functions. For example, future research may examine if the development of students' executive functions, through appropriately designed educational or physical activity programs, can positively affect students' calibration accuracy and enhance their self-regulatory skills.

Limitations

This study focused exclusively on students' performance calibration in one sport skill. Future research should focus on more than one sport skills and physical activities that students are taught in physical education to examine potential effects of the skills used (e.g., open versus closed skills) on the associations between performance calibration and executive functions. Students level of competence in specific sport skills or the levels of their physical activity out of school may also be considered in such research.

Funding

The research was supported by the Hellenic Foundation for Research and Innovation (H.F.R.I.) under the "1st Call for H.F.R.I. Research Projects to support Faculty Members & Researchers and the Procurement of High-and the procurement of high-cost research equipment grant" (Project Number: 1041).

Authorship Contribution Statement

Samara: Drafting manuscript, data acquisition, data analysis / interpretation. Kolovelonis: Concept and design, critical revision of manuscript. Goudas: Concept and design, critical revision of manuscript, securing funding.

References

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology, 8*(2), 71–82. https://doi.org/10.1076/chin.8.2.71.8724

Bellon, E., Fias, W., & De Smedt, B. (2019). More than number sense: The additional role of executive functions and metacognition in arithmetic. *Journal of Experimental Child Psychology*, *182*, 38–60. https://doi.org/10.1016/j.jecp.2019.01.012

Bjorklund, D. F. (1997). The role of immaturity in human development. *Psychological Bulletin, 122*(2), 153–169. https://doi.org/10.1037/0033-2909.122.2.153

Blair, C., & Diamond, A. (2008). Biological processes in prevention and intervention: The promotion of self-regulation as a means of preventing school failure. *Development and Psychopathology*, *20*(3), 899-911. https://doi.org/10.1017/S0954579408000436

Bol, L., & Hacker, D. J. (2012). Calibration research: Where do we go from here? *Frontiers in Psychology, 3,* Article 229. https://doi.org/10.3389/fpsyg.2012.00229

Bol, L., Hacker, D. J., Walck, C. C., & Nunnery, J. A. (2012). The effects of individual or group guidelines on the calibration accuracy and achievement of high school biology students. *Contemporary Educational Psychology, 37*, 280–287. https://doi.org/10.1016/j.cedpsych.2012.02.004

Brown, A. L. (1978). Knowing when, where, and how to remember: A problem of metacognition. In R. Glaser (Ed.), *Advances in instructional psychology* (Vol. 1, pp.77-165). Lawrence Erlbaum Associates.

Bryce, D., Whitebread, D., & Szűcs, D. (2015). The relationships among executive functions, metacognitive skills and educational achievement in 5 and 7 year-old children. *Metacognition and Learning, 10*(2), 181–198. https://doi.org/10.1007/s11409-014-9120-4

Chen, P. (2003). Exploring the accuracy and predictability of the self-efficacy beliefs of seventh grade mathematics students. *Learning and Individual Differences, 14,* 77-90. https://doi.org/10.1016/j.lindif.2003.08.003

Chen, P. P., & Bembenutty, H. (2018). Calibration of performance and academic delay of gratification: Individual and group differences in self-regulation of learning. In D. H. Schunk & J. A. Greene (Eds.), *Handbook of self-regulation of learning and performance* (2nd ed., pp. 407–420). Routledge. https://doi.org/10.4324/9781315697048

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Routledge. https://doi.org/10.4324/9780203771587

de Greeff, J. W., Bosker, R. J., Oosterlaan, J., Visscher, C., & Hartman, E. (2018). Effects of physical activity on executive functions, attention and academic performance in preadolescent children: A meta-analysis. *Journal of Science and Medicine in Sport*, *21*(5), 501-507. https://doi.org/10.1016/j.jsams.2017.09.595

Delis, D. C., Kaplan, E., & Kramer, J. H. (2001). *Delis-Kaplan executive function system (D-KEFS).* The Psychological Corporation. https://doi.org/10.1037/t15082-000

Delis, D. C., Kramer, J. H., Kaplan, E., & Holdnack, J. (2004). Reliability and validity of the Delis-Kaplan executive function system: An Update. *Journal of the International Neuropsychological Society*, *10*(2), 301–303. https://doi.org/10.1017/S1355617704102191

Dermitzaki, I., Leondari, A., & Goudas, M. (2009). Relations between young students' strategic behaviours, domain-specific self-concept, and performance in a problem-solving situation. *Learning and Instruction*, *19*(2), 144-157. https://doi.org/10.1016/j.learninstruc.2008.03.002

Destan, N., & Roebers, C. M. (2015). What are the metacognitive costs of young children's overconfidence? *Metacognition and Learning*, *10*(3), 347-374. https://doi.org/10.1007/s11409-014-9133-z

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*(1), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Diamond, A. (2015). Effects of physical exercise on executive functions: Going beyond simply moving to moving with thought. *Annals of Sports Medicine and Research, 2,* Article 1011. https://pubmed.ncbi.nlm.nih.gov/26000340/

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4–12 years old. *Science, 333*(6045), 959–964. https://doi.org/10.1126/science.1204529

Diamond, A., & Ling, D. S. (2016). Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. *Developmental Cognitive Neuroscience*, *18*, 34-48. https://doi.org/10.1016/j.dcn.2015.11.005

Dunlosky, J., & Rawson, K. A. (2012). Overconfidence produces underachievement: Inaccurate self evaluations undermine students' learning and retention. *Learning and Instruction*, *22*(4), 271-280. https://doi.org/10.1016/j.learninstruc.2011.08.003

Effeney, G., Carroll, A., & Bahr, N. (2013). Self-regulated learning and executive function: Exploring the relationships in a sample of adolescent males. *Educational Psychology: An International Journal of Experimental Educational Psychology, 33*, 773–796. https://doi.org/10.1080/01443410.2013.785054

Efklides, A. (2008). Metacognition: Defining its facets and levels of functioning in relation to self-regulation and co-regulation. *European Psychologist, 13*(4), 277–287. https://doi.org/10.1027/1016-9040.13.4.277

Efklides, A. (2014). How does metacognition contribute to the regulation of learning? An integrative approach. *Psychological Topics, 23*(1)*,* 1–30. https://psycnet.apa.org/record/2014-25618-001

Efklides, A., & Misailidi, P. (2010). Introduction: The present and the future in metacognition. In A. Efklides & P. Misailidi (Eds.), *Trends and prospects in metacognition research* (pp. 1-18). Springer. https://doi.org/10.1007/978-1-4419-6546-2_1

Egger, F., Benzing, V., Conzelmann, A., & Schmidt, M. (2019). Boost your brain, while having a break! The effects of long-term cognitively engaging physical activity breaks on children's executive functions and academic achievement. *PLoS ONE, 14*(3). https://doi.org/10.1371/journal.pone.0212482

Eme, E., Puustinen, M., & Coutelet, B. (2006). Individual and developmental differences in reading monitoring: When and how do children evaluate their comprehension? *European Journal of Psychology of Education, 21,* 91-115. https://doi.org/10.1007/BF03173571

Ennis, C. (2011). Physical education curriculum priorities: Evidence for education and skillfulness. *Quest, 63*(1)*,* 5-18. https://doi.org/10.1080/00336297.2011.10483659

Eslinger, P. J. (1996). Conceptualizing, describing, and measuring components of executive function: A summary. In G. R. Lyon & N. A. Krasnegor (Eds.), *Attention, memory, and executive function* (pp. 367–395). Paul H. Brookes Publishing Co.

Flavell, J. H. (1978). Metacognitive development. In J. M. Scandura & C. J. Brainerd (Eds.), *Structural/process theories of complex human behavior.* Sijthoff & Noordhoff.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive– developmental inquiry. *American Psychologist*, *34*(10), 906-911. https://doi.org/10.1037/0003-066X.34.10.906

Flavell, J. H., & Wellman, H. M. (1977). Metamemory. In R.V. Kail & J. W. Hagen (Eds.), *Perspectives on the development of memory and cognition*. Lawrence Erlbaum.

Follmer, D. J. (2021). Examining the role of calibration of executive function performance in college learners' regulation. *Applied Cognitive Psychology*, *35*(3), 646-658. https://doi.org/10.1002/acp.3787

Franchak, J. M. (2019). Development of affordance perception and recalibration in children and adults. *Journal of Experimental Child Psychology*, *183*, 100-114. https://doi.org/10.1016/j.jecp.2019.01.016

Fuhs, M. W., Nesbitt, K. T., Farran, D. C., & Dong, N. (2014). Longitudinal associations between executive functioning and academic skills across content areas. *Developmental Psychology,* *50*(6), 1698-1709. https://doi.org/10.1037/a0036633

Gallotta, M. C., Guidetti, L., Franciosi, E., Emerenziani, G. P., Bonavolonta, V., & Baldari, C. (2012). Effects of varying type of exertion on children's attention capacity. *Medicine and Science in Sports and Exercise*, *44*(3), 550-555. https://doi.org/10.1249/mss.0b013e3182305552

Goudas, M., Kolovelonis, A., & Dermitzaki, I. (2013). Implementation of self-regulation interventions in physical education and sports contexts. In H. Bembenutty, T. Cleary, & A. Kitsantas (Eds.), *Applications of self-regulated learning across diverse disciplines: A tribute to Barry J. Zimmerman* (pp. 383-415). Information Age.

Griffin, T., Wiley, J., & Salas, C. (2013). Supporting effective self-regulated learning: The critical role of monitoring. In R. Azevedo & V. Aleven (Eds.), *International handbook of metacognition and learning technologies* (pp. 19-34). Springer. https://doi.org/10.1007/978-1-4419-5546-3_2

Gu, X., Zhang, T. L., Chu, T., Zhang, X., & Thomas, K. T. (2019). Do physically literate adolescents have better academic performance? *Perceptual and Motor Skills, 126*(4), 585-602. https://doi.org/10.1177/0031512519845274

Hacker, D. J., & Bol, L. (2004). Metacognitive theory: Considering the social-cognitive influences. In D. M. McInerney & S. Van Etten (Eds.), *Big theories revisited: 4. Research on sociocultural influences on motivation and learning* (pp. 275-297). Information Age.

Hacker, D. J., Bol, L., & Bahbahani, K. (2008). Explaining calibration accuracy in classroom contexts: The effects of incentives, reflection, and explanatory style. *Metacognition and Learning, 3,* 101-121. https://doi.org/10.1007/s11409-008-9021-5

Jager, K., Schmidt, M., Conzelmann, A., & Roebers, C. M. (2014). Cognitive and physiological effects of an acute physical activity intervention in elementary school children. *Frontiers in Psychology, 5,* Article 1473. https://doi.org/10.3389/fpsyg.2014.01473

Keren, G. (1991). Calibration and probability judgements: Conceptual and methodological issues. *Acta Psychologica, 77*(3), 217-273. https://doi.org/10.1016/0001-6918(91)90036-Y

Kolovelonis, A. (2019a). Greek physical education students' calibration accuracy in sport and knowledge tasks – a comparison. *International Sports Studies, 41*(1), 16-28. https://doi.org/10.30819/iss.41-1.03

Kolovelonis, A. (2019b). Relating students' participation in sport out of school and performance calibration in physical education. *Issues in Educational Research, 29*(3), 774-789. http://www.iier.org.au/iier29/kolovelonis.pdf

Kolovelonis, A., & Goudas, M. (2018). The relation of physical self-perceptions of competence, goal orientation, and optimism with students' performance calibration in physical education. *Learning and Individual Differences, 61,* 77-86. https://doi.org/10.1016/j.lindif.2017.11.013

Kolovelonis, A., & Goudas, M. (2019). Does performance calibration generalize across sport tasks? A multiexperiment study in physical education. *Journal of Sport and Exercise Psychology, 41*(6), 333-344. https://doi.org/10.1123/jsep.2018-0255

Kolovelonis, A., Goudas, M., & Dermitzaki, I. (2012). Students' performance calibration in a basketball dibbling task in elementary physical education. *International Electronic Journal of Elementary Education, 4*(3), 507-517. https://www.iejee.com/index.php/IEJEE/article/view/193

Kolovelonis, A., Goudas, M., Dermitzaki, I., & Kitsantas, A. (2013). Self-regulated learning and performance calibration among elementary physical education students. *European Journal of Psychology of Education, 28*(3), 685-701. https://doi.org/10.1007/s10212-012-0135-4

Kolovelonis, A., Goudas, M., & Samara, E. (2020). The effects of a self-regulated learning teaching unit on students' performance calibration, goal attainment, and attributions in physical education. *The Journal of Experimental Education*, *90*(1), 112-129. https://doi.org/10.1080/00220973.2020.1724852

Lipko, A. R., Dunlosky, J., Hartwig, M. K., Rawson, K. A., Swan, K., & Cook, D. (2009). Using standards to improve middle school students' accuracy at evaluating the quality of their recall. *Journal of Experimental Psychology: Applied*, *15*(4), 307-318. https://doi.org/10.1037/a0017599

Lipko-Speed, A. R. (2013). Can young children be more accurate predictors of their recall performance? *Journal of Experimental Child Psychology*, *114*(2), 357-363. https://doi.org/10.1016/j.jecp.2012.09.012

Moreau, D., Kirk, I. J., & Waldie, K. E. (2017). High-intensity training enhances executive function in children in a randomized, placebo-controlled trial. *Elife, 6*, Article e25062. https://doi.org/10.7554/eLife.25062

Pesce, C., Crova, C., Cereatti, L., Casella, R., & Bellucci, M. (2009). Physical activity and mental performance in preadolescents: Effects of acute exercise on free-recall memory. *Mental Health and Physical Activity 2*(1), 16-22. https://doi.org/10.1016/j.mhpa.2009.02.001

Pojskić, H., Šeparović, V., & Užičanin, E. (2011). Reliability and factorial validity of basketball shooting accuracy tests. *Sport Scientific and Practical Aspects, 8*(1), 25-32. http://www.sportspa.com.ba/images/june2011/full/rad5.pdf

Roebers, C. M. (2017). Executive function and metacognition: Towards a unifying framework of cognitive self-regulation. *Developmental Review, 45,* 31–51. https://doi.org/10.1016/j.dr.2017.04.001

Roebers, C. M., Cimeli, P., Röthlisberger, M., & Neuenschwander, R. (2012). Executive functioning, metacognition, and self-perceived competence in elementary school children: An explorative study on their interrelations and their role for school achievement. *Metacognition and Learning*, *7*(3), 151-173. https://doi.org/10.1007/s11409-012-9089-9

Roebers, C. M., & Feurer, E. (2016). Linking executive functions and procedural metacognition. *Child Development Perspectives*, *10*(1), 39-44. https://doi.org/10.1111/cdep.12159

Schmidt, M., Egger, F., Benzing, V., Jäger, K., Conzelmann, A., Roebers, C. M., & Pesce, C. (2017). Disentangling the relationship between children's motor ability, executive function and academic achievement. *PloS ONE*, *12*(8), Article e0182845. https://doi.org/10.1371/journal.pone.0182845

Schneider, W. (1998). Performance prediction in young children: Effects of skill, metacognition and wishful thinking. *Developmental Science*, *1*(2), 291–297. https://doi.org/10.1111/1467-7687.00044

Schraw, G. (2009). A conceptual analysis of five measures of metacognitive monitoring. *Metacognition and Learning, 4*(1), 33–45. https://doi.org/10.1007/s11409-008-9031-3

Schunk, D., & Pajares, F. (2004). Self-efficacy in education revisited: Empirical and applied evidence. In D. McInerney & S. Van Etten (Eds.), *Big theories revisited, 4: Research on sociocultural influences on motivation and learning* (pp. 115-138). Information Age.

Schunk, D., & Pajares, F. (2009). Self-efficacy theory. In K. R. Wentzel & A. Wigfield (Eds.), *Handbook of motivation at school* (pp. 35-53). Routledge /Taylor & Francis Group.

Schwebel, D. C., & Plumert, J. M. (1999). Longitudinal and concurrent relations among temperament, ability estimation, and injury proneness. *Child Development, 70*(3), 700-712. https://doi.org/10.1111/1467-8624.00050

Spiess, M., Meier, B., & Roebersm, C. M. (2016). Development and longitudinal relationships between children's executive functions, prospective memory, and metacognition. *Cognitive Development*, *38*, 99-113. https://doi.org/10.1016/j.cogdev.2016.02.003

Stankov, L., Lee, J., Luo, W., & Hogan, D. J. (2012). Confidence: A better predictor of academic achievement than self-efficacy, self-concept and anxiety? *Learning and Individual Differences, 22*(6), 747–758. https://doi.org/10.1016/j.lindif.2012.05.013

Stolp, S., & Zabrucky, K. M. (2009). Contributions of metacognitive and self-regulated learning theories to investigations of calibration of comprehension. *International Electronic Journal of Elementary Education, 2*(1), 7–31. https://files.eric.ed.gov/fulltext/EJ1052046.pdf

Vazou, S., Pesce, C., Lakes, K., & Smiley-Oyen, A. (2019). More than one road leads to Rome: A narrative review and meta-analysis of physical activity intervention effects on cognition in youth. *International Journal of Sport and Exercise Psychology*, *17*(2), 153-178. https://doi.org/10.1080/1612197X.2016.1223423

Veenman, M. V., & Spaans, M. A. (2005). Relation between intellectual and metacognitive skills: Age and task differences. *Learning and Individual Differences*, *15*(2), 159-176. https://doi.org/10.1016/j.lindif.2004.12.001

Veenman, M. V. J., Van Hout-Wolters, B. H. A. M., & Afflerbach, P. (2006). Metacognition and learning: Conceptual and methodological considerations. *Metacognition & Learning, 1*, 3–14. https://doi.org/10.1007/s11409-006-6893-0

Veldman, S. L., Jones, R. A., Stanley, R. M., Cliff, D. P., Vella, S. A., Howard, S. J., Parrish, A. M., & Okely, A. D. (2020). Promoting physical activity and executive functions among children: A cluster randomized controlled trial of an after-school program in Australia. *Journal of Physical Activity and Health*, *17*(10), 940-946. https://doi.org/10.1123/jpah.2019-0381

Visier-Alfonso, M. E., Álvarez-Bueno, C., Sánchez-López, M., Cavero-Redondo, I., Martínez-Hortelano, J. A., Nieto-López, M., & Martínez-Vizcaíno, V. (2021). Fitness and executive function as mediators between physical activity and academic achievement: Mediators between physical activity and academic achievement. *Journal of Sports Sciences*, *39*(14), 1576-1584. https://doi.org/10.1080/02640414.2021.1886665

Welsh, J. A., Nix, R. L., Blair, C., Bierman, K. L., & Nelson, K. E. (2010). The development of cognitive skills and gains in academic school readiness for children from low-income families. *Journal of Educational Psychology*, *102*(1), 43-53. https://doi.org/10.1037/a0016738

Xia, M., Poorthuis, A. M. G., Zhou, Q., & Thomaes, S. (2022). Young children's overestimation of performance: A cross-cultural comparison. *Child Development, 93*(2), 207-221. https://doi.org/10.1111/cdev.13709

Zhang, H., & Whitebread, D. (2017). Linking parental scaffolding with self-regulated learning in Chinese kindergarten children. *Learning and Instruction*, *49*, 121-130. https://doi.org/10.1016/j.learninstruc.2017.01.001

Zimmerman, B. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13–39). Academic Press. https://doi.org/10.1016/B978-012109890-2/50031-7

Zimmerman, B. J., & Moylan, A. R. (2009). Self-regulation: Where metacognition and motivation intersect. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Handbook of metacognition in education* (pp. 299–315). Routledge/Taylor & Francis Group.