COGNITIVE-MOTOR MECHANISMS IN LEARNING COMPLEX KINESIOLOGICAL TASKS IN TEN-YEAR-OLD CHILDREN

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Abstract: The aim of this study was to determine the effect of cognitive-motor learning on the acquisition of complex kinesiological tasks in 10-year-old children. The research was conducted on a sample of 25 fourth-grade elementary school students (13 girls and 12 boys). Over the course of five consecutive instructional sessions, the students practiced a complex motor obstacle course that involved jumping, crawling, and ball handling. Task performance time was measured using Witty photo cells, with both descriptive and inferential statistical methods applied. The results showed a statistically significant reduction in task completion time between the initial and final measurements ($t = 10.27$; $p < .001$), indicating effective motor learning. Gender-based analysis revealed that boys performed slightly better in the final series compared to girls, with significant differences observed in the final stages ($p < .01$). A stable normal distribution of results was also observed, which enabled the use of parametric statistical tests. This study confirms that systematically organized motor tasks engaging cognitive processes can enhance the efficiency of motor pattern acquisition in children. The obstacle course proved to be an effective tool for integrating cognitive-motor mechanisms into school practice.
Keywords: motor learning, cognitive processes, child development, obstacle course, physical education

INTRODUCTION

The development of motor abilities and the acquisition of complex kinesiological structures during childhood represent a fundamental component of overall psychophysical development. The age of ten is marked by significant progress in the integration of cognitive and motor functions, enabling children to more efficiently acquire new movements, techniques, and motor patterns. This period is particularly important due to the enhancement of cognitive processes such as attention, working memory, planning, and problem-solving, all of which significantly influence the quality of motor learning (Gabbard, 2018).

According to Piaget's theory, children at this age begin to develop concrete operational thinking, allowing for better understanding and application of new motor tasks (Piaget, 1952). Cognitive-motor mechanisms involve complex interactions between neurophysiological systems responsible for information processing and motor control. Processes such as the perception of spatial-temporal relationships, motor program formation, conscious movement correction, and learning through feedback are key elements in mastering demanding kinesiological tasks. It is important to note that motor abilities are closely linked with cognitive processes such as attention and working memory, which facilitate faster and more efficient learning of new movements (Lezak et al., 2012; Gabbard, 2018). Children's ability to synchronize cognitive processes with motor task execution directly affects the speed and efficiency of learning, as well as the eventual level of motor skill automatization (Schmidt & Lee, 2014; Prodić et al., 2024).

The study of cognitive-motor mechanisms in ten-year-olds holds particular significance as it provides deeper insight into how developmental characteristics of cognitive capacities influence motor competence during the sensitive period of early school age. As children develop, their ability to integrate cognitive processes with motor actions improves, forming the basis for the creation of optimal motor learning programs tailored to the individual abilities and needs of each child (Fitts & Posner, 1967; Shea & Morgan, 1979).

Within the field of motor learning, a specific methodological format known as the obstacle course holds a notable position. The obstacle course is a systematically organized path where children encounter a series of diverse motor tasks performed in sequence (Švraka, 2012). Performing exercises on such a course facilitates the development of complex motor patterns, enhances spatial orientation, balance, coordination, and reaction speed, thereby directly promoting the integration of cognitive and motor processes (Ersöz & Bediz, 2020; Canli et al., 2023; Gajević et al., 2022). Due to its complexity and the constant demands placed on attention and motor control, the obstacle course represents an ideal model for examining cognitive-motor mechanisms in school-aged children (Ersöz & Bediz, 2020).

The originality of this study lies in the application of the methodological obstacle course as a model for investigating cognitive-motor mechanisms in children, a topic that has not been systematically explored within domestic pedagogical practice. While the importance of motor learning is well documented in the literature, there is a lack of research that combines contemporary knowledge from neuroscience, motor control, and school-based instruction under real-life conditions. This study contributes to the understanding of how children respond to cognitively demanding motor tasks and may serve as a foundation for creating differentiated programs in physical education. Accordingly, the analysis of cognitive-motor mechanisms in the context of learning complex kinesiological tasks in ten-year-olds not only enhances our understanding of developmental processes but also has practical value for the fields of physical education, sports, rehabilitation, and pedagogy.

METHODS

Participants

The study included 25 fourth-grade elementary school students from Šabac, with an average age of 10 ± 0.5 years. The sample consisted of 13 girls and 12 boys. Over the course of five consecutive physical education classes, participants practiced the same motor task structure, with three repetitions per class session, totaling 15 repetitions.

Experimental program

The experimental program was implemented as part of the regular physical education curriculum and lasted for two weeks. Students participated in five sessions, held at a frequency of two to three classes per week. Each session began with a warm-up and task explanation, followed by three repetitions of the designated obstacle course. The course consisted of three main segments: (1) jumping over an obstacle, (2) crawling through a tunnel, and (3) dribbling a ball in a slalom pattern between cones. The objective was to complete the course as efficiently and accurately as possible.

All motor components were integrated into a methodological-organizational format of an obstacle course, with a total length of 12 meters. Task execution time was measured using the Witty photo-cell timing system (Microgate, Italy), which provides high precision in tracking motor performance. Photo cells were positioned at the start and end of the course, and measurements were automatically recorded by the system, eliminating the possibility of subjective error.

All participants performed the task under identical conditions, and the testing was conducted in a controlled environment. The study was conducted with approval from the school administration and written informed consent from the children's parents. All data were handled in accordance with ethical standards for research involving children, ensuring anonymity and voluntary participation.

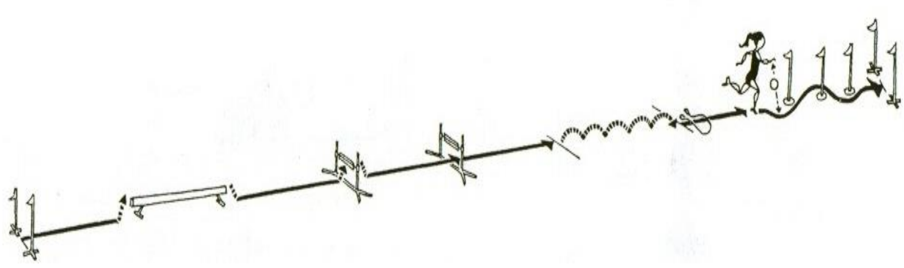

Figure 1. Obstacle Course

Statistical Analysis

The measurement data were processed using Statistica software, version 7.0. Basic descriptive statistical parameters were analyzed, including arithmetic mean, standard deviation, and minimum and maximum values. The normality of the data distribution was tested using the Kolmogorov–Smirnov test. To assess the statistical significance of differences between the initial and final measurements, as well as between groups based on gender, paired and independent samples t-tests were applied.

RESULTS AND DISCUSSION

This section presents the results of the study on the effects of cognitive-motor learning in 10-year-old children, with a focus on performance changes across five consecutive measurement sessions. The data were analyzed using both descriptive and inferential statistics, including paired and independent samples t-tests, as well as the Kolmogorov–Smirnov test for normality. Table 1 displays the basic descriptive statistical parameters for all three measurements within each of the five sessions.

Table 1. Basic Descriptive Parameters for the Entire Sample of Participants

Measurement	Session	N	Mean	Mean-Series	Min	Max	SD	Max D	K-S
1	**1**	25	10,47	10,11	8,95	12,72	1,17	0,18	p > .20
2	**1**	25	9,97		8,44	12,85	1,11	0,11	p > .20
3	**1**	25	9,87		8,24	11,84	0,92	0,12	p > .20
1	**2**	25	8,72	8,88	7,84	10,74	0,78	0,15	p > .20
2	**2**	25	8,54		7,37	10,39	0,80	0,13	p > .20
3	**2**	25	8,39		6,98	9,74	0,86	0,12	p > .20
1	**3**	25	8,76	9,12	7,54	10,11	0,77	0,12	p > .20
2	**3**	25	8,91		7,15	11,68	1,09	0,11	p > .20
3	**3**	25	8,79		6,85	11,84	1,25	0,09	p> .20
1	**4**	25	8,67	8,55	7,08	11,06	0,99	0,14	p > .20
2	**4**	25	8,59		6,68	10,43	1,14	0,13	p > .20
3	**4**	25	8,39		6,65	9,85	0,94	0,18	p > .20
1	**5**	25	8,44	8,30	6,61	10,52	1,00	0,14	p > .20
2	**5**	25	8,29		6,70	9,80	0,81	0,21	p > .20
3	**5**	25	8,16		6,46	9,99	0,97	0,11	p > .20

Legend: *N – number of participants, Mean – arithmetic mean, Mean- Series – arithmetic mean per session, Min – minimum result, Max – maximum result, SD – standard deviation, Max D - maximum deviation, K-S - Kolmogorov–Smirnov test*

Data were collected through three measurements in five series of motor tasks. For each measurement, arithmetic means, minimum and maximum values, standard deviations, and values from the Kolmogorov-Smirnov test for normal distribution were calculated. The results of this study indicate a continuous decrease in the execution time of the motor task across the five measurement series, representing a typical pattern of progress in motor learning. The average time decreased from an initial 10.45 ± 1.19 seconds to a final 8.14 ± 0.97 seconds, with a statistically significant difference observed ($t(23) = 10.27$; $p < 0.001$). This finding is consistent with the classic learning model proposed by Fitts & Posner (1967), in which motor skill learning progresses through cognitive, associative, and autonomous phases.

Performance improvement is evident as early as the second measurement series, indicating that subjects quickly transitioned from the cognitive to the associative phase, where motor responses stabilize and become more efficient. The greatest individual variability was observed in the third series, likely due to cognitive effort characteristic of the motor pattern consolidation phase. This phenomenon aligns with cognitive load theory (Sweller, 1988), which suggests that high information processing demands can lead to temporary instability in performance.

Normality of distribution in all measurements was confirmed by the Kolmogorov-Smirnov test (p > 0.20), enabling reliable application of parametric tests and increasing the validity of the conclusions drawn. Overall, the data support theoretical perspectives that consistent repetition under conditions of optimal cognitive engagement is a prerequisite for forming stable and automated motor patterns (Ericsson et al., 1993; Magill & Anderson, 2017).

Table 2. Basic descriptive parameters for the sample of girls and boys

Measurement	Session	Mean Girls	Mean of Girls' Series	SD Girls	K-S girl	Mean Boys	Mean of Boys' Series	SD Boys	K-S Boys
1	**1**	10,81	10,30	1,14	p > .20	9,87	9,80	1,04	p > .20
2	**1**	10,27	-	1,16	p > .20	9,47	-	0,87	p > .20
3	**1**	9,85	-	1,01	p > .20	9,98	-	0,82	p > .20
1	**2**	8,86	8,70	0,71	p > .20	8,48	8,20	0,87	p < .15
2	**2**	8,75	-	0,84	p > .20	8,19	-	0,65	p > .20
3	**2**	8,59	-	0,87	p > .20	8,05	-	0,77	p > .20
1	**3**	8,90	9,10	0,82	p > .20	8,53	8,40	0,68	p > .20
2	**3**	9,20	-	1,09	p > .20	8,43	-	0,96	p > .20
3	**3**	9,21	-	1,23	p > .20	8,11	-	1,02	p > .20
1	**4**	9,12	9,00	0,95	p > .20	7,95	7,80	0,61	p > .20
2	**4**	9,16	-	1,00	p > .20	7,84	-	0,98	p > .20
3	**4**	8,86	-	0,76	p > .20	7,63	-	0,71	p > .20
1	**5**	8,97	8,70	0,86	p > .20	7,60	7,60	0,57	p > .20
2	**5**	8,60	-	0,79	p > .20	7,82	-	0,62	p > .20
3	**5**	8,59	-	0,90	p > .20	7,46	-	0,66	p > .20

Legend*: Mean – arithmetic mean, Mean of series – arithmetic mean of the series, SD – standard deviation, K-S - Kolmogorov–Smirnov test for normality*

Table 2 presents the basic descriptive statistics for girls and boys across five task series measured at three time points within the motor learning program. For each measurement, the mean, standard deviation, and results of the Kolmogorov–Smirnov test of normality are provided, which is essential for determining whether the distribution of results within each group follows a normal curve. In most cases, the average scores for girls are slightly higher than those for boys, suggesting marginally better performance in terms of motor learning outcomes.

The arithmetic means across series indicate that both girls and boys maintained relatively similar levels within each series, without extreme fluctuations, which suggests consistency in task execution. In Measurement 1, Series 1, girls had a mean score of 10.81, compared to 9.87 for boys, potentially indicating a difference in initial performance levels. Standard deviations generally ranged from 0.6 to 1.2, reflecting moderate variability within groups. Girls displayed slightly greater variability in some measurements (Measurement 3, Series 3: SD = 1.23), which may point to greater individual differences in task performance. In contrast, lower variability among boys in certain series (Series 5: SD = 0.57) suggests a higher degree of consistency in their executions.

All Kolmogorov–Smirnov test results were within the acceptable range ($p > .20$), with the exception of one instance for boys in Measurement 1, Series 2 ($p < .15$), which still falls within the boundaries of acceptable normality, though it may indicate a slightly divergent distribution pattern. These results confirm that the data distributions are sufficiently normal, thereby allowing the use of parametric statistical tests such as the t-test to further examine the significance of differences or effects.

A slightly declining trend in mean values was observed in both groups, which may suggest fatigue, adaptation, or changes in task approach (e.g., Series 1 for girls: 10.81 → 10.27 → 9.85). However, in some series (e.g., Series 3 for girls: 8.90 → 9.20 → 9.21), an increase was observed, possibly reflecting a learning effect. Among boys, a more stable or gradual decline was noted, which could indicate a different dynamic in the learning process.

This table, along with the analyzed data, provides a valid foundation for further application of parametric statistical methods in assessing the effects of motor learning in girls and boys. The normality of distribution, consistent standard deviations, and coherent trends in mean values suggest that the sample behaves in accordance with expectations for both qualitative and quantitative analysis in pedagogical practice and research.

Table 3. Results of the t-test for the entire sample – initial and final measurements

Group	Mean	SD	N	Diff. Mean	SD Diff.	t	DF	p
Initial	10,45	1,19	25					
Final	8,14	0,97	25	2,31	1,09	10,27	23	0.00

Legend: *Mean – Arithmetic Mean; SD – Standard Deviation; N – Number of participants; Diff. Mean – Difference between Initial and Final means; SD Diff. – Standard Deviation of the difference; DF – Degrees of Freedom; t – t-test value; p – Level of statistical significance.*

Based on the presented t-test results analyzing the significance of the difference between the initial and final measurements for the entire sample, it can be concluded that motor learning produced positive effects for all participants in the study. Specifically, the execution time of the assigned motor task was statistically significantly reduced.

Table 4. Results of the t-test for girls and boys – Initial vs. Final measurement

Group	Measurement	Mean	SD	N	Diff.	SD Diff.	t	DF	p
Girls	Initial	10,8	1,14						
	Final	8,6	0,90	13	2,22	1,13	7,31	13	0,00
Boys	Initial	9,87	1,04						
	Final	7,64	0,66	12	2,41	1,02	7,06	8	0,00

Legend: *Mean – arithmetic mean; SD – standard deviation; N – number of participants; Diff. – difference between initial and final measurement; SD of Diff. – standard deviation of the difference; t – t-test value; DF – degrees of freedom; p – level of statistical significance.*

Sex differences become more pronounced in the final trials. Boys achieved better results at the final measurement (7.64 ± 0.66) compared to girls (8.60 ± 0.90), with a statistically significant difference ($t(21) = 3.18$; $p < 0.01$). Although girls started with higher initial values, their progress was stable and consistent, indicating the effectiveness of the program even among groups with lower motor dominance. Differences in the rate of acquisition may be influenced by biological and experiential factors. Research suggests that boys more frequently engage in informal sports activities, which may contribute to better spatial orientation, faster adaptation to dynamic demands, and more efficient movement (Prodić et al., 2024).

In conclusion, both observed groups demonstrated statistically significant improvements following the application of motor learning, suggesting that the program was effective in enhancing the motor skills required for the completion of the assigned task.

Table 5. Results of the t-test for differences between initial and final measurements based on gender

	Mean Girls	**Mean Boys**	**t**	**DF**	**p**
Initial	10,81	9,89	1,97	21	006
Final	8,59	7,48	3,18	21	0,00

Legend: *Mean – arithmetic mean; t – value of the t-test; DF – degrees of freedom; p – level of statistical significance.*

Analysis of the t-test results for independent samples reveals performance differences between girls and boys across various phases of the motor learning process.

At the initial measurement, boys achieved slightly better results compared to girls ($M = 9.89$ vs. $M = 10.81$), with the difference approaching statistical significance ($t(21) = 1.97$, $p = 0.05$). This finding suggests that boys may have had a certain initial advantage in performing the targeted motor task, although this advantage did not reach a high level of statistical certainty.

However, following the implementation of the learning process, the final measurement revealed a statistically significant difference in favor of the boys ($M = 7.48$ for boys vs. $M = 8.59$ for girls), with the result confirmed as highly significant ($t(21) = 3.18$, $p < 0.01$). This indicates that the effect of motor learning was more pronounced among boys.

A possible explanation for these results may lie in potential differences in prior motor experience. Boys are more frequently involved in extracurricular sports activities, which may contribute to faster acquisition and execution of new motor tasks.

Nevertheless, it is important to emphasize that girls also demonstrated significant improvement throughout the learning period, indicating that the implemented program was effective for both genders.

Table 6. Independent Samples t-test Results – Gender Differences by Series and Measurements

Measurement	Session	Mean Girls	Mean Boys	t	df	p	N (Girls)	N (Boys)
1	**1**	10,81	9,89	1,97	21	0,06	13	12
2	**1**	10,27	9,49	1,70	21	0,10	13	12
3	**1**	9,86	9,99	-0,36	21	0,72	13	12
1	**2**	8,87	8,51	1,08	21	0,29	13	12
2	**2**	8,76	8,21	1,64	21	0,11	13	12
3	**2**	8,60	8,08	1,46	21	0,16	13	12
1	**3**	8,91	8,56	1,06	21	0,30	13	12
2	**3**	9,21	8,45	1,68	21	0,12	13	12
3	**3**	9,22	8,13	2,18	21	0,04	13	12
1	**4**	9,12	7,97	3,21	21	0,00	13	12
2	**4**	9,07	7,86	2,86	21	0,01	13	12
3	**4**	8,86	7,65	3,80	21	0,00	13	12
1	**5**	8,97	7,62	4,14	21	0,00	13	12
2	**5**	8,62	7,84	2,45	21	0,02	13	12
3	**5**	8,59	7,48	3,18	21	0,00	13	12

The results of the independent samples t-test presented in Table 6 provide a detailed overview of the gender-related performance dynamics throughout all phases of motor learning, assessed across five series of measurements, each consisting of three trials. The analysis explored the statistical significance of differences between boys and girls in each individual measurement.

In the initial learning phases (Series 1 and 2), observable differences favored boys (e.g., M1 Series 1: $t = 1.95$, $p = 0.06$), though these differences did not reach statistical significance. This indicates that both genders began the program with relatively comparable motor abilities. Throughout Series 1 and 2, the gender differences remained statistically non-significant, suggesting that sex was not a determining factor in performance during the early learning stages.

Beginning with Series 3, and particularly in the third measurement (M3 Series 3: $t = 2.18$, $p = 0.04$), statistically significant differences in favor of boys began to emerge. These differences became more pronounced in Series 4 and 5, where nearly all measurements indicated statistically significant results (e.g., M1 Series 4: $t = 3.21$, $p = 0.00$; M3 Series 5: $t = 3.16$, $p = 0.00$), with boys consistently outperforming girls.

This trend suggests that over time, boys demonstrated a faster and more efficient improvement in mastering the motor task. The gender gap that became statistically significant in the later stages of the program may be attributed to differences in learning styles, prior motor experience outside school, or higher frequency of physical activity among boys.

Nonetheless, it is important to emphasize that girls also showed notable improvement, confirming the effectiveness of the motor learning program for both genders. However, the tempo and progression dynamics differed, with boys exhibiting greater acceleration in the final phases of training.

CONCLUSION

The results of this study demonstrated the positive effects of the motor learning process on participants in all aspects of mastering a complex motor task—both at the total sample level and within the groups of girls and boys individually. The analysis showed significant improvement in the time required to perform the given task across all measurements, indicating the effectiveness of the motor learning program implemented during the study.

When analyzing the results through the lens of gender, an interesting pattern emerges, suggesting certain differences in the effects of motor learning between boys and girls. Although both groups achieved significant progress, boys outperformed girls in the final measurement. This performance gap may be attributed to the broader and more diverse motor experience that boys often possess, particularly due to their more frequent involvement in extracurricular sports activities. While girls also made notable progress, they did not reach the same level of improvement as boys, which could be due to various factors such as the nature of pre-study physical activities and previous motor experience.

The results of the t-tests indicate statistically significant differences between the initial and final measurements in task execution time, confirming that the motor learning process was effective and led to meaningful improvements in participants' performance. However, the performance difference between boys and girls at the end of the study highlights the need to further explore the factors influencing motor learning in the context of gender and to develop programs that more precisely address the specific needs of both groups.

Future research would benefit from involving a larger sample size and diverse types of activities to gain deeper insights into the causes of gender differences in motor learning effects. It would also be valuable to investigate how previous motor experience may influence progress throughout the learning process and to identify which aspects of motor learning might be better tailored to achieve optimal outcomes for each gender.

REFERENCES

Canli, T., Canli, U., Taskin, C., & Aldhahi, M. I. (2023). Motor coordination in primary school students: The role of age, sex, and physical activity participation in Turkey. *Children, 10*(9), 1524. https://doi.org/10.3390/children10091524

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*(3), 363–406. https://doi.org/10.1037/0033-295X.100.3.363

Ersöz, Y., & Bediz, C. Ş. (2020). Effects of twelve week multi-skills movement programme on motor development in 7-10 years old boys. *Advance*. https://doi.org/10.31124/advance.13625585.v1

Fitts, P. M., & Posner, M. I. (1967). *Human performance*. Brooks/Cole.

Gabbard, C. P. (2018). *Lifelong motor development* (8th ed.). Pearson Education.

Gajević, A., Ivanović, J., & Pržulj, R. (2022). Differences in the physical development of primary school children by gender. *Sport and Health, 17*(1), 125-133. https://doi.org/10.7251/SIZ2201125G

Lezak, M. D., Howieson, D. B., Bigler, E. D., & Tranel, D. (2012). *Neuropsychological assessment* (5th ed.). Oxford University Press.

Magill, R. A., & Anderson, D. (2017). *Motor learning and control: Concepts and applications* (11th ed.). McGraw-Hill Education.

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

Prodić, D., Bijelić, S., Jovanović, S., & Fulurija, D. (2024). The effects of proprioceptive training on the speed of assumption of gymnastic elements in children of primary school age. *Sport and Health, 19*(1), 283–296. https://doi.org/10.7251/SIZ2401283P

Schmidt, R. A., & Lee, T. D. (2014). *Motor control and learning: A behavioral emphasis* (5th ed.). Human Kinetics.

Shea, C. H., & Morgan, P. T. (1979). Contextual interference and motor skill acquisition: Evidence for multiple movements in learning. *Journal of Experimental Psychology: Human Learning and Memory, 5*(2), 179-187.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*(2), 257–285. https://doi.org/10.1207/s15516709cog1202_4

Шврака, Н., (2012) *Методика наставе физичког васпитања*. НУБЛ, Бања Лука.

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