

The Importance of Music in the Development of Executive Functions in 6–7-Year-Old Children

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The aim of this work was to study the differences in the development of executive functions in senior preschool children who are systematically engaged in music and those who are not. The study involved 236 children ($M_{age}=78,17$, $SD_{age}=4,3$), 113 of whom additionally engaged in music at additional education centers. To diagnose the level of development of regulatory functions (inhibition, cognitive flexibility, and working memory) subtests of the neuropsychological diagnostic complex NEPSY-II were used. A comparison of averages using the Mann-Whitney U-criterion revealed that children attending music schools have higher measures of auditory working memory, that is, they are better at remembering and correctly reproducing what has been listened to. They are also better able to restrain their behavioral impulses, depending on the demands of the situation, compared to those who do not additionally study music. Thus, the study demonstrated significant differences in the development of some parameters of regulatory functions in children depending on their involvement in music lessons, which emphasizes the importance of children's creative development for the formation of their cognitive abilities.

Keywords: executive functions; inhibition; cognitive flexibility; working memory; preschool age; children; music lessons.

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Роль занятий музыкой в развитии регуляторных функций у детей 6-7 лет

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Целью данной работы было изучение различий в развитии регуляторных функций у детей старшего дошкольного возраста, которые систематически занимаются музыкой и не занимаются ей. В исследовании приняли участие 236 детей ($M_{age}=78,17$, $SD_{age}=4,3$), 113 из которых занимаются музыкой в центрах дополнительного образования. Для диагностики уровня развития регуляторных функций (торможения, когнитивной гибкости и рабочей памяти) были использованы субтесты нейропсихологического диагностического комплекса NEPSY-II. В результате сравнения средних с помощью U-критерия Манна-Уитни было выявлено, что дети, посещающие музыкальные школы, обладают более высокими показателями слухоречевой рабочей памяти, то есть они лучше запоминают и правильно воспроизводят то, что было прослушано. Также они способны лучше сдерживать свои поведенческие импульсы в зависимости от требований ситуации по сравнению с теми, кто не занимается дополнительно музыкой. Таким образом, проведенное исследование продемонстрировало значимые различия в развитии некоторых параметров регуляторных функций у детей в зависимости от их вовлеченности в занятия музыкой, что подчеркивает важность творческого развития ребенка для формирования его когнитивных способностей.

Ключевые слова: регуляторные функции; торможение; когнитивная гибкость; рабочая память; дошкольный возраст; дети; занятия музыкой.

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Introduction

Regulatory functions refer to general cognitive functions that are necessary for the implementation of purposeful behavior and adaptation to various life conditions [3; 4; 12; 28]. Regulatory functions include components such as inhibition, cognitive flexibility, and working memory, which are most actively developed from preschool to adolescence [22; 23; 31; 39]. Despite the fact that the components of regulatory functions have a long-term development perspective that extends into adulthood, the formation of self-regulation is fastest in early childhood [5; 15; 18]. This is due to the fact that prefrontal areas of the brain, which play an important role in the formation of self-regulation, develop structurally throughout childhood. As noted in a study by J. Zuk et al [41], there is a correlation between a decrease in cortical thickness in various brain regions and an increase in the efficiency of performing various tasks to diagnose regulatory functions in children aged five to ten years. However, the developmental trajectories of individual components of regulatory functions differ [8; 10]. For example, inhibition shows rapid improvement at preschool age, whereas this rate slows down in school-aged children [32; 37]. Like inhibition, working memory develops early in life. However, the ability to hold multiple objects in mind or to mentally work with representations develops more linearly and more slowly than inhibition [9]. Compared to inhibition and working memory, the maturation of cognitive flexibility is the slowest. Task-switching is less developed in preschool children because it relies on inhibition and working memory [32; 36]. While preschoolers do well on simple switching tasks, more complex tasks become available only to older children [13; 15; 39].

As many researchers have noted, regulatory functions are critical predictors of academic success, social adaptation, and well-being [6; 11; 17; 21; 27]. Due to the fact that the development of regulatory function components is important for a successful future, there is great potential in developing educational strategies aimed at developing and strengthening these abilities starting from childhood. According to A. Diamond and K. Lee, the performance of regulatory functions can be improved through specially designed programs [19]. Learning should take into account the interests of children and be aimed not only at practicing specific skills, but also at emotional and social development. Moreover, training should be continuous with gradual complication. One of such activities can be purposeful music lessons in centers of extracurricular education [2].

As many researchers note, learning to play a musical instrument can develop children's regulatory functions, as music lessons rely heavily on various components of regulatory functions [7; 14; 16; 20; 25; 29]. For example, in the study by A. Jaschke and co-authors [25] involved 74 children who were divided into a musical, visual arts and a group without additional lessons. As a result of observing the children for 2.5 years, it was shown that children from the visual arts group performed better on visual-spatial memory tasks compared to the other groups. However, scores on tests of inhibition, planning, and verbal intelligence improved significantly in the music group over time, in contrast to the visual arts group and the group with no additional lessons [25]. In a study by I. Roden et al [29], a group of children in the music group was compared with a science group. The authors concluded that the music group increased auditory working memory over a period of 18 months [29].

Thus, the purpose of this study was to investigate the differences in the regulatory functions of six- to seven-year-old children who are systematically engaged in music and those who are not.

Methods and Organization of the Study

Subtests from the NEPSY-II neuropsychological complex [26] were used to investigate the main components of regulatory functions (working memory, cognitive flexibility, and inhibitory control).

Auditory-verbal working memory. The NEPSY-II "Repetition of sentences" subtest was used. The stimuli included 17 sentences of increasing length and complexity. The child was read one sentence and asked to repeat it immediately after presentation. Each correct repetition of a sentence was scored with 2 points.

Visual working memory. The "Memory for Construction" subtest was used. Stimuli included four pictures of a grid with four to eight colored pictures on it. The child was shown the picture for 10 s and then the picture was removed from view. The child selected pictures from a set of cards and placed them in the grid in the same place as previously shown.

Cognitive Inhibition. The "Inhibition" subtest was used. The subtest consists of two blocks: a series of white and black figures (circles and squares) and a series of arrows pointing in different directions (up and down). Two tasks were performed with each series of pictures: a figure-naming task (in this case, the child simply had to name the figures he saw as quickly as possible), and an inhibition task (in this case, the child had to say the opposite of what he saw).

Physical inhibition. The "Statue" subtest was used, which aims to investigate inhibition and the self-control of bodily movements. In this task, the child was required to stand in a specific pose for 75 s without moving or being distracted by external auditory stimuli. For each 5-second interval, errors were recorded, i.e., movements such as eye opening, shaking, etc.

Cognitive flexibility. The "Variable Sorting" subtest was used. Children were required to sort a series of test cards that depicted a red rabbit and a blue boat. They first sorted 6 cards on one dimension (color) and then 6 cards on another attribute (shape). In the third series, the child had to sort 12 cards according to a more complex rule with an additional factor (if a card had a frame, they had to sort it by color, and if there was no frame, they had to sort it by shape).

Sample. A total of 236 children ($M_{\text{age}}=78.17$, $SD_{\text{age}}=4.3$) participated in the study, including 108 boys and 128 girls. All children participating in the study attended the preparatory group of kindergarten. 113 children practiced music in institutions of extracurricular education (children's music schools and children's art schools) in Moscow and Krasnodar. The children studied in the 1st grade of music school and attended classes from 1 to 3 times a week. The classes consisted of directly learning a musical instrument, singing in a choir, and learning musical literacy. Each child had 2 sessions lasting 20-25 minutes. The order in which tasks were presented in each meeting was the same for all children.

Results

Microsoft Excel 2016 and IBM SPSS Statistics 22 programs were used to process the empirical data. As a result of testing the distribution for normality, it was found that the distribution of the sample is mixed (Kolmogorov-Smirnov test), so to further test the hypotheses non-parametric methods of data processing were applied.

Table 1

Descriptive statistics		
Parameters of regulatory functions	Mean and standard deviation of children	Mean and standard deviation of children

	attending music classes	not attending music classes
Cognitive flexibility	M=20,9; SE=2,7	M=18,9; SE=3,5
Visual working memory	M=85,9; SE=21,5	M=79,9; SE=2,4
Auditory-verbal working memory	M=21,5; SE=4,5	M=19,6; SE=4,3
Inhibition	M=10,9; SE=3,2	
Errors	M=11,2; SE=3,5	
Physical control	M=27; SE=3,2	

As a result of analyzing the descriptive statistics of the indicators of children's regulatory functions, it was demonstrated that the indicators of preschool children attending additional music classes are within the norm relative to the indicators of children not attending additional music classes of the same age (Table 1) [1].

Next, we compared the mean scores of regulatory functions according to the gender of the children.

Table 2

Indicators of Regulatory Functions Differentiated by Gender

	Mann-Whitney U-criterion and significance level	Effect size (rank-biserial coefficient)	Gender	N	M	SD
Cognitive inhibition	U=5289,5 p=0,008	0,2	Male	108	10,3	3,2
			Female	128	11,4	3,1
Physical control	U=4857,5 p=0,001	0,253	Male	108	26,5	3,3
			Female	128	27,6	3,1

As a result, it was demonstrated that girls are better than boys at tasks related to controlling their impulses, both physical and cognitive (Table 2). Girls pay less attention to distractions when performing a set task and are able to restrain their impulses longer.

To analyze the differences in the development of regulatory functions in children attending and not attending additional music classes, the mean was compared using the Mann-Whitney U-criterion.

Table 3

Differences in the Indicators of Regulatory Functions Differentiated by Gender

	Mann-Whitney U-criterion and significance level	Effect size (rank-biserial coefficient)	Attendance of music classes	N	M	SD
Auditory-verbal working memory	U=3041 p<0,0001	0,551	Attend	103	23,7	4,1
			Don't attend	123	19,4	3,9
Physical control	U=4346,5	0,339	Attend	103	26,5	3,4

	p<0,0001		Don't attend	123	27,7	3,1
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It was shown that there were significant differences in measures such as auditory and verbal working memory and physical control (Table 3). Children who attend additional music classes are better at memorization and auditory reproduction tasks, and they also find it easier not to react to external stimuli and to restrain themselves if the situation requires it.

Discussion of the Results

The results of the study revealed significant differences in the development of regulatory functions in children attending and not attending additional music classes. It was demonstrated that those who regularly practiced music had higher scores of auditory-verbal memory and physical inhibitory control. Children who take regular music lessons are better at memorizing and reproducing aurally what they have heard. These findings are consistent with the results of other research studies [7; 24]. In our opinion, this is explained by the fact that music training in specialized institutions is associated with frequent listening and aural reproduction of melodies, as well as the repetition of rhythmic series and musical intervals in solfeggio lessons. Such exercises contribute not only to the learning of musical literacy and the development of musical abilities, but also lead to the improvement of regulatory functions, in particular, working memory [33; 34].

In addition, this work showed that children who regularly attended additional music lessons had higher levels of physical inhibitory control. The findings are consistent with the results of multiple studies demonstrating improved inhibition scores in children who attend music lessons [20; 30]. This may be due to the fact that playing a musical instrument implies concentration of attention on the music piece and control of hand and finger movements. At this time, the child actually has to suppress his or her impulsive behavior to be able to play the instrument for an extended period of time. Music lessons also promote the development of inhibitory control, as children must follow the teacher's instructions and generally reflect the modality of the piece of music while learning.

It should be noted that our study did not reveal significant differences in the level of development of cognitive flexibility in children attending and not attending music classes. In our opinion, this may be due to the fact that the children in our study have been practicing music for no more than two years. At this stage, music schools do not yet require a large number of attention-switching tasks, such as adjusting to partners' parts while playing in an ensemble or reading sheet music while playing two-handed parts simultaneously. In addition, according to some studies [13; 40], cognitive flexibility begins to develop at a later age and becomes most active when the child has already mastered certain skills, while in the process of initial learning this ability is of the least importance, unlike working memory and inhibition.

Additionally, significant gender differences in the development of regulatory functions in children aged 6-7 years were revealed. It was shown that girls have higher scores in such parameters as cognitive inhibition and physical restraint. They are more capable, compared to boys, of performing tasks related to the ability to disengage from stimuli that are not relevant to the current task and to concentrate on what is relevant now. In our opinion, these differences may be related to the peculiarities of the development of brain areas that are activated when solving inhibition tasks [18; 23]. Girls also cope better with tasks involving the need to suppress their physical impulses and hold a stationary body position for a given time. This may be due to the earlier and more frequent involvement of girls in social role-playing games that allow children to play the roles of adults in

various life situations and promote the development of general behavioral regulation by suppressing their impulses and following the rules of behavior typical of those or other situations in which an adult is usually found [35; 38]. However, it should be noted that gender differences in the development of regulatory functions are contradictory and are not always confirmed empirically. This is due to other factors that influence the formation of regulatory functions, in particular, features of upbringing, the child's social environment, his/her physical activity, and others.

As for the limitations of this study, it can be noted that we did not take into account other activities of children (e.g., sports or dance, learning a foreign language), characteristics of the family situation (e.g., listening to music together at home, creative activities, use of digital devices) and other factors that may contribute meaningfully to the results. In addition, the study demonstrates only the existence of group differences, but a longitudinal study that considers development characteristics is needed to determine the full impact of music lessons on children's cognitive development.

Conclusion

Thus, as a result of the conducted research, higher indicators of development of such regulatory functions as inhibitory control and auditory-verbal working memory were revealed in children aged 6-7 years who attend additional music classes, compared to children of the same age who do not attend such classes. Since regulatory functions are one of the predictors of a child's success in later life, the results obtained may indicate the need to develop specialized music teaching programs to create conditions that promote the purposeful formation of regulatory functions in children during the period of their greatest sensitivity.

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