frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 25 March 2024
DOI 10.3389/feduc.2024.1333580

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RECEIVED 05 November 2023
ACCEPTED 12 March 2024
PUBLISHED 25 March 2024

CITATION
Bayanova L, Chichinina E and Aslanova M (2024) The association between music training and executive function in 6–7-year-old children.
Front. Educ. 9:1333580.
doi: 10.3389/feduc.2024.1333580

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The association between music training and executive function in 6–7-year-old children

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Executive function development is especially important in the last year of the preschool period because this period precedes the transition to school. Therefore, it is relevant to study extracurricular activities that can positively impact the development of executive function in 6–7-year-old children. According to earlier research, executive function development might be positively influenced by music training. The current cross-sectional study aimed to explore differences in executive function among 6–7-year-old preschoolers depending on participation in music training. In the current research, children were divided into two groups of 37 participants each: children who received music training for at least half a year and children who did not receive music training. Children in both groups did not participate in dance training because music is also actively used during dance training. Background variables such as participation in extracurricular activities, screen time, family singing activities, maternal education, and family income level did not differ between the groups. The study revealed that the children who received music training had a higher level of motor inhibitory control compared to the children who did not receive music or dance training. This study offers further support for the association between executive function and music training in preschoolers.

KEYWORDS

executive function, inhibitory control, working memory, cognitive flexibility, music training, children

1 Introduction

One of the most important aspects of development in preschool age is executive function (EF), which is domain-general cognitive ability. EF is an umbrella term for the cognitive processes that underpin goal-directed behaviors, cognitive processes, and adaptive behavior in new situations (Diamond, 2013; Friedman and Miyake, 2017). According to the model proposed by Miyake et al. (2000), there are three interrelated EF skills: inhibitory control (cognitive and motor), working memory (verbal and visual), and cognitive flexibility. EF has been shown to influence speech development (Kovyazina et al., 2021; Oshchepkova and Shatskaya, 2023), positive adaptation to school (Blair and Diamond, 2008), academic achievement and performance (Willoughby et al., 2012; Cortés Pascual et al., 2019; Morosanova et al., 2021), imagination (Veraksa et al., 2022), and general well-being in adulthood (Robson et al., 2020; Korneev et al., 2022; Morosanova et al., 2023). Preschool age is the most sensitive age for the development of EF (Garon et al., 2008; Diamond and Lee, 2011). The development of EF in preschool age is influenced by many factors, such as quality of caregiver–child interaction (Valcan et al., 2018), engagement in play (Yogman et al., 2018), screen time (McNeill et al., 2019), physical activity (Bai et al., 2022), family SES (Kellens et al., 2023), and participation in extracurricular activities (Rosas et al., 2019). Music training is one of the possible extracurricular activities that influence EF development in preschoolers (Chen et al., 2022).

Music training – is "group or individual lessons with a teacher, focused on learning how to sing and/or play a musical instrument" (Schellenberg and Lima, 2024). Many researchers argue that music training enhances not only music-related skills in preschool children (Münte et al., 2002), but also plays a major role in the development of personality (Savenkova, 2023), cultural learning (Ķestere, 2017; Klimova, 2023), and aesthetic upbringing (Volkova and Shestovskaya, 2021; Ailamazyan, 2023). Arguing in favor of a far transfer from music training to cognitive functioning remains difficult (Schellenberg and Lima, 2024). The cognitive ability for which an impact of music training makes the most intuitive sense is EF (Schellenberg and Lima, 2024). This is because music training involves a variety of cognitive tasks such as reading, listening, understanding, and performing music, which engage multiple cognitive functions, higher-order perceptual processing, and sensory-motor coordination (Münte et al., 2002). Additionally, music training demands self-control, attention, ability to suppress impulses, and planning and implementation of goal-directed behaviors (Schellenberg and Lima, 2024).

1.1 Music training and EF development in preschool children

According to a number of studies, music training is associated with the development of EF in preschool children (Janus et al., 2016; Jaschke et al., 2018; Frischen et al., 2021; Bayanova et al., 2022; Chen et al., 2022; Degé and Frischen, 2022; Rodriguez-Gomez and Talero-Gutiérrez, 2022; Veraksa et al., 2023). The most positive findings were observed for inhibitory control (Bolduc et al., 2021; Degé et al., 2022; Degé and Frischen, 2022; Rodriguez-Gomez and Talero-Gutiérrez, 2022; Schellenberg and Lima, 2024). The association between music training and working memory (both verbal and visual) has been shown predominantly in studies with school-aged rather than preschool-aged children (Bergman Nutley et al., 2014; Kausel et al., 2020; Nie et al., 2022; Vuust et al., 2022). We found only two studies where music training has been shown to influence the development of cognitive flexibility in preschoolers (Shen et al., 2019; Ilari et al., 2021). More studies show that cognitive flexibility is higher in adult musicians compared to non-musicians (Moradzadeh et al., 2015; Bugos et al., 2019; Hao et al., 2023). However, a large number of studies show no relationship between music training and the development of working memory and cognitive flexibility in preschoolers (Rodriguez-Gomez and Talero-Gutiérrez, 2022; Schellenberg and Lima, 2024). This may be due to the fact that it is inhibitory control that is more actively developed at preschool age (Shanmugan and Satterthwaite, 2016).

The notion of music training is broad, considering many different types of training simultaneously: instrumental and non-instrumental, individual and group, with different lessons duration, with different lessons frequency (Schellenberg and Lima, 2024). Undefined notion of music training makes it difficult to be precise about the mechanisms of association between music training and EF (Schellenberg and Lima, 2024). But it is possible to explain the benefit of music training for the development of EF in general.

There are several explanations for why music training benefits EF development in preschoolers. The first explanation is that music training affects the brain structures that are the foundation of EF. There are music-related anatomical differences between musicians and non-musicians in brain regions engaged in immediate sensorimotor demands of music-making (auditory and sensorimotor areas), and also those regions that are not (frontal regions, multimodal integration regions, corpus callosum) (Habibi et al., 2017). Music-making often requires sensory-motor involvement, thereby supporting EF development (Diamond and Lee, 2011). The second explanation is that music training promotes emotional development and harmonization of the emotional state, which, in turn, is important for the development of EF (Ferrier et al., 2014). Music training has been shown to influence children's socio-emotional well-being (Dumont et al., 2017; Blasco-Magraner et al., 2021; Schellenberg and Lima, 2024). Listening to music is in itself beneficial to a child's emotional state (Zatorre and Salimpoor, 2013). Listening to harmonious melodies has a soothing and relaxing effect on children, reducing aggression and stress levels (Choi et al., 2010). Neurobiological evidence indicates a link between objective stimulation indices and subjective feelings of pleasure that music induces (Zatorre and Salimpoor, 2013). Numerous studies show that listening to music changes heart rate, skin temperature and conductance, respiration, and hormone secretion (Blasco-Magraner et al., 2021). Playing a musical instrument or singing can also be a joyful activity because of communication with a peers and teacher during music lessons. This activity gives a child a feeling of social belonging and acceptance, which is crucial for successful EF training (Diamond and Lee, 2011). Also, successful EF training depends upon engaging the child's interest (Diamond and Lee, 2011), and music lessons are often engaging for children. The third explanation involves the fact that music is an important part of culture. Music training contributes to the child's cultural and aesthetic development (Ailamazyan, 2023), which is an important factor in the cognitive development of the child (Volkova and Shestovskaya, 2021). In the process of musical training, the child acquires music as a "cultural tool" (Vygotsky, 1983). This means that a child learns to understand the semantic content of a musical work (Ailamazyan, 2023), masters the cultural aspects, and thereby also develops EF (Vygotsky, 1978).

It should be noted that not only music training, but also family singing activities (when child listens, how the caregiver sings songs for the child) are assumed to be associated with EF (Williams et al., 2015; Hughes and Devine, 2019). It has been shown that the frequency of family singing activities when children were 2–3 years old was associated with the children's progress in vocabulary, numeracy, attentional and emotional regulation, and prosocial skills at 4–5 years (Williams et al., 2015). Family singing activities may function as a "cultural tool" (Vygotsky, 1983) because during these activities, the parent builds the child's understanding of cultural conventions. Moreover, family singing activities might be a situation when caregiver and child engage in "mutually responsive interactions requiring joint attention, active cooperation, turn-taking, and immediate feedback," thus supporting EF development (Williams et al., 2015).

Despite the large amount of research that shows an association between music training and EF development, it remains unclear whether music training promotes the development of EF or whether children with more developed EF are more likely to take music lessons (Román-Caballero et al., 2020; Schellenberg and Lima, 2024). Music training requires discipline and the ability to concentrate, as well as other personality traits associated with cognitive improvements (Román-Caballero et al., 2020). In other words, it can be assumed that preexisting differences in personality and cognitive ability determine who takes music lessons and for how long (Román-Caballero et al., 2020; Schellenberg and Lima, 2024). It could also be hypothesized that children with higher musical abilities are more likely to continue studying music than children with lower musical abilities (Román-Caballero et al., 2020), since musical abilities (modal perception, pitch perception, and sense of rhythm) have been shown to correlate with EF (Dolgikh et al., 2022). Also parenting strategies and SES of caregivers who decided that their child should study music may be more favorable to the development of EF than those of caregivers who did not (Román-Caballero et al., 2020). Although many studies have noted the association between music training and EF, when taking in consideration background variables other than music training, some authors have shown that differences in family lifestyle and SES may contribute to the child's participation in music training (Criscuolo et al., 2019; Allen et al., 2022). In turn, this can ultimately explain the differences in EF performance in children. Based on all of the above, it is relevant to continue research on this topic controlling background variables.

1.2 Current study

Based on previous studies, we assumed that musical training is associated with better EF in preschoolers. To test this hypothesis, we assessed EF in children who had received music training for at least 6 months and those who did not receive music training. We controlled for background variables such as SES, screen time, and participation in extracurricular activities. Consistent with prior research, we hypothesized that children with at least 6 months of music training would demonstrate higher level of inhibitory control compared to those without music training (Bolduc et al., 2021; Degé and Frischen, 2022; Rodriguez-Gomez and Talero-Gutiérrez, 2022; Schellenberg and Lima, 2024).

Differently from experimental studies, the current cross-sectional study mirrors real-life scenarios of preschoolers engaged in music training. Unlike controlled experiments where children adhere strictly to structured music lessons conducted by specially trained teachers, real-life participation may involve occasionally skipped lessons, different types of music training, and different teachers (Degé et al., 2022). Furthermore, in reality, children often participate in multiple extracurricular activities, not only music training (Allen et al., 2022). Thus, in this research, children who participated in different extracurricular activities additionally to music training were included. But children who participated in dance training were excluded from the study sample. Because dance training, like music training, involves listening to music, analyzing music, and working with rhythm (Shen et al., 2020). Throughout the whole both music and dance lesson, children are guided by pace and rhythmical structure, the tune, and the mood of the music. By excluding children who participated in dance training, it was possible to compare those children who received music training and those who participated in extracurricular activities not related to music.

In the current research, all children had participated in music training and other extracurricular activities for at least 6 months. This timeframe was selected based on studies indicated that short-term music training may not impact cognitive development (Hennessy et al., 2019; Román-Caballero et al., 2020). The current study sample comprised children aged 6–7 years, in their final year of kindergarten, a critical period for EF development (Diamond and Lee, 2011). The level of EF at this period influences children's academic achievements and successful transition to school (Blair and Diamond, 2008).

2 Materials and methods

2.1 Measures

2.1.1 The questionnaire for caregivers about extracurricular activities, screen time and sociodemographic data

To investigate the preschoolers' involvement in extracurricular activities, a questionnaire for caregivers was used. This questionnaire comprised four sections: one on extracurricular activities, including music training; another on family singing activities; a section on screen time; and one focusing on sociodemographic information.

In the section regarding the child's extracurricular activities, caregivers were asked to indicate which activities their child participated in, such as music, drawing, dancing, sports, math and literacy, foreign language, chess, or any other training specified by caregivers. For each extracurricular activity, caregivers were asked to specify the type of extracurricular activity attended (e.g., type of sports – gymnastics, swimming, boxing, etc.), frequency of lessons per week, duration of one lesson in minutes, and the duration of participation in years. Regarding family singing, caregivers were asked to indicate how many days per week they, or other adult family members, sang with the child, using a scale from 0 to 7. In the section on screen time, caregivers were asked to specify the duration (in hours and minutes) that the child typically spent on electronic devices separately for weekdays and weekends. Lastly, in the sociodemographic section, caregivers were asked to select the appropriate option to describe family income level ("below average," "average," or "above average") and the level of maternal education ("school education," "secondary vocational education," "bachelor's ", "master's," "Ph.D."), with the option to provide an alternative response if necessary.

2.1.2 EF assessment

Verbal working memory was assessed using the NEPSY-II subtest Sentence Repetition (Korkman et al., 2007). The stimuli included 17 sentences that increased in length and complexity. The child was to read one sentence and then immediately asked to repeat it. Each correct repetition of the sentence was scored 2 points. If the child made one or two mistakes, the response was scored 1; if there were many more mistaken attempts, the sentence was scored 0 points. The procedure was stopped when the child received 0 points three times consecutively. Accuracy scores were calculated (range was 0 to 34).

Visual working memory was assessed using the NEPSY-II subtest Memory for Designs (Korkman et al., 2007). It was designed to assess spatial working memory for novel visual material for children ages 3 to 16 years. The stimuli included four pictures of a grid with four to eight colored designs on it. The child was shown a picture for 10 s, and then it was removed from view. The child was asked to select the designs from a set of cards and to place the cards on a grid at the same location as previously shown. For each trial, points were scored separately for four parameters: (1) the Content score to reflect the child's ability to recall which designs were shown for each trial; (2) the Spatial score to reflect the child's ability to recall where a design was shown for the trial; (3) the Bonus score to reflect the child's ability to recall which designs were in which locations for that trial; and (4) the Total score for each trial was the sum of the Content, Spatial, and Bonus scores. The final results of this subtest were the sum of each kind of score (range was 0–120).

Cognitive inhibitory control was assessed using the NEPSY-II subtest Inhibition (Korkman et al., 2007). The subtest consisted of two blocks: a series of white and black figures (circles and squares) and a series of arrows with different directions (up and down). Two tasks were posed using a series of pictures: (1) naming the figures (in this case, a child simply had to name the figures that he or she saw as quickly as possible), and (2) inhibition (in this case, the child was supposed to say the opposite of what he or she saw; for example, if child saw a square, he or she had to say "circle," etc.). Three indicators were recorded for each task: (1) the number of self-corrected errors that occurred when the child provided an incorrect response or skipped a shape; (2) the number of uncorrected errors that occurred when the child did not correct his or her mistakes; and (3) the completion time. These three indicators were translated into a combined score using tables from the NEPSY-II manual (range was 0–20).

Motor inhibitory control was assessed using the NEPSY-II subtest Statue (Korkman et al., 2007). This assessment was aimed at measuring inhibition and self-control of bodily movements. In this task, a child was asked to stand motionless in a certain position for 75 s, without being distracted by external sound stimuli. For each 5-s interval, three types of mistakes made were recorded (i.e., movements, opening of the eyes, and vocalizations). The child received points from 0 to 2 for the successful completion of the task: 2 points if he or she did not make mistakes during the 5-s interval; 1 point if he or she made one mistake; 0 points if the child made 2 or more mistakes (range was 0–30).

Cognitive flexibility was assessed using Dimensional Change Card Sort (Zelazo, 2006). Children were required to sort a series of bivalent test cards (with pictures of red rabbits and blue boats), the first 6 cards according to one dimension (color), and the second 6 cards according to another (shape). On the third trail, a child has to sort the 12 cards according to a more complicated rule which features an additional factor (if the card has a frame, then he or she must sort it by color, and if there is no frame, then he or she has to sort it by shape). For each correctly sorted card, a child was awarded one point. At the end the number of points for each try was calculated (range was 0–24).

2.2 Procedure

The EF assessment was carried out individually with each child, in a quiet room familiar to children in their kindergarten. The assessment was carried out by specially trained testers. The assessment was carried out over two 20-min meetings, with a few days break in between. The tasks were divided into two meetings to avoid overwhelming the children during the assessment. During the first meeting, the children performed tasks aimed at cognitive flexibility and inhibitory control assessment, and during the second one, the tests of working memory assessment. The tasks were given to all children in the same order and with the same instructions. During the assessments a child was allowed to stop the procedure if for some reason they he or she did not feel like continuing. The assessment was carried out with each child in the morning, between 8:00 am and 11:00 am.

In addition to the children's assessment, caregivers completed a questionnaire. There were 757 children who participated in the EF assessment and whose caregivers completed the questionnaire. Based on the data from the questionnaire for caregivers, children who participated in any extracurricular activity for less than 6 months were excluded from the sample. Then children who received music training for at least 6 months and did not receive dance lessons were selected. There were 37 such children (group with music training). Each child in the group with music training was matched with a peer of the same age, sex, SES, and number, frequency, and duration of other extracurricular activities but without music or dance training (group with no music or dance training). For example, for a child in the group with music training who participated in music training (e.g., 2 years, 45 min twice a week) and sports training (e.g., 1 year, 60 min once a week), a child of the same age, sex, and SES who also participated in sports training (also 1 year, 60 min once a week) and one other extracurricular activity (e.g., drawing or chess, also 2 years, 45 min twice a week) was selected. Therefore, 74 participants were included in this research (37 children in each group).

This study and its consent procedures were approved by the Ethics Committee of the Lomonosov Moscow State University (approval no: 2023/31). All caregivers gave their written informed consent to participate in the study of their child.

2.3 Participants

The sample consisted of 74 typically developing preschool children aged 6–7 years (M = 79.4 months, SD = 4.79). There were two groups of 37 children each (17 girls in each group). The first group consisted of children who received music training for at least 6 months and did not ever receive dance training (group with music training). The second group consisted of children who did not ever receive music or dance training (group with no music or dance training).

All children participated in general kindergarten program aimed at cognitive, speech, physical, artistic-aesthetic, and socio-communicative development (Veraksa et al., 2019). There were sports, music, dance, art, math and literacy lessons in the kindergarten program every week. In both groups, children participated in 2–7 types of extracurricular activities additionally to general kindergarten program. Namely, in the group with music training, 100% of children participated in music training, 54% – sports, 46% – literacy and math, 22% – foreign language, 22% – drawing, 16% – chess lessons, and 11% – other lessons (e.g., floristics, acting courses, modelling agency, robotics, LEGO learning). In the group with no music or dance training, 59% of children participated in sports, 59% – literacy and math, 35% – foreign language, 35% – drawing, 32% – chess lessons, and 40% – other lessons. In both groups, most of children took extracurricular lessons of one type two times a week (66%), 20% of the children took lessons of one type three times a week, 12% – once a week, 2% – four or more times a week. In both groups, 40% of children had lessons of any type that lasted 60 min, 25% – 45 min, 25% – 30 min, 10% – 90 min or more. In both groups, 50% of children had taken lessons for 1–2 years, 30% for 0.5–0.1 year, 20% for more than 2 years.

It both groups, 80% of the mothers had higher education, 20% had secondary vocational education. In both groups, 86% of the families had an average level of income, 14% had a level of income above average.

3 Results

3.1 Comparing background variables between the group with music training and the group with no music or dance training

Background variables such as sex, age, SES and frequency and duration of extracurricular activities were controlled when selecting children into the group with no music or dance training. The Chi-Squared test was conducted to investigate whether the groups differed in the types of extracurricular activities attended by the children. The results showed that there were no differences between the groups in the percentage of children who took sports, math and literacy, drawing, foreign language, and chess training (see Table 1). But in the group with music training, significantly fewer children attended extracurricular activities marked by caregivers as "other" (11% of the children in the group with music training and 40% in the group with no music or dance training, $\chi^2 = 9.02$, $p = 0.003$). So, the groups did not differ in background variables such as sex, age, SES, and participation in extracurricular activities except extracurricular activities marked as "other" (for example, floristics, acting courses, modelling agency, robotics, LEGO learning). The next step was to explore whether the groups differed in other background variables, such as family singing activities and screen time.

Descriptive statistics for all the study variables are presented in Table 2. According to the Kolmogorov–Smirnov test, not all parameters were distributed normally; that is why the nonparametric Mann–Whitney *U* test for independent samples was used onwards.

The Mann–Whitney *U* test was conducted to explore whether the frequency of family singing activities differed between the group with music training and the group with no music or dance training. The results indicated that there were no significant differences between the groups in the frequency of family singing activities ($M = 2.81$ times per week, $SD = 2.37$ in the group with music training; $M = 2.24$, $SD = 2.15$ in the group with no music or dance training; $U = 592.500$, $p = 0.312$).

The Mann–Whitney U test was conducted to explore whether the screen time differed between the groups. There were no significant differences between the groups in the screen time: $M = 188$ min per day, $SD = 120$ in the group with music training, and $M = 178$, $SD = 129$ in the group with no music or dance training ($U = 600.000$, $p = 0.596$).

TABLE 1 Differences in attended types of extracurricular activities between the group with music training and the group with no music or dance training.

	Group with music training	Group with no music or dance training	χ^2 test	*p*
Sports	54%	59%	0.220	0.639
Literacy and math	46%	59%	1.36	0.244
Foreign language	22%	35%	1.66	0.197
Drawing	22%	35%	1.66	0.197
Chess	16%	32%	2.64	0.104
Other lessons	11%	40%	9.02	0.003

3.2 Comparing EF between the group with music training and the group with no music or dance training

The Mann–Whitney *U* test was conducted to investigate whether EF differed by receiving music training for at least half a year. The results shown that children in the group with music training had significantly higher motor inhibitory control level than children in the group with no music or dance training ($M = 28.29$, $SD = 2.83$ in the group with music training, $M = 26.72$, $SD = 3.47$ in the group with no music or dance training; $U = 302.500$, $p = 0.025$). There were no significant differences between the groups in other EF skills (see Table 2).

4 Discussion

The current study investigated the difference in EF between 6- and 7-year-old children who received music training for at least 6 months and children who did not receive music or dance training. The groups were similar in terms of maternal education, family income level, screen time, the frequency of family singing activities, and the number, frequency, and duration of extracurricular activities child attended. It was shown that children in the group with music training had a higher motor inhibitory control level. The result of this study is congruent with the findings from the experiment by Degé et al. (2022). In that experiment, 6-year-old preschoolers were randomly assigned to the two training programs: music and sports (20 min 3 times a week, 14 weeks). The musically trained group, but not the sports trained, significantly better performed the NEPSY-II subtest Statue in post-test comparing to pre-test. The authors speculated that musically trained children performed Statue better because music training more than sports learnt children to be less easily distracted (Degé et al., 2022). Also, the result of the current study is consistent with the results of many studies showing a beneficial effect of music training on inhibitory control in general (Chen et al., 2022; Degé and Frischen, 2022; Rodriguez-Gomez and Talero-Gutiérrez, 2022).

The results of the study showed that children in the group with music training had a higher level of motor inhibitory control than children in the group with no music or dance training. On the basis of this result, it can be assumed that music training enhances motor inhibitory control. When a child plays a musical instrument, he or she needs to control his or her fine movements very carefully. Learning to play a musical instrument involves learning many fine motor skills. And fine motor skills are associated with motor inhibitory control (Malambo et al., 2022). When playing such instruments as piano or

TABLE 2 Descriptive statistics and comparison of the group with music training and the group with no music or dance training.

	Group with music training, *n* = 37		Group with no music or dance training, *n* = 37		Mann–Whitney Test	
	M	*SD*	*M*	*SD*	*U*	*p*
Caregivers sing songs with the child, days per week	2.81	2.37	2.24	2.15	592.500	0.312
Screen time, minutes per day	188	120	178	129	600.000	0.596
Verbal working memory (“Sentence Repetition,” total score)	19.82	5.64	21.50	4.39	464.000	0.163
Visual working memory (“Memory for Designs,” total score)	85.16	26.95	93.31	24.50	479.500	0.308
Cognitive inhibitory control (“Inhibition,” combined score)	12.23	3.42	11.96	2.70	415.000	0.777
Motor inhibitory control (“Statue,” total score)	28.29	2.83	26.72	3.47	302.500	0.025
Cognitive flexibility (“Dimensional Change Card Sort,” total score)	21.25	2.31	21.56	2.58	482.000	0.420

drumkit, a child needs to follow both hand and foot movements at the same time (Degé et al., 2022). Also, when learning to sing, a child needs to control body movements such as articulation and breathing. Additionally, both learning to play a musical instrument and learning to sing require staying or sitting at the same place for the duration of the lesson. In the Statue subtest which was used to assess motor inhibitory control, a child is also required to stay in a certain position. In other words, motor inhibitory control is required in a similar way during music training and during Statue performance. To sum up, listening to and performing music during music training may actively engage motor inhibitory control (Chen et al., 2022).

In the current study, there were no differences between the group with music training and the group with no music or dance training in the percentage of children who took sports, literacy and math lessons, foreign language lessons, drawing lessons, and chess lessons. However, the groups differed in the percent of children who took lessons marked as “other lessons.” This category included lessons such as floristics, acting, modelling, robotics, and LEGO learning. Perhaps the difference between the groups in the level of motor inhibitory control was related to the features of music training versus the extracurricular activities marked “other lessons.” First, all of these “other lessons” (floristics, acting courses, modelling agency, robotics, and LEGO learning), compared to music training, do not involve practicing at home. Usually, music training in a music school requires playing scales and music exercises at home every day, as well as learning by heart and practicing pieces on a musical instrument. Music training, in conjunction with music homework, makes music practice almost day-to-day. Such systematic music practice enhances motor inhibitory control (Kosokabe et al., 2021). Second, all of these “other lessons” do not imply relation of body movements and rhythm. In music training, a child needs to subordinate his or her body movements to the rhythm of the melody, which must be observed when performing a piece of music. It has been shown that tasks related to rhythm develop motor inhibitory control (Frischen et al., 2019). Third, music training more often involves discipline. However, this depends on the personality of the teacher, and this parameter is unknown in this study. In addition, the degree of discipline expected from the child depends on whether the child is enrolled in a music school or just goes to less formal music training. These data are also not available in the current study. Thus, the higher level of motor inhibitory control in the group with music training can be explained both by the content of music training (the role of rhythm, the role of fine motor skills and body movements control, coordination of hand and foot movements) and the organization of music lessons (homework, the need to stay in place during the lesson, discipline).

Vygotsky’s idea of the “cultural tool” can be invoked to explain how music training contributes to the development of motor inhibitory control (Vygotsky, 1983). If a child simply listens to music on his or her own, music serves only as a source of pleasure or entertainment. However, if a child is engaged in music training with an adult, then music acts as a “cultural tool” for regulating his or her own behavior. In the process of music training with an adult, the assimilation of cultural sign systems takes place (Vygotsky, 1983). By mastering a musical instrument or singing, a child also masters his or her own mental functions. This includes mastering the abilities of one’s own body and acquiring cultural forms of behavior and movement control, and thus motor inhibitory control.

Based on the result that children in the group with music training had a higher level of motor inhibitory control than children in the group with no music or dance training, it can also be assumed that children in the group with music training had better motor inhibitory control when started music training (Schellenberg and Lima, 2024). If a child is not yet prepared to control body movements at a sufficient level, his or her caregivers more often find other extracurricular activities for such child, but not music training. Therefore, the current study did not show the causality of the association between music training and motor inhibitory control.

The results of the study showed that the groups did not differ in cognitive inhibitory control, working memory, and cognitive flexibility. In the current study, the two groups were similar in terms of maternal education, family income level, screen time, and frequency of family singing activities. Probably these features of family lifestyle, which were similar in both groups, mediate the development of cognitive inhibitory control, working memory and cognitive flexibility more than music training does. Furthermore, the two groups were similar in terms of the number, frequency, and duration of extracurricular activities that the child attended. In the current study, children in both groups participated in various extracurricular activities – sports, drawing, math and literacy, etc. It can be assumed that, in terms of influence on cognitive inhibitory control, working memory, and cognitive flexibility, different types of extracurricular activities are not less effective at this age than music training. The absence of differences in EF skills except motor inhibitory control between the groups can also be explained by the fact that all children attended a preschool kindergarten education program (Veraksa et al., 2019). In this program, educational, art, and sports lessons take up several hours a day, and the rest of the time in kindergarten children spend on play, which also contributes to the development of EF (Yogman et al., 2018; Rosas et al., 2019).

The main limitation of this study is that the level of the children's EF at the time they started to take music lessons was unknown. Therefore, it can be assumed that children who received music training initially had higher motor inhibitory control than children who did not. The next limitation is that all children were from middle or high SES families. But children from low SES families may benefit from music training more (Diamond and Ling, 2016). The limitations and results of this cross-sectional study allow one to draw recommendations for further research design. Further studies should include different groups of participants: typically developing children and children with special needs; children from families with low, medium, and high SES; children with initially low, medium, and high EF level. Also, it is important to monitor as much as possible variables that may affect EF development. In addition to the background variables controlled in this study, it is worth controlling intelligence and child's attitude toward music training. To conclude, this study highlights an association between musical training and motor inhibitory control in preschool children. The nature of this association will be further explored.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The study was approved by the Ethics Committee of the Lomonosov Moscow State University (approval no: 2023/31). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

LB: Conceptualization, Methodology, Project administration, Resources, Supervision, Validation, Writing – review & editing. EC: Conceptualization, Formal analysis, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. MA: Data curation, Software, Supervision, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research, authorship, and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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