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Article

A comparative study on the long-term effects of music and sports activities on cognitive skills of children

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SUMMARY
Learning music and engaging in sports have both been shown to develop cognitive skills in young children. With the rising incidence of learning disorders, such as attention deficit hyperactivity disorder (ADHD) and dyslexia, in young children, understanding the impact of music and sports on cognitive skills in the developing brain is imperative. Our study aims to shed light on this topic by comparing three groups of children – those who learn music, those who practice sports, and those who don't participate in either activity. We hypothesized a positive correlation between music and nonverbal cognitive skills and similarly between sports and verbal cognitive skills. Our dataset comprises the scores of Wechsler Abbreviated Scale of Intelligence (WASI) to measure overall cognitive, nonverbal, and verbal elements of working memory. Analysis of this dataset reveals that students who participated in music performed better in tests assessing nonverbal intelligence, while children engaged in sports activities performed better in tests assessing verbal intelligence. Our results suggest that children who participate in music may show increased activity of the parietal cortex, which is responsible for nonverbal tasks, while children who participate in sports may show increased activity of the prefrontal cortex, which is responsible for verbal tasks. Collectively, our results recommend music learning to improve math and mental manipulations for children with nonverbal disorders. Also, our results recommend sports participation to improve reading comprehension for children with verbal disorders. Future research with increased sample size is proposed for a better estimation of the WASI tests scores.

INTRODUCTION
An essential childhood developmental milestone is the achievement of verbal comprehension that involves the ability to understand instructions and communicate through words (1). While this crystallized intelligence, which is developed by applying previously learned facts and skills, is essential in the early years of a child, growth of fluid intelligence to nurture nonverbal skills like creativity, pattern recognition, and imagination is equally important in young children for their problem-solving abilities. Crystallized intelligence involves learned abilities accumulated based on prior experience and knowledge, while fluid intelligence *denotes one's ability to* reason and solve abstract problems. Crystallized intelligence tends to be retained, while fluid intelligence tends to decline with age (2). The early years of childhood are the prime time to focus on the development of their working memory, a form of short-term memory that facilitates cognitive processing by holding data for a brief period of around 10-15 seconds (3). Research claims that the development of working memory happens from 4 to 15 years of age (4).

The Measurement of Intelligence Quotient (IQ) in young children can help provide important information about their cognitive development and can help identify if a child is gifted or has dyslexia (5). However, there are limitations with such IQ tests. For example, young children may not demonstrate their full potential at the time of being tested. They could be unwell, shy, tired, anxious, or even fail to cooperate with a stranger (6,7).

One of the most common tests to measure the IQ of children is the Wechsler Abbreviated Scale of Intelligence (WASI) that estimates a student's general intellectual ability by measuring verbal, nonverbal, and general cognitive skills. The Verbal Intelligence Index (VCI) of WASI measures crystallized intelligence of children, the Perception Reasoning Index (PRI) of WASI measures nonverbal fluid abilities and visual motor/coordination skills, and the Full-Scale IQ (FSIQ-4) score is derived from the combination of the VCI and PRI scores (8). Brain imaging studies reveal that the prefrontal cortex is involved in working memory (9). An increased gray matter volume in the prefrontal cortex has also been observed to predict better reading comprehension (10). Moreover, neurophysiological studies have shown that the prefrontal cortex could dynamically allocate more or less neuronal activity to balance the load from two concurrent tasks (11). Neuroimaging has also shown that the parietal cortex region processes time, space, numbers, and other attributes related to nonverbal cognitive skills (12).

The harmonious relationship between music and emotion has been extensively studied, establishing a link between music and specific regions in brain (13,14). For example, high intensity positive emotions induced significant increases in the left striatum, whereas low intensity positive emotion preferentially activated the right striatum (13). Additionally, higher levels of psychological well-being have been observed to be associated with better cognitive function (15). For instance, cognitive skills such as numerical ability, cognitive speed, and attention showed improvement when patients were treated for depressive symptoms. Thus, a positive effect of music on emotion can be deduced to foster these skills. Scientists back up our conclusion through their finding that music training facilitates neuroplasticity in children, particularly with developmental disorders (16). Also, research has shown evidence supporting that musical training improves spatial–

JOURNAL OF
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temporal reasoning, while there exists a positive correlation between spatial-temporal activation and improved math skills for children (17,18).

Another area of focus in building cognitive skills for children is engaging them in sports activities. In particular, children who participate in organized sports have been shown to have enhanced executive function (19). A study on classroom-based physical activity revealed positive effects on attention and reading comprehension (20). Similarly, research shows that physical activity enhances cognitive skills including verbal functions in children (21,22).

Thus, the results of various scientific research helped us to hypothesize that music learning would aid children in improving nonverbal skills like math while sports activities would help children to get better at comprehending verbal instructions. Our research established a common baseline amongst the two experimental groups (music- and sports-learning children) as well as for the control group (children who do not engage in either of these activities) and analyzed the rate of verbal and nonverbal cognitive growth over a period of five years during the early school years of children. The results obtained from our research provide valuable inputs for parents in choosing an extracurricular activity with a targeted skill for their children based on their need, while setting up their expectations with the chosen activity over a period of time. In summary, our results suggest young children to learn music in order to improve their nonverbal cognitive skills and to engage in sports activities in order to improve their verbal cognitive skills.

RESULTS

Our study involved the measurement of IQ for three different groups of children, with fifteen children in each group, to find if one set of children would perform better than the other groups in either verbal or non-verbal tests. We used the WASI-II test suite that scores a child's ability to register, recall, and manipulate information based on visual and auditory discrimination skills. It consists of four subtests.

As part of this test suite, a set of four tests were performed for each child once every year for five years. In the Vocabulary test, children were shown a picture of a design and were asked to define a series of words presented to them. This test was intended to measure an individual's verbal knowledge, verbal concept formation, and expressive language skills. In the Block Design test, children were shown a picture of a design and were asked to recreate a set of geometric blocks. This subtest measures an individual's spatial visualization and perceptual organization skills. In the Matrix Reasoning test, children were presented with a group of four or six images and were asked to choose a missing piece to complete a visual pattern. This test was intended to measure an individual's nonverbal abstract reasoning, problem-solving, and perceptual organization skills. In the Similarities test, children were presented with two words that represent common objects and were asked to describe the similarities between those objects. This test was intended to measure abstract reasoning, verbal concept formation, and verbal comprehension skills.

The FSIQ-4 score is based on all the four subtests while the PRI score is based on the Block Design and the Matrix Reasoning subtests, and the VCI score is based on the Vocabulary and the Similarities tests.

The WASI FSIQ-4 scores showed a mean growth of 57.19 points for the music group, 50.44 points for the sports group, and 45.58 points for the control group (**Figure 1**). All the plots show an overall positive slope, indicative of expected normal intellectual growth in childhood. However, children who participated in music showed a higher FSIQ-4 score compared to children who participated in sports or the control group, implying a greater correlation of participation in music-learning with overall cognitive ability.

The PRI scores showed a mean growth of 104.62 points for the music group, 97.28 points for the sports group, and 101.63 points for the control group (**Figure 2**). All the plots

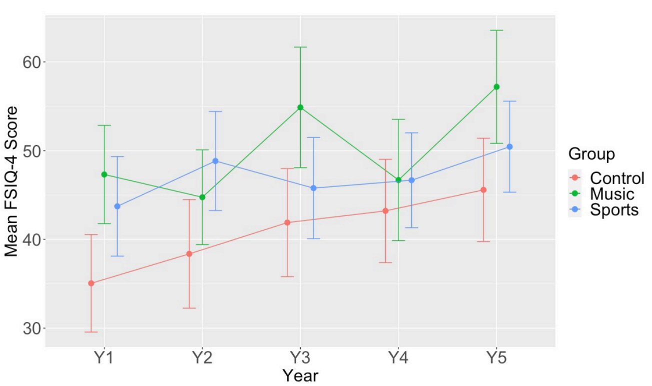

Figure 1: Line plot of FSIQ-4 score vs. Year. The dots represent the mean scores for each group of children for each year. The error bars represent the standard error of the mean scores. Three different groups of elementary school children were tested annually for verbal and nonverbal cognitive intelligence. After five years of study, the music learning children had a mean FSIQ-4 score of 57.19 with a standard error of 6.37, the children engaged in sports activities had a mean FSIQ-4 score of 50.44 with a standard error of 5.13, and the control group of children had a mean FSIQ-4 score of 45.58 with a standard error of 5.82. On average, music-learning children outperformed the other two groups in the FSIQ-4 tests.

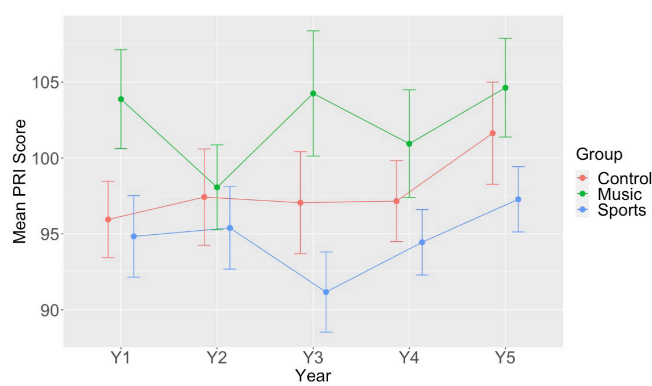

Figure 2: Line plot of PRI score vs. Year. The dots represent the mean scores for each group of children for each year. The error bars represent the standard error of the mean scores. Three different groups of elementary school children were tested annually for nonverbal cognitive intelligence. After five years of study, the music learning children had a mean PRI score of 104.62 with a standard error of 3.25, the children engaged in sports activities had a mean PRI score of 97.28 with a standard error of 2.15, and the control group of children had a mean PRI score of 101.63 with a standard error of 3.63. On average, music-learning children consistently outperformed the other two groups in the Perceptual Reasoning test.

JOURNAL OF
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show an overall positive slope, indicative of expected normal intellectual growth in childhood. However, children who participated in music showed a higher PRI score compared to children who participated in sports or the control group, highlighting a stronger link between music and nonverbal memory relative to the sports group.

The VCI scores showed a mean growth of 100.94 points for the music group, 102.56 points for the sports group, and 95.74 points for the control group (**Figure 3**). All the plots show an overall positive slope, indicative of expected normal intellectual growth in childhood. However, children who participated in sports showed a higher VCI score compared to children who participated in music or the control group, emphasizing superior association of sports with verbal memory when compared to the other two groups.

Our observations on both the PRI and VCI scores align with our analytical model (**Figure 4**). This model shows a positive correlation between music and nonverbal skills due to a possible activation of parietal cortex region in the brain. It also shows a positive correlation between sports and verbal skills due to a possible activation of the prefrontal cortex region of the brain.

In addition, we plotted a scatter plot of FSIQ-4 scores that showed a low coefficient of determination (R^2) in the range of 0.01 to 0.02, pointing significant variation among the dataset (**Figure 5**).

Also, it should be noted that the baseline tests showed similar development amongst all the children in all the groups for both verbal and nonverbal skills. However, these tests were not exactly identical to the four subtests done over the five-year longitudinal period of study. Hence data for Year 0 were not plotted in our graphs.

DISCUSSION

Both music and sports are scientifically proven methods for improving cognitive skills of young children (23). Our research aims to understand the distinction between their effects

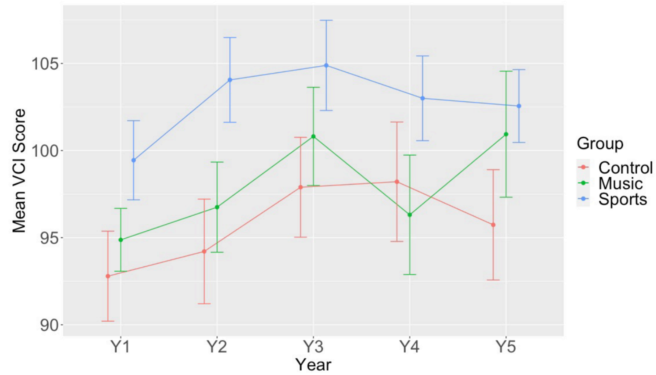

Figure 3: Line plot of VCI score vs. Year. The dots represent the mean scores for each group of children for each year. The error bars represent the standard error of the mean scores. Three different groups of elementary school children were tested annually for verbal cognitive intelligence. After five years of study, the music learning children had a mean VCI score of 100.94 with a standard error of 3.62, the children engaged in sports activities had a mean VCI score of 102.56 with a standard error of 2.09, and the control group of children had a mean VCI score of 95.74 with a standard error of 3.17. On average, sports-learning children consistently outperformed the other two groups in the Verbal Comprehension test.

on crystallized intelligence and fluid intelligence. While we recognize that there could be other factors such as the child's motivation and skill in performing an activity, along with how the activity fits in the family's lifestyle, our research is based on the test score data collected during the study and assumes the experimental data to be the key factor in evaluating a child's cognitive development.

Repeated stimuli and patterning are known to have a strong correlation with visual memory (24,25). Research also shows that repeated stimuli reduces the load on neural activity, thereby improving its efficiency (26). Repetitive musical note memorization and tonal and rhythmic patterns are prominent with music-learning, particularly when children

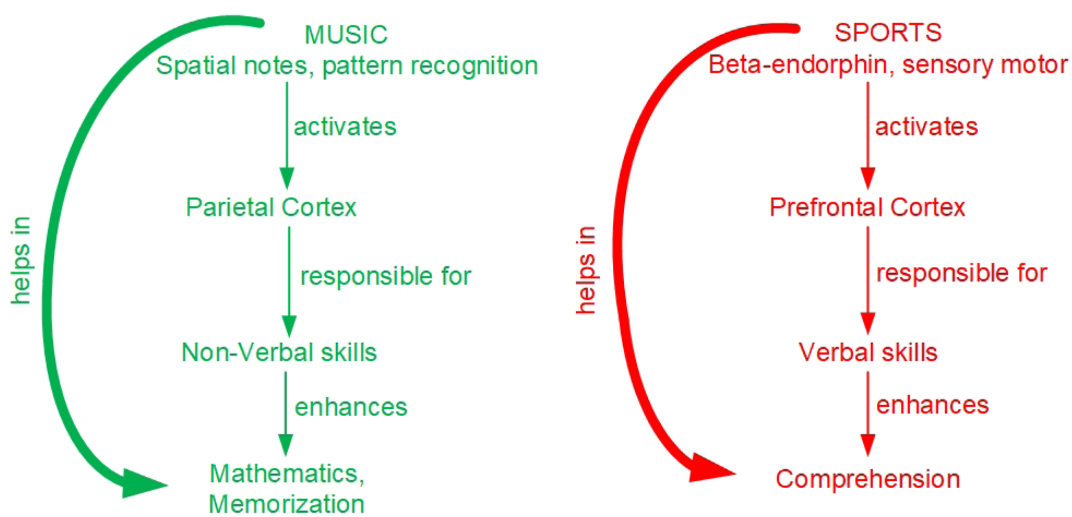

Figure 4: Association of Music and Sports to Nonverbal and Verbal skills respectively. Learning music may result in an increased activation of the parietal cortex, which enhances nonverbal skills like mathematics and memorization, thereby implying an association of music-learning with nonverbal skills. Learning sports may result in an increased activation of the prefrontal cortex, which enhances verbal skills like verbal comprehension, thereby implying an association of sports-learning with verbal skills.

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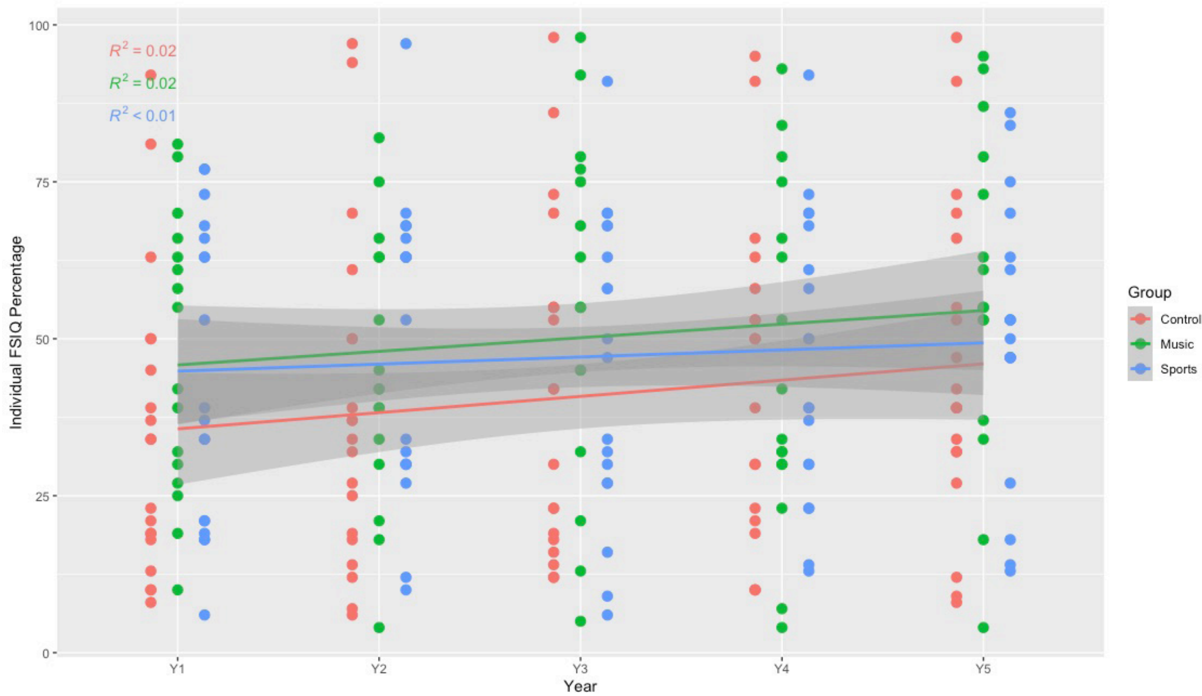

Figure 5: Scatter plot of FSIQ-4 score vs. Year. The dots represent the raw FSIQ-4 scores for each group of children for each year. The lines represent the regression lines fitting the scattered data points. Three different groups of elementary school children were tested annually for verbal and nonverbal cognitive intelligence. A poor fit of the data points to the regression lines is shown by a low coefficient of determination (R2 in the range of 0.01 – 0.02). This shows a significant variation in scores among children even in the same group for every year.

learn to visually follow musical notes. Perceptual reasoning is another skill that gets developed during music-learning, as it involves beat perception, intonation perception, and harmony perception (27). Also, reading musical notes involving half notes, quarter notes, and sixteenth notes is associated with the mathematical concept of subdivision (28). The abilities to distinguish consonance from dissonance and to identify pitch variation involve mental manipulations similar to solving mathematical problems. Interestingly, a similar study involving young children who learned music prior to seven years of age showed increased spatial-temporal activity and performed better in numerical reasoning tasks than the children who did not learn music (29). These observations are in sync with our current findings that confirm that music tends to have a greater impact on nonverbal tasks such as perceptual reasoning and mathematics than sports activities.

Similarly, scientific evidence exists that show the benefits of sports activities. A strong positive correlation has been found between physical activity and reduced anxiety, possibly due to the subsequent release of beta-endorphins, an endogenous opioid that elevates mood (30). Research also shows that participation in athletics relates to superior multitasking abilities (31). According to a study on sports psychology, language comprehension is interconnected with the sensorimotor experiences implied by the text one reads (32). In parallel to our findings, this study also points to a hypothesis by Zwaan and Taylor that says that if reading about an action employs the sensorimotor region of the brain, then engaging in an action that triggers the same region of the brain would ease the comprehension of the related passage (33). For instance, while reading sentences like ‘I bit the apple’ or ‘I kick the ball’, the premotor cortex region gets activated in an identical manner when similar actions are performed using the mouth and leg respectively (34). This clearly shows a correlation between action, sensory motor, and language comprehension that depends on multitasking between verbal decoding and language comprehension.

Structural analysis also arrives at the same inferences. With music notations being spatial in nature and the parietal cortex region of our brain being responsible for spatial awareness, music learning seems to activate the parietal cortex (35). Also, as children use rote memorization during their early years of music-learning, their parietal cortex tends to get activated more than their prefrontal cortex (36). Similarly, as children engage with action-oriented tasks during their sports activities, their prefrontal cortex is likely to be activated based on the research that observed prefrontal cortex oxygenation during cognitive testing with intense physical activity (37). **Figure 4** (Association of Music and Sports to Nonverbal and Verbal skills respectively) summarizes these findings. Learning music may result in an increased activation of the parietal cortex, which enhances nonverbal skills like mathematics and memorization, thereby implying an association of music-learning with nonverbal skills. Learning sports may result in an increased activation of the prefrontal cortex, which enhances verbal skills like verbal comprehension, thereby implying an association of sports-learning with verbal skills.

Our research suggests an impact of music on nonverbal skills such as math calculations and mental manipulations. This may encourage young children, especially those with nonverbal disorders such as autism and bipolar disorder, to learn music and hone their nonverbal skills. Our research also suggests links between sports and verbal skills such as reading comprehension. This may encourage young children, especially those showing signs of verbal disorders like ADHD and dyslexia, to engage in sports activities and tone their verbal skills.

There are few areas where our research could be improved. For example, an increased sample size is likely to reduce variability and margin of error in estimating the population parameters. Moreover, the results of our study can be validated by adding a few more experimental groups such as children learning either instrumental or vocal music but not both, children learning music in group setting, children engaged only in solo sports like swimming and bicycling, and children of specific gender, race, or ethnic group. Such variations could mitigate any bias caused by our project's limitations including a lack of well-balanced child gender and diversified socioeconomic class.

MATERIALS AND METHODS

Participants

The participants for our study included forty-five 6- and 7-year-old children attending public elementary schools in the greater Los Angeles area. The first experimental group, comprised of fifteen of these children including seven girls and eight boys, learned music five days a week at the Youth Orchestra of Los Angeles at Heart of Los Angeles (YOLA at HOLA). As one of the male students was identified as a gifted child, the data associated with this child has been discarded in order to avoid any possible skew in the results. Based on IQR outlier analysis, the gifted child's test scores were found to be an outlier consistently in almost all of the tests for every year. The second experimental group of our study included fifteen children, comprised of five girls and ten boys, who were enrolled in a community-based soccer program undergoing training three times a week for two hours in addition to a one-hour game each weekend. The control group of our study included the remaining fifteen children, comprised of four girls and eleven boys, who did not enroll in any extracurricular activities.

Testing Protocol

Study protocols were approved by the University of Southern California Institutional Review Board. Informed consent was obtained in writing from the parents/guardians on behalf of the child participants. Privacy was ensured at all steps including selection of participants, data collection, and data analysis.

Assessment of cognitive development was based on the second version of the Wechsler Abbreviated Scale of Intelligence (WASI-II) tests.

The scoring from the WASI-II subtests is divided into three sections: WASI VCI (Verbal Comprehension Index) that measures crystallized abilities to understand and verbalize learned concepts, WASI PRI (Perceptual Reasoning Index) that measures nonverbal fluid abilities and visuomotor skills, and WASI FSIQ-4 that estimates general cognitive ability using all four sections of test. The WASI VCI score is based on the vocabulary and similarities subtests, while the WASI PRI score is based on the block design and matrix reasoning subtests. The WASI FSIQ-4 score is based on all four of the subtests.

Baseline Study

A baseline dataset was established for all the participating children. Several cognitive tests including WASI FSIQ-2 (block and matrix reasoning subsets only), digit span, auditory analysis, and Gordon's primary measures of music audiation were performed. In addition, emotional development was also evaluated using tests such as Reading the mind in the eyes, Index of empathy and Video emotion match. Structural analysis using brain imaging was also performed for all the participants. The results of this baseline study showed no neural, cognitive, motor, emotional, or social differences among the three groups of participants.

Software Plots

Line and scatter plots of FSIQ-4, PRI, and VCI scores over a span of five years were plotted using RStudio (version 4.2.2). Graphs of summary datasets were created with ggplot2 plotting software across all three metrics. Also, statistical parameters such as standard error and mean score were calculated at each year for all the average plots.

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