frontiers | Frontiers in Education

ORIGINAL RESEARCH
published: 04 July 2022
doi: 10.3389/feduc.2022.875511

Effectiveness of Musical Training on Reading Comprehension in Elementary School Children. Is There an Associative Cognitive Benefit?

Maria Sofologi[1,2], Efthymios Papatzikis[3,4], Georgios Kougioumtzis[5], Elina Kosmidou[6], Asimenia Klitsioti[6], Andreani Droutme[6], Aggeliki-Anna Sourbi[6], Dimitra Chrisostomou[6] and Maria Efstratopoulou[2]*

[1] Department of Early Childhood Education, School of Education, University of Ioannina, Ioannina, Greece, [2] Department of Special Education, College of Education, United Arab Emirates University, Al Ain, United Arab Emirates, [3] Department of Early Childhood Education and Care, Oslo Metropolitan University, Oslo, Norway, [4] Bright Start Foundation for Maternal and Child Health, Geneva, Switzerland, [5] Department of Turkish Studies and Modern Asian Studies, School of Economics and Political Sciences, National and Kapodistrian University of Athens, Athens, Greece, [6] Department of Psychology, School of Humanities and Social Sciences, University of Western Macedonia, Ioannina, Greece

OPEN ACCESS

Edited by:
J. W. (Bill) Whitlow,
Rutgers University Camden,
United States

Reviewed by:
Christopher Maute,
Rutgers University Camden,
United States
Isaías Martín-Ruiz,
Universidad de Málaga, Spain

***Correspondence:**
Efthymios Papatzikis
efp331@mail.harvard.edu

Specialty section:
This article was submitted to Educational Psychology, a section of the journal Frontiers in Education

Received: 14 February 2022
Accepted: 17 May 2022
Published: 04 July 2022

Citation:
Sofologi M, Papatzikis E, Kougioumtzis G, Kosmidou E, Klitsioti A, Droutme A, Sourbi A-A, Chrisostomou D and Efstratopoulou M (2022) Effectiveness of Musical Training on Reading Comprehension in Elementary School Children. Is There an Associative Cognitive Benefit? Front. Educ. 7:875511. doi: 10.3389/feduc.2022.875511

The current study investigated the impact of instrumental music training on reading comprehension, working memory, and executive function in elementary school children in Greece. A series of studies suggested the possibility of a cognitive advantage from instrumental music training. For the purpose of the present study 80, elementary school children were evaluated. The experimental group consisted of 40 students in 5th grade with at least 5 years of music training and the control group consisted of 40 children who did not have any music training. The two groups were examined in working memory measurements of the Wechsler Intelligence Scale for children (WISC-III; Digit and Forward Digit Recall), in Stoop Test, which is an executive function evaluation and reading comprehension test. The reading ability of both group participants was evaluated with the standardized test in the Greek population Test-A. Children with instrumental music training registered higher performances in reading comprehension tests and all cognitive measurements reflecting a possible cognitive advantage compared to participants without music training. The present results attempt to shed light on the possible link between instrumental music training on cognitive abilities and reading comprehension.

Keywords: text comprehension, working memory, music training, elementary school children, music

INTRODUCTION

The last decades' long-term influences of musical training on cognitive functions have motivated a growing number of studies in the field of educational research and cognitive science. The literature review reveals a series of empirical studies investigating the possibility of a causal link between music training and cognitive performance. The idea that practicing an instrument that

is a highly cognitive demanding task may lead to a cognitive advantage shows contradictive evidence that cannot be interpreted with accuracy (Sala and Gobet, 2020). Research findings revealed inconsistent evidence failing to clearly explain this specific association. In this vein, a series of studies investigate the idea that there are general and domain-specific associations between instrumental music training and cognition. More specifically, researchers have proposed that music training is associated with IQ performance (Schellenberg, 2006; Ritchie and Tucker-Drob, 2018), mathematics (Schlaug, 2015), working memory (Morrison and Chein, 2011; Talamini et al., 2017; Diamond and Ling, 2019), and attention (Saarikivi et al., 2016). The same pattern of research findings seems to be aligned with academic achievement. In specific, music training appears to be related also to reading abilities (Dege and Schwarzer, 2011) and phonological processing (Patel, 2011; Tierney and Kraus, 2013). Additionally, a plethora of studies have linked short-term and long-term music training to a variety of differences in speech perception basic auditory perception (Skoe and Kraus, 2012), and acquisition of a second language (Brod and Opitz, 2012). In this vein, long-term music training is associated with both superior auditory perception (Seither-Preisler et al., 2014) and enhanced language skills. Researchers proposed that learning to play a musical instrument clearly trains auditory perception and for this reason, it is not surprising that music training is associated with skills that depend heavily on auditory processing abilities.

In parallel, other studies indicate a possible association between aspects of executive functions, like switching, monitoring, selective attention, and musical performance (Bialystok and DePape, 2009; Christopher and Shelton, 2017). Analogously, in the last two decades, researchers emphasize the possible contributing role of executive functions in music education (Vojtech et al., 2019). It is widely accepted that executive functions play a positive role in nearly all cognitive tasks and abilities (Hannon and Trainor, 2007), and playing an instrument involves daily use of selective attention, switching, inhibition, and monitoring which are aspects of executive functions (Jäncke, 2009). The research community argues that children with instrumental music training can steadily and systematically activate executive functions and, in particular, shift, monitoring, and selective attention because of their ability to enable conscious and goal-directed problem solving (Moreno, 2009). For example, playing an instrument often demands the activation of executive functions, including planning, working memory, shifting, and recalling a variety of music pieces from working memory (Moradzadeh et al., 2015).

At this point, it is essential to mention that researchers in this specific research pathway have reached inconsistent conclusions facing difficulties to interpret with accuracy the precise nature of the association. Albeit a series of the above-mentioned empirical studies have supported the idea of a cognitive benefit because of instrumental music training (Johann et al., 2020), others have found this advantage unjustified mirroring the heterogeneity of the results (Rickard et al., 2012; Kempert et al., 2016; Sala and Gobet, 2020).

Because music skills are associated with reading skills, it is reasonable to ask whether music training improves reading skills and reading comprehension. Several explanations for such potential transfer have been proposed. For example, it has been suggested that learning to read musical notation involves many of the same processes as learning to read words, such as understanding that written notation proceeds from left to right, recognizing visual patterns, and understanding that visual symbols map on to particular sounds (Forgeard et al., 2008). A series of research findings attempt to enlighten the relationship of instrumental music education with reading comprehension. In specific, some researchers claim that children trained with instrumental music lessons may register better performances in phonological working memory tasks (Roden et al., 2012, 2014), verbal intelligence (Moreno et al., 2011), and language processing, and reading ability skills (Corrigall and Trainor, 2011). Accordingly, these findings seem to show a possible research trend and are aligned with research findings from adults, for a generalized "boosting effect hypothesis" of music training (Sofologi and Theofilidis, 2020). To illustrate the unjustified possible effect of music training, as a significant factor on cognition, Piro and Ortiz (2009) evaluated the influence of long-term music training on different cognitive measures of 103 second-grade elementary school children. In specific, 46 children comprised the experimental group with 3 years of piano lessons whereas the control group (57 children) had never had any piano lessons. All participants were measured in phonological working memory tasks and linguistic abilities measures. Research findings revealed that children with music education showed better performances on both vocabulary and phonological working memory measurements when compared with participants without any music education (Piro and Ortiz, 2009).

In line with the above research findings, Herring and Scott (2018) evaluated the impact of music on reading comprehension in elementary school children. This study aimed to examine whether different types of music enable students to better comprehend a text according to their performances on text comprehension questions. For the purpose of the present study, 37 students from the eighth and ninth grades (12–15 years old) were examined. All group participants had no music training. Also, both groups matched for their vocabulary skills, digit span, general reading, and text comprehension ability. Furthermore, a website, called Readworks, was used for the evaluation process. This site encompasses some text passages with historical content, approachable to the level of the participants, and at the end of the three texts, there were some reading comprehension questions concerning the content of every text. After the reading of each text, the participants were asked to answer eight comprehension questions for each text (a total of 24 questions). Each student participated in four different conditions: listening to instrumental music, Spanish lyrical music, English lyrical music, and not listening to music. The findings revealed that the reading comprehension performance of the students in two different music conditions, listening to foreign, instrumental music, was higher when compared to the reading comprehension performance with English lyrical music. As a result, it appears that listening to English lyrical music while reading a text adversely affects reading comprehension as it can be a distractive

stimulus and affect the quality of comprehension according to the results of the study. As a result, teachers should not prefer it instead of foreign and instrumental music (Herring and Scott, 2018).

An analogous study by Khaghaninejad et al. (2016), attempts to emphasize the effect of classical music on reading text comprehension in elementary school children. More specifically, a total sample of 80 students, between the age of 12 and 15 years old, was evaluated. They were divided into two groups. In the experimental group, the participants with instrumental music training had to study and learn the two passages with scientific content while the music of Mozart was playing. Consequently, after reading the two texts, the participants were asked to answer eight comprehension questions for each text. On the contrary, the participants of the control group had to study and learn the two texts without a music background. The results of the current study revealed that simultaneously reading a text with background music had a positive effect on the reading comprehension of the experimental group of participants with music training. Researchers supported the idea that their findings mirrored the idea that music training can enhance reading comprehension in elementary school children (Khaghaninejad et al., 2016).

Under the aegis of the above-mentioned research findings and theoretical framework, the present study attempts to make a further research step by finding a possible link between instrumental music training, reading comprehension, and different cognitive measures, in elementary school children. It is fundamental to mention that few studies have examined whether music training is associated with higher-level reading abilities such as reading comprehension in elementary school children. According to our first research hypothesis, we hypothesize that elementary school children with instrumental music training would show higher performances in reading comprehension measurements when compared with elementary school children of the same age without instrumental music training. More specifically, we assumed that children with music training will register higher performances in reading comprehension questions in comparison with children without music training (Hypothesis 1). Additionally, we hypothesized that elementary school children with instrumental music training would show an upper trend of performances in working memory assessment tests in comparison with the cognitive performances of students without music training (Hypothesis 2). Finally, according to our third hypothesis, we assume that children with instrumental music training will have better performances on executive function evaluation (Stroop Test) in comparison with group participants without music training (Hypothesis 3).

MATERIALS AND METHODS

Sample

Data for this study were obtained from 80 elementary school children in 5th grade (M.D. = 130.54 months, SD = 9.13). Gender was equivalent in representation. More specifically, two groups were created. The quasi- experimental group consisted of 40 Greek elementary school students (20 boys and 20 girls) (M.D. = 130.54 months, SD = 9.13). from the 5th grade with a minimum of 5 years of formal music training in a state music school according to the National Music Curriculum of Hellenic Ministry of Education and Religious Affairs. The control group, consisted of 40 Greek elementary school students (20 boys and 20 girls) (M.D. = 130.54 months, SD = 9.13), with no music training. All students in the study were general education students and were proficient in speaking, reading, and writing Greek. All students came from urban areas of Northern Greece and different state schools. The participants of both groups came from different socioeconomic strata based on their parents' educational level and professions. Parents whose children met the inclusion criteria received a package containing an informative letter about the study and its purpose, and a consent form. Students who participated in the present study had no official diagnosis of special learning difficulties, mental disabilities (based on the reports of their teachers and their parents), or sensory impairments. Due to the specific type of the current research, demographic data such as age, gender, or occupation of parents were selected. In specific, parents filled out a questionnaire on their child's demographics, basic health, and formal and informal music experience (through which we obtained information about each child's length of music training, number of instruments, and age of onset of music training). The data collection was anonymous. Since these are considered personal data, the European Union law that exists since 28 May, 2018 was applied and followed the principles outlined in the Helsinki Declaration. According to the law, the use of sensitive personal data is allowed only due to research reasons.

Procedure

The participants were individually tested in two phases. The first phase consisted of working memory assessment tests (Georgas et al., 1997), executive function assessment (Stroop, 1935), and reading and text comprehension ability were also evaluated by administering the Test-A (Panteliadou and Antoniou, 2007). In the second phase, all the participants were tested individually in text comprehension. The data collection was carried out from January 2020 to April of the same year.

Assessment Instruments

The evaluation of Verbal Working Memory was conducted with the implementation of the Forward Digit Recall and Backward Digit Recall. The two sub-scales are part of the WISC-III standardized Greek version assessment tool (Georgas et al., 1997) whereas executive functions were measured with the Stroop Test which is also standardized in the Greek population (Stroop, 1935). The reading ability was evaluated by administering the Test-A (Panteliadou and Antoniou, 2007). Test-A is a Greek standardized psychometric diagnostic tool for evaluating reading ability in elementary school students and high school students in Greece. The reading test (Panteliadou and Antoniou, 2007) aims at the comprehensive assessment of the reading skills of students attending classes from the third grade of Elementary school to the third grade of Secondary school (8–15 years of age) as well as the detection of students facing serious reading difficulties at the ages of compulsory education. The comprehension ability was evaluated with two texts with scientific content.

Working Memory Measurements

Digit Span – Forward Digit Recall

The task of digit recall consists of 15 complex gradient arithmetic sequences. In this project, the researchers read a list of digits or a series of digits at a rate of one digit per second each time, and the participant is asked to recall it in the same order. The use of the Digit Recall Scale aims at evaluating participants' working memory. The task of the individual is to repeat each sequence either from the beginning to the end (straight repeat) or from the end to the beginning (reverse repeat). Each question contains two rows, each with the same number of digits. The first row in the pair is Attempt 1, and the second row is Attempt 2. In the process of direct repetition, the individual is asked to recall a total of eight pairs of rows correctly. Correspondingly for the reverse iteration, it must retract a total of seven pairs of rows. The evaluation process in the straight repetition starts with Question 1, which is given to all participants. The evaluator evaluates both attempts to each question, even if the participant has succeeded in Attempt 1. The main process is interrupted after a failed retry in both attempts. This cut-off criterion applies to both straight-repeat and reverse-repeat questions. The evaluator is required to provide the reverse repetition questions, even if the participant has scored zero points in the direct repetition process.

Backward Digit Recall

Backward digit recall is preceded by a familiarization process, where the evaluator provides an example of a sequence of digits, and the participant is asked to recall it in reverse order. If the participant answers correctly, the familiarization process is completed and the evaluator answers Question 1. If a wrong answer is given, the second example of familiarization is given. Upon completion of the second example, the evaluator provides Question 1 regardless of whether the participant answered correctly or incorrectly. Each question is scored with 2 points if the participant succeeds in both attempts of the question, with 1 point if he successfully revokes only one of the two attempts of the question, and with zero points if he fails to recall the sequence of digits in both attempts at the question. The total sum of the straight digits recall comes from all the successfully replicated answers. Accordingly, the sum of the correct answers for the backward digit recall is the sum of the correct answers. The degree of the scale is the sum of the units in the two parts of the scale, that is, the total sum of the straight repeat is added to the total of the reverse repeat. The maximum number of points in a forward repeat is 16, while in the backward digit recall, it is 14. The upper point of the scale is 30.

Executive Function Measurement

The Stroop Test was used to measure and evaluate students' inhibitory control. The purpose of the Stroop test is to measure the ability the participant must inhibit and switch a response. The format we used includes a series of repetitive words which are "red," "blue," and "green," each of which is printed randomly in red, blue, or green ink. The word may not be written in the respective color of the ink, in other words, the word blue may not be written in blue ink but in red ink. This tool consists of three parts. The first part of this tool has three names of colors which are printed in ink (blue, red, and green), and the participant is asked to voice the color he or she sees, out aloud. The second part has the XXX symbols printed in color and the job of the participant is to call out the color of the ink which is printed each time. Finally, the third part of the evaluation has color names that are printed in ink, but the color of the ink and the word do not correspond, for example, the word red is printed in green. The participant is asked to name the color of the ink, not the printed word. The main purpose here is to encourage the participant to name the color but not to read the word which is presented each time. The total result is derived from the total number of items that the participant will read within 45 s. The rating is based on the number of errors that the examiner made and did not correct and the time it took to complete the test in seconds.

Test-A

Test A is an assessment instrument, standardized on the Greek population, created by Panteliadou and Antoniou (2007) for the evaluation of the reading ability of elementary and high school students in Greece (8–15 years). The assessment battery consists of four different sub-categories: (i) Decoding (evaluation of reading fluency of non-words and real words), (ii) Reading Fluency, (text reading fluency), (iii) Morphology-Grammar (evaluation of syntactical, morphological, and grammatical errors in a series of sentences, and (iv) Reading Comprehension (evaluation of reading comprehension of three different texts with different reading comprehension questions for each text).

Comprehension Text Evaluation

In the present study children's reading comprehension was tested with two different texts with scientific content. More specifically, two texts with scientific content or results from experimental studies were presented on a computer screen (texts were 250 words long). Each passage consisted of three paragraphs (three to four sentences in each paragraph). After reading every text all participants had to answer reading comprehension questions; 8 questions for every text (16 questions for two texts). The participants had to choose either the "True" or "False" answer based on text information. Half of the questions tap information that is explicitly stated in the text (memory-based questions); the other half focuses on information that could be inferred from the text (Sofologi et al., 2020a). Texts were presented line-by-line on a computer screen. Participants controlled the rate of sentence presentation by pressing a keyboard button to advance to the next screen.

Data Analysis

An analysis of Variance (ANOVA) was used to evaluate the differences in the reading ability performances in Test-A (Panteliadou and Antoniou, 2007) among the two groups of participants. Moreover, for the evaluation of the mean differences in reading comprehension test for the two groups of participants two *t*-test analyses were performed for each text. Finally, a *t*-test analysis was applied in order to evaluate differences in the performances of two groups, in both working memory assessment tasks (Forward Digit Recall Test and Backward Digit Recall Test). To fully investigate the differences in the

performances between the two groups on the three conditions of the Stroop test, an analysis of variance was performed. All analyses were performed using IBM SPSS v28.

RESULTS

Initially, to evaluate possible differences in reading ability of both groups, participants' mean differences and standard deviations in all sub-scales of the reading ability Test-A were evaluated. It should be noted that the actual scores arise by aggregating the sets of the correct answers to all sub-scales (decoding, fluency, morphology-syntax, and reading comprehension) corresponding to each sub-scale. **Table 1** presents the average and standard deviations for all participants in both groups in the reading ability evaluation test Test-A. To evaluate possible differences in the reading ability of both group participants an Analysis of Variance (ANOVA) was conducted with the independent variable the music training of participants and dependent variables the performances in the reading ability assessment test. Results revealed no statistically significant differences for all the variables of reading ability among the two groups [Decoding Scale $F_{(1,78)} = 2.06$, $p > 0.05$, Verbal Fluency Scale, $F_{(1,78)} = 0.73$, $p > 0.05$, Morphology-Syntax Scale $F_{(1,78)} = 2.55$, $p > 0.05$, and Reading Comprehension Scale, $F_{(1,78)} = 0.92$, $p > 0.05$].

In the next step of the statistical analysis, in order to evaluate the possible mean differences in reading comprehension test for the two groups of participants a t-test analysis was performed for the first text. In specific, the difference in reading comprehension performance in all reading comprehension questions of the first text between children with music training ($M = 3.63$, $SD = 0.89$) and children with no music training ($M = 2.85$, $SD = 1.33$) was statistically significant [t (78) $= -3.054$, $p < 0.001$, $\eta^2 = 0.06$]. Furthermore, a t-test analysis was used for the second text. Again, the difference in reading comprehension performance in all reading comprehension questions of the second text between children with music training ($M = 4.05$, $SD = 0.98$) and children with no music training ($M = 3.53$, $SD = 1.10$) was statistically significant [t (78) $= -2.238$, $p < 0.001$, $\eta^2 = 0.05$]. The findings confirm our first hypothesis.

To evaluate the second hypothesis concerning the possible difference in the performance of both group participants in both working memory assessment tasks a t-test analysis was conducted. More specifically, the difference in performance in Forward Digit Recall sub-scale between children with music training ($M = 11.38$, $SD = 2.63$) and children with no music training ($M = 9.73$, $SD = 0.87$) was statistically significant [t (78) $= -3.754$, $p < 0.001$, $\eta^2 = 0.05$], and the same statistically significant result registered in Backward Digit recall measurement. In specific, t-test analysis revealed that the difference in this specific subscale between children with music training (M = 6.60, SD = 1.90) and children with no music training ($M = 5.48$, $SD = 0.67$) was statistically significant [t (78) $= -3.517$, $p < 0.001$, $\eta^2 = 0.06$]. The statistically significant differences between the two groups in the working memory tasks confirm the second research hypothesis. **Table 2** presents the average and standard deviations of the two groups regarding their performances in all cognitive measures.

TABLE 2 | Mean differences and standard deviations for the two groups for all working memory measures.

Group participants	Forward digit recall		Backward digit recall	
	M.D.	S.D.	M.D.	S.D.
Group with music training	11.38	2.63	6.60	1.90
Group without music training	9.78	0.87	5.48	0.67

In the next part of the analysis, and in order to evaluate the third hypothesis according to which students with music training will register higher performances in the inhibition control task, an analysis of variance was performed for the two groups, with the independent variable being the three different conditions of the Stroop assessment test. To fully investigate the differences in the performances in the case of non-parametric distribution of the data, on the three conditions of the Stroop test, a multiple comparison *post hoc* tests [Tukey's Honest Significant Difference (HSD)] were performed. The results of the analyses showed that the main effect of the group (the group with music training and the group with no music training) was significant in two of the three conditions of the executive function test. Specifically, for the first condition of the Stroop test, the group with music training had statistically significant higher performances $F_{(3,76)} = 39.410$, $p < 0.001$, $\eta^2 = 0.34$, as compared with the group of participants with no music training (90.45 vs. 59.55, $p < 0.001$). Respectively, a statistically significant difference was found for the group of

TABLE 1 | Mean and standard deviations, maximum and minimum, and values for skewness and kurtosis for measuring the reading comprehension of the two groups.

Sub-scales of Test-A	M.D.	S.D.	Min.	Max.	Skewness St.E.		Kurtosis St.E.	
Group without music training								
Decoding	96.01	9.92	65	112	−0.42	0.26	0.01	0.51
Fluency in reading	123.09	28.53	69	178	0.16	0.26	−0.70	0.51
Morphology-syntax	19.96	4.42	11	28	−0.57	0.26	−0.47	0.51
Reading comprehension	18.52	2.99	13	24	0.27	0.26	−0.93	0.51
Group with music training								
Decoding	98.2	9.92	65	124	−0.83	0.26	1.55	0.51
Fluency in reading	125.27	26.93	69	187	0.42	0.26	−0.78	0.51
Morphology-syntax	20.89	3.02	13	27	−0.51	0.26	0.22	0.51
Reading comprehension	18.05	3.37	10	25	−0.04	0.26	−0.68	0.51

participants with music training in the third condition of the Stroop test, $F_{(3,76)} = 5.059$, $p < 0.001$, $\eta^2 = 0.06$, (36.40 vs. 30.07, $p < 0.001$) whereas no statistical difference was found in the second condition of the Stroop Test $F_{(3,76)} = 0.099$, $p < 0.001$, $\eta^2 = 0.00$ (61.23 vs. 58.83, $p < 0.001$). Research findings confirmed partially the third hypothesis according to which students with music training show an upper trend in inhibitory control when compared to students with no music training.

Finally, in an attempt to investigate the relations of cognitive measures and music training the Pearson's correlation coefficients between the research variables was estimated to evaluate possible correlations between the working memory assessment tests (Forward Digit Recall and Backward Digit Recall), and the executive function test (Stroop Test), for each group separately. According to the correlation matrix among measures, music training is positively correlated with almost all cognitive measures. Specifically, music training is statistically significant correlated with Forward Digit Recall ($r = 0.391$), Backward Digit Recall ($r = 0.370$), the Stroop A condition ($r = 0.637$), and Stroop C condition ($r = 0.411$). Finally, music training did not show any statistically significant correlational relationship with the Stroop B condition ($r = 0.122$).

DISCUSSION

The current study aimed to evaluate the effect of music training on working memory, executive function, and reading comprehension ability. The focus of the current research was to determine whether instrumental music training can improve reading comprehension, working memory, and executive function performances. The research findings showed an upper trend for children with music training in cognitive measurements and reading comprehension performance. In specific, the research findings confirmed our first hypothesis and in fact, the results showed a higher performance of students with a minimum of a 5-year period of musical training in reading comprehension evaluation tasks, when compared with the control group performances. In the meta-analysis of Butzlaff (2000) a series of studies evaluated a possible link between music training and reading ability and comprehension. Analysis revealed that music training seems to be aligned with higher reading performances on standardized reading ability tests. According to Corrigall and Trainor (2011), instrumental music training is associated with reading comprehension in 6- to 9-year-old children enrolled in music lessons. This overall effect is confirmed in the meta-analysis of Standely (2008). Furthermore, Corrigall and Trainor (2011) considered that the time duration of instrumental music training is a significant factor associated with reading comprehension, thus students, who had more experience in music were superior to those who were inexperienced. An analogous study by Tsang and Conrad (2011) confirms the current research finding. They support the hypothesis that the association between music training and reading comprehension may be partially mediated through phonological processing skills. In specific, phonological processing skills such as segmentation and word decoding mirror working memory ability and are the best predictors of reading success. If music training accelerates phonological awareness in children, this association can lead to earlier and proficient reading comprehension in children with music training. Perhaps music training helps children to become efficient readers who can focus better and concentrate for longer periods of time, which ultimately leads to better reading comprehension (Portowitz et al., 2009; Smit et al., 2022).

The second hypothesis of the research seemed to be confirmed as the group of participants with music training performed better in two working memory assessment tests. These results correspond to previous research findings according to which music training has been shown to enhance cognitive processing beyond general intelligence (Roden et al., 2012). Considerable research reports significant associations between music training and cognitive ability in a series of retrospective studies of groups of musicians or children with short-term and long-term music training and a group of participants without any music training (Schellenberg, 2004, 2006). Individuals practicing music showed higher performances in working memory tasks (Schellenberg, 2006) as well as processing speed (Guo et al., 2018). Furthermore, Schlaug et al. (2005), in a study comparing two age groups, showed that music training in children in their early years had a significant effect on working memory measurements in comparison with children at the same age without music training. Additionally, researchers proposed that multimodal cognitive demanding tasks such as learning a musical instrument can enhance working memory capacity (Talamini et al., 2017; Diamond and Ling, 2019). In specific, during music processing, working memory integrates sound events, recollects information from long-term memory, links sounds to meaning, and maintain them as mnemonic musical representations in working memory (Burunat et al., 2014; Saarikivi et al., 2019). These effects point to a possible cognitive advantage for children and adults with music training as in previous quasi-experimental research. A recent longitudinal study by Bergman et al. (2014), confirmed the current findings. More specifically, researchers investigated the association between musical training and performance on processing speed and working memory during development. Children, adolescents, and adults ($n = 352$) between the ages of 6 and 25 years participated in a series of neuropsychological assessments. Research findings proposed that music training had an overall positive association with working memory capacity across all ages for the group of participants with music education in comparison with participants with no music training. In conclusion, these findings point to a more specific enhancement of cognitive processing in response to music training and support the importance of practice for the development of working memory during childhood and adolescence, as well (Patel, 2003, 2014; Bergman et al., 2014).

Finally, according to the third hypothesis, we hypothesized that students with long-term music education would have a higher performance in the executive functions in comparison with students without any music education. In specific, in our research, we found that elementary students with a long-term music background outperform students without a musical background in the executive function assessment task. This conclusion is aligned with the findings of another similar research. In an analogous study, Bialystok and DePape (2009)

provided two executive function tasks, the Simon Arrows task, and the Auditory Stroop task, to bilingual non-musicians, monolingual musicians, and monolingual non-musicians. The findings of this research showed that musicians and bilingual individuals performed better on the Simon Arrows task and on the Auditory Stroop, in comparison with non-musicians. Additionally, Holochwost et al. (2017) examined whether music training has an impact on executive functions by assessing 265 school-age children (with and without music training) through a computerized battery of executive function tasks. The results showed that students with music training had a better performance on the executive function tasks. Furthermore, Jaschke et al. (2018) conducted longitudinal research, in which 147 elementary school children were classified into four groups, two musical, one visual art, and a control group. Results revealed that the two music groups with instrumental music training registered significantly higher performances in the executive functions measurements when compared with the performances of the visual art and the control group, as well. Researchers have argued that an increase in academic skills was mediated by higher performances on executive function tasks in children receiving music lessons (Degé et al., 2011; François and Schön, 2011). Also, improvements in executive functions and cognitive flexibility in children with long-term musical training have been observed in Finnish school-age children, and these improvements positively correlated to enhanced neural sound discrimination (Saarikivi et al., 2016). Furthermore, Habibi et al. (2016), in their longitudinal study claim that music training is responsible for changes in brain function of preschool children and elementary school children emphasizing a cognitive advantage for this specific group. These findings are in line with the hypothesis put forward at the beginning of this research, as well as with the findings of other similar research (Bialystok et al., 2010; Kuperberg and Jaeger, 2016). The results from this study underline the fact that music training may be associated with cognitive and reading ability benefits. Several experimental designs proposed that music training strengthens the association between cognitive functions, working memory, and reading comprehension ability. Furthermore, researchers claim that learning a musical language may have cognitive benefits like those in bilingual children (Craik and Bialystok, 2005; Sofologi et al., 2020b). Although this view has intuitive appeal because music and language are both auditory communication systems, the positive effects of bilingualism are evident for fluid intelligence (i.e., executive control) but not for crystallized intelligence (e.g., knowledge acquired through experience, such as vocabulary), whereas the effects of music lessons and music training appear to extend to both domains (Shen et al., 2019). In conclusion, the association between music and working memory performance is clearly a research idea that undoubtedly merits further investigation, particularly among children of different ages. The current study focused specifically on working memory and reading comprehension. Other studies could explore different aspects of literacy, such as mathematics and writing tasks, as well as visuo-spatial working memory and intelligence. In specific, a series of research studies in favor of the link between music training and intelligence show higher scores on IQ assessment tests for music-trained children in comparison with children with no music training enhancing the hypothesis that music training in childhood is associated with positive academic achievement (Schellenberg, 2006). Obtaining further clarification should be a priority for educational researchers concerned with helping children gain skills that will benefit them in academic endeavors as well as in other activities in an environment where multitasking prevails.

Important to note in this context is that beyond possible cognitive benefits music training teaches children self-discipline and attentional skills that help them concentrate for long periods of time (Anderson and Fuller, 2010). These accounts are not mutually exclusive: more intelligent and harder working children are probably more likely to take music lessons in the first place, but then those music lessons likely develop concentration and self-discipline skills even further. This specific hypothesis remains a question for future research to address. Additionally, children's music training may impact their motivation and emotional well-being in the school setting as satisfies personal needs and built a positive self-identity.

Limitations of the Study

By attempting to illustrate the complex framework of music training in school populations, this study sought to shed light on the relationship between working memory and executive functions in elementary school students. The above findings indicate the need to further study the relationship between working memory and executive functions in children with music training. In that direction, it would help to provide more sensitive tools for measuring verbal working memory and visuo-spatial working memory in populations with music training to compare their performance with students with no music education. One limitation of the present study is the sample size for the two group participants. It is important to highlight this parameter as a larger sample could reveal more accurate distinct working memory patterns and reading comprehension performances. Furthermore, another limitation of the current study is the nature of the working memory tasks. By attempting to illustrate the working memory profiles of the two different groups a proposal for future research will be the use of computerized assessment working memory tests for more accurate measurements. The neuropsychological instruments are proposed to be given through a computer in a controlled environment to measure more efficiently without the help of the examiner. Also, it is advisable to be carried out research relevant to the contribution of the duration of music education to reading comprehension and working memory. For instance, researchers can compare whether a student with 10 years of music education has a better academic achievement rather than a student with fewer years of music training. Finally, another limitation of the study is the lack of Intelligence evaluation. Bonetti and Costa (2017) showed possible associations between fluid intelligence and music tasks in elementary school children aged 4–6 years old, showing a possible innate connection between some musical skills and intelligence that could potentially lead to a higher probability of engaging in musical studies for children with

higher IQ. Moreover, in Schellenberg's study (2006), a positive association was found between playing music in childhood and IQ enhancement in later stages of life. In future studies, further evaluation is needed to clarify the complex relationship between music training and IQ development. The lack of uncontrolled variables like parents' educational level, and family income can be seen as a further limitation of the current study. In the context of the limitations mentioned here, the conclusions drawn from the present study must be interpreted with caution.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

MS and EP: conceptualization, investigation, writing—original draft preparation, writing—review and editing, supervision, and project administration. MS and ME: methodology. MS, EP, and GK: validation, resources, and data curation. MS, EK, AD, AK, A-AS, DC, and ME: formal analysis. EK, AD, AK, A-AS, and DC: visualization. All authors have read and agreed to the published version of the manuscript.

FUNDING

This publication has received a grant by Oslo Metropolitan University toward covering the open access publication fees.

REFERENCES

Anderson, S. A., and Fuller, G. B. (2010). Effect of music on reading comprehension of junior high school students. *Sch. Psychol. Q.* 25, 178–189. doi: 10.1037/a0021213

Bergman, N. S., Darki, F., and Klingberg, T. (2014). Music practice is associated with the development of working memory during childhood and adolescence. *Front. Hum. Neurosci.* 7:926. doi: 10.3389/fnhum.2013.00926

Bialystok, E., and DePape, A. M. (2009). Musical expertise, bilingualism, and executive functioning. *J. Exp. Psychol. Hum. Percept. Perform.* 35, 565–574. doi: 10.1037/a0012735

Bialystok, E., Luk, G., Peets, K. F., and Yang, S. (2010). Receptive vocabulary differences in monolingual and bilingual children. *Bilingualism* 13, 525–531. doi: 10.1017/s1366728909990423

Bonetti, L., and Costa, M. (2017). Musical mode and visual-spatial cross-modal associations in infants and adults. *Music. Sci.* 23, 50–68. doi: 10.1177/1029864917705001

Brod, G., and Opitz, B. (2012). Does it really matter? Separating the effects of musical training on syntax acquisition. *Front. Psychol.* 3:543. doi: 10.3389/fpsyg.2012.00543

Burunat, I., Alluri, V., Toiviainen, P., Numminen, J., and Brattico, E. (2014). Dynamics of brain activity underlying working memory for music in a naturalistic condition. *Cortex* 57, 254–269. doi: 10.1016/j.cortex.2014.04.012

Butzlaff, R. (2000). Can Music Be Used to Teach Reading? *J. Aesthet. Educ.* 34, 167–178.

Christopher, E. A., and Shelton, J. T. (2017). Individual differences in working memory predict the effect of music on student performance. *J. Appl. Res. Mem. Cogn.* 6, 167–173.

Corrigall, K. A., and Trainor, L. J. (2011). Associations between length of music training and reading skills in children. *Music Percept.* 29, 147–155. doi: 10.1525/MP.2011.29.2.147

Craik, F., and Bialystok, E. (2005). Intelligence and executive control: evidence from aging and bilingualism. *Cortex* 41, 222–224. doi: 10.1016/s0010-9452(08)70899-2

Degé, F., Kubicek, C., and Schwarzer, G. (2011). Music lessons and intelligence: a relation mediated by executive functions. *Music Percept.* 29, 195–201. doi: 10.1525/mp.2011.29.2.195

Dege, F., and Schwarzer, G. (2011). The effect of a music program in a phonological awareness in preschoolers. *Front. Psychol.* 2:124. doi: 10.3389/fpsyg.2011.00124

Diamond, D., and Ling, D. S. (2019). "Review of the evidence on, and fundamental questions about, efforts to improve executive functions, including working memory," in *Cognitive and Working Memory Training: Perspectives from Psychology, Neuroscience, and Human Development*, eds J. M. Novick, M. F. Bunting, M. R. Dougherty, and R. W. Engle (Oxford: Oxford University Press), 145–389.

Forgeard, M., Schlaug, G., Norton, A., Rosam, C., and Iyengar, U. (2008). The relation between music and phonological processing in normal-reading children and children with dyslexia. *Music Percept.* 25, 383–390. doi: 10.1525/mp.2008.25.4.383

François, C., and Schön, D. (2011). Musical expertise boosts implicit learning of both musical and linguistic structures. *Cereb. Cortex* 21, 2357–2365. doi: 10.1093/cercor/bhr022

Georgas, G., Paraskevopoulos, HN, Bezevegis, Z, and Giannitsis, N. G. (1997). *Greek WISC- III*. Athens, GA: Hellinika Grammata.

Guo, X., Ohsawa, C., Suzuki, A., and Sekiyama, K. (2018). Improved digit span in hildren after a 6-week intervention of playing a musical instrument: an exploratory randomized controlled trial. *Front. Psychol.* 8:2303. doi: 10.3389/fpsyg.2017.02303

Habibi, A., Cahn, B. R., Damasio, A., and Damasio, H. (2016). Neural correlates of accelerated auditory processing in children engaged in music training. *Dev. Cogn. Neurosci.* 21, 1–14. doi: 10.1016/j.dcn.2016.04.003

Hannon, E. E., and Trainor, L. J. (2007). Music acquisition: effects of enculturation and formal training on development. *Trends Cogn. Sci.* 11, 466–472. doi: 10.1016/j.tics.2007.08.008

Herring, D., and Scott, J. (2018). The effect of lyrical and instrumental music on reading comprehension tasks. *J. Emerg. Investig.* 1, 1–6.

Holochwost, S. J., Propper, C. B., Wolf, D. P., Willoughby, M. T., Fisher, K. R., Kolacz, J., et al. (2017). Music education, academic achievement, and executive functions. *Psychol. Aesthet. Creat. Arts* 11, 147–166. doi: 10.1037/aca0000112

Jäncke, L. (2009). Music drives brain plasticity. *F1000 Biol. Rep.* 1:78. doi: 10.3410/b1-78

Jaschke, A. C., Honing, H., and Scherder, E. (2018). Longitudinal Analysis of Music Education on Executive Functions in Primary School Children. *Front. Neurosci.* 12:103. doi: 10.3389/fnins.2018.00103

Johann, V., Könen, T., and Karbach, J. (2020). The unique contribution of working memory, inhibition, cognitive flexibility, and intelligence to reading comprehension and reading speed. *Child Neuropsychol.* 26, 324–344. doi: 10.1080/09297049.2019.1649381

Kempert, S., Götz, R., Blatter, K., Tibken, C., Artelt, C., Schneider, W., et al. (2016). Training early literacy related skills: To which degree does a musical training contribute to phonological awareness development? *Front. Psychol.* 7:1803. doi: 10.3389/fpsyg.2016.01803

Khaghaninejad, M. S., Motlagh, H. S., and Chamacham, R. (2016). How does Mozart's music affect the reading comprehension of Iranian learners of both genders? *Int. J. Hum. Cult. Stud.* 488–499.

Kuperberg, G. R., and Jaeger, T. F. (2016). What do we mean by prediction in language comprehension? *Lang. Cogn. Neurosci.* 31, 32–59. doi: 10.1080/23273798.2015.1102299

Moradzadeh, L., Blumenthal, G., and Wiseheart, M. (2015). Musical training, bilingualism, and executive function: a closer look at task switching and dual-task performance. *Cogn. Sci.* 39, 992–1020. doi: /10.1111/cogs.12183

Moreno, S. (2009). Can music influence language and cognition? *Contemp. Music Rev.* 28, 329–345. doi: 10.1080/07494460903404410

Moreno, S., Bialystok, E., Barac, R., Schellenberg, E. G., Cepeda, N. J., and Chau, T. (2011). Short-term music training enhances verbal intelligence and executive function. *Psychol. Sci.* 22, 1425–1433. doi: 10.1177/0956797611416999

Morrison, A. B., and Chein, J. M. (2011). Does working memory training work? The promise and challenges of enhancing cognition by train- ing working memory. *Psychon. Bull. Rev.* 18, 46–60. doi: 10.3758/s13423-010-0034-0

Panteliadou, S., and Antoniou, F. (2007). *Test Alpha (Reading test).* Athens: YPEPQ-EPEAEK. doi: 10.12681/icw.18133

Patel, A. D. (2003). Language, music, syntax and the brain. *Nat. Neurosci.* 6, 674–681. doi: 10.1038/nn1082

Patel, A. D. (2011). Why would musical training benefit the neural encoding of speech? The OPERA hypothesis. *Front. Psychol.* 2:142. doi: 10.3389/fpsyg.2011.00142

Patel, A. D. (2014). Can nonlinguistic musical training change the way the brain processes speech? The expanded Opera hypothesis. *Hear. Res.* 308, 98–108. doi: 10.1016/j.heares.2013.08.011

Piro, J. M., and Ortiz, C. (2009). The effect of piano lessons on the vocabulary and verbal sequencing skills of primary grade students. *Psychol. Music* 37, 325–347. doi: 10.1177/0305735608097248

Portowitz, A., Lichtenstein, O., Egorova, L., and Brand, E. (2009). Underlying mechanisms linking music education and cognitive modifiability. *Res. Stud. Music Educ.* 31, 107–128. doi: 10.1177/1321103X09344378

Rickard, N. S., Bambrick, C. J., and Gill, A. (2012). Absence of widespread psychosocial and cognitive effects of school-based music instruction in 10-13-year-old students. *Int. J. Music Educ.* 30, 57–78. doi: 10.1177/0255761411431399

Ritchie, S. J., and Tucker-Drob, E. M. (2018). How much does education improve intelligence? A meta-analysis. *Psychol. Sci.* 29, 1358–1369. doi: 10.1177/0956797618774253

Roden, I., Grube, D., Bongard, S., and Kreutz, G. (2014). Does music training enhance working memory performance? Findings from a quasi-experimental longitudinal study. *Psychol. Music* 42, 284–298. doi: 10.1177/0305735612471239

Roden, I., Kreutz, G., and Bongard, S. (2012). Effects of a school-based instrumental music program on verbal and visual memory in primary school children: a longitudinal study. *Front. Neurosci.* 6:572. doi: 10.3389/fpsyg.2012.00572

Saarikivi, K., Putkinen, V., Tervaniemi, M., and Huotilainen, M. (2016). Cognitive flexibility modulates maturation and music-training- related changes in neural sound discrimination. *Eur. J. Neurosci.* 44, 1815–1825. doi: 10.1111/ejn.13176

Saarikivi, K. A., Huotilainen, M., Tervaniemi, M., and Putkinen, V. (2019). Selectively enhanced development of working memory in musically trained children and adolescents. *Front. Integr. Neurosci.* 13:62. doi: 10.3389/fnint.2019.00062

Sala, G., and Gobet, F. (2020). Cognitive and academic benefits of music training with children: a multilevel meta-analysis. *Mem. Cogn.* 48, 1429–1441. doi: 10.3758/s13421-020-01060-2

Schellenberg, E. G. (2004). Music lessons enhance IQ. *Psychol. Sci.* 15, 511–514. doi: 10.1111/j.0956-7976.2004.00711.x

Schellenberg, E. G. (2006). Long-term positive associations between music lessons and IQ. *J. Educ. Psychol.* 98, 457–468.

Schlaug, G. (2015). Musicians and Music Making as a Model for the Study of Brain Plasticity. *Progress Brain Res.* 217, 37–55. doi: 10.1016/bs.pbr.2014.11.020

Schlaug, G., Norton, A., Overy, K., and Winner, E. (2005). Effects of music training on the child's brain and cognitive development. *Ann. N. Y. Acad. Sci.* 1060, 219–230. doi: 10.1196/annals.1360.015

Seither-Preisler, A., Parncutt, R., and Schneider, P. (2014). Size and synchronization of auditory cortex promotes musical, literacy, and attentional skills in children. *J. Neurosci.* 34, 10937–10949. doi: 10.1523/JNEUROSCI.5315-13.2014

Shen, Y., Lin, Y., Liu, S., Fang, L., and Liu, G. (2019). Sustained effect of music training on the enhancement of executive function in preschool children. *Front. Psychol.* 10:1910. doi: 10.3389/fpsyg.2019.01910

Skoe, E., and Kraus, N. (2012). A little goes a long way: How the adult brain is shaped by musical training in childhood. *J. Neurosci.* 32, 11507–11510. doi: 10.1523/JNEUROSCI.1949-12.2012

Smit, E. A., Milne, A. J., and Escudero, P. (2022). Music perception abilities and ambiguous word learning: Is there cross-domain transfer in nonmusicians? *Front. Psychol.* 13:801263. doi: 10.3389/fpsyg.2022.801263

Sofologi, M., Efstratopoulou, M., Kamari, A., Bonti, E., and Katsiana, A. (2020a). Different strategies for assessing reading comprehension in adults. From alpha to omega. *Eur. J. Spec. Educ. Res.* 7, 38–53. doi: 10.37118/ijdr.18520.06.2020

Sofologi, M., Zafiri, M., and Pliogou, V. (2020b). Investigating the relationship of working memory and inhibitory control: bilingual education and pedagogical implications in elementary school. *Int. J. Learn. Teach. Educ. Res.* 19, 163–183. doi: 10.26803/ijlter.19.11.10

Sofologi, M., and Theofilidis, A. (2020). Music awareness and cognitive function. *J. Biol. Todays World* 9, 1–6.

Standely, J. M. (2008). Does music instruction help children learn to read? Evidence of a Meta-analysis. *Update: Appl. Res. Music Educ.* 27, 17–32. doi: 10.1177/8755123308322270

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *J. Exp. Psychol.* 18, 643–662. doi: 10.1037/h0054651

Talamini, F., Altoè, G., Carretti, B., and Grassi, M. (2017). Musicians have better memory than nonmusicians: a meta-analysis. *PLoS One* 12:e0186773. doi: 10.1371/journal.pone.0186773

Tierney, A., and Kraus, N. (2013). Music training for the development of reading skills. *Progress Brain Res.* 207, 209–241. doi: 10.1016/B978-0-444-63327-9.00008-4

Tsang, C. D., and Conrad, N. J. (2011). Music Training and Reading Readiness. *Music Percept.* 29, 157–163. doi: 10.1525/mp.2011.29.2.157

Vojtech, J. M., Noordzij, J. P. Jr., Cler, G. J., and Stepp, C. E. (2019). The effects of modulating fundamental frequency and speech rate on the intelligibility, communication efficiency, and perceived naturalness of synthetic speech. *Am. J. Speech Lang. Pathol.* 28, 875–886. doi: 10.1044/2019_AJSLP-MSC18-18-0052

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.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.