frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 25 August 2025
DOI 10.3389/feduc.2025.1613039

EDITED BY
Ariel Mariah Lindorff,
University of Oxford, United Kingdom

REVIEWED BY
Edgar R. Eslit,
St. Michael's College, Philippines
Efren De La Mora Velasco,
University of Central Florida, United States

*CORRESPONDENCE
Nurit Paz-Baruch
✉ nurit.paz@biu.ac.il

RECEIVED 16 April 2025
ACCEPTED 22 July 2025
PUBLISHED 25 August 2025

CITATION
Milman A and Paz-Baruch N (2025) The effect of preferred background music on mathematical performance of adolescents with mathematics difficulties.
Front. Educ. 10:1613039.
doi: 10.3389/feduc.2025.1613039

The effect of preferred background music on mathematical performance of adolescents with mathematics difficulties

Alex Milman and Nurit Paz-Baruch*

Science and Technology Education Program, Faculty of Education, Bar-Ilan University, Ramat Gan, Gan, Israel

Introduction: There is substantial evidence indicating the favorable influence of music on task performance; however, few studies have explored the specific impact of background music on mathematics achievements. This paper addresses the gaps in the existing literature and explores the effect of background music on adolescents' performance in mathematics. It also examines the impact of preferred background music on students' mathematical achievements.
Methods: Data were collected from 65 10th-grade students with difficulties in mathematics, who were randomly assigned to two study groups. All participants took three mathematics tests in algebra. The experimental group solved the tests under three different conditions: without background music, with background music, and with self-selected background music. The control group took the tests without background music.
Results: The results indicated that solving mathematics tasks while listening to self-selected background music enhances students' mathematical performance compared to solving mathematics tasks with predetermined background music or without any background music.
Discussion: These findings add to the theoretical literature regarding the impact of background music on students' mathematics achievements and provide practical guidance for mathematics educators in their discourse on students' mathematics learning in class. The findings underscore the necessity for further investigations to elucidate the underlying factors of the effects of background music on learning.

KEYWORDS

background music, mathematics achievement, difficulties in mathematics, adolescents, preferred background music

Introduction

Music plays a central role in human life, influencing cognition, emotion, and behavior through its melodic, rhythmic, and harmonic structures (Husain et al., 2002). These musical components engage multiple domains of human experience, including mental, emotional, and even physical facets, and are often used to enhance mood, concentration, and motivation (Portowitz et al., 2009).

Background music refers to music played while individuals are engaged in tasks or activities that are not related to the music itself. Research in various fields has shown that many students—from elementary to graduate school—habitually use background music while performing learning assignments (de la Mora Velasco and Hirumi, 2020; Lehmann and Seufert, 2017; Que et al., 2023).

There is substantial evidence indicating the favorable influence of music on the cognitive development, academic achievements, self-efficacy, and social aptitude of students (e.g., Lehmann and Seufert, 2017; Portowitz et al., 2009). Numerous studies have examined the impact of music on academic performance across diverse disciplines among students and adults (e.g., Azaryahu et al., 2020; Madjar et al., 2020; Stramkale and Timermane, 2020; de la Mora Velasco et al., 2023). These studies, however, have predominantly employed predetermined music, disregarding listener preferences.

Hitherto, few studies have explored the impact of background music specifically on mathematics achievements (Hallam et al., 2002; Taylor and Rowe, 2012). Previous studies addressed the need to examine the impact of background music on learning outcomes other than spatial skills (e.g., de la Mora Velasco and Hirumi, 2020). Furthermore, recent theoretical work has emphasized the need to consider both cognitive and emotional aspects of background music's impact on learning, calling for more comprehensive empirical research in educational settings (de la Mora Velasco and Moreno, 2025).

This study aims to fill the literature gap by investigating the contribution of background music to mathematics performance among high school students experiencing difficulties in mathematics. Additionally, although some studies have examined the effects of self-selected background music (e.g., Homann et al., 2023; Kiss and Linnell, 2021; Que et al., 2023), only a few have specifically focused on mathematics performance (see Cheah et al., 2022). More replication studies are needed to increase the knowledge of how self-selected background music impacts mathematical performance. This study examines how the choice of preferred background music impacts students' achievements in mathematical tests.

The following literature review will address theoretical models connecting background music and learning. It will present empirical studies examining the impact of background music on general academic performance. Finally, it will discuss studies that have explored the specific impact of background music on mathematics learning.

Literature review

Theoretical models connecting background music and learning

Several theoretical models have been proposed to explain the mechanisms through which background music may influence learning processes and outcomes. These models integrate cognitive, emotional, and contextual factors to account for the varied effects observed in empirical research. Hallam and MacDonald (2016) proposed a comprehensive framework describing how internal and external factors interact to influence the effects of background music on learning. Internal factors include learners' mood, arousal levels, attentional control, and working memory capacity, while external factors relate to the music itself—such as tempo, complexity, and whether it includes lyrics. Their model suggests that when background music aligns with the learner's emotional and cognitive state, it can enhance focus, mood regulation, and, ultimately, task performance. Their model aligns with Gagne (1985) conditions of learning, which distinguish between internal and external factors necessary to achieve different types of learning.

Similarly, de la Mora Velasco and Moreno (2025) proposed an integrative theoretical model based on a meta-analysis of research on background music and learning. Their framework further supports the differentiation between internal variables (e.g., learner preferences, mood, and prior knowledge) and external factors (e.g., music characteristics, task demands, and environmental context) in understanding the educational effects of background music. The authors emphasize the importance of aligning music with task characteristics and learner needs.

From a cognitive perspective, the Cognitive Load Theory (Sweller et al., 2011) offers another explanation for the inconsistent findings regarding background music. This theory suggests that because working memory is limited, background music can interfere with performance if it imposes an extraneous cognitive load, particularly in tasks requiring high mental effort. Background music may be a type of extraneous load in cases where it has a negative impact (Que et al., 2023). However, background music can be a low level of extraneous load that could motivate learners to devote more time to a learning task, potentially leading to positive effects on learning (Skulmowski and Xu, 2022).

The Arousal and Mood Hypothesis (Thompson et al., 2001) is another theory that discusses the effects of background music. It posits that background music influences cognitive abilities through the mediators of mood and arousal rather than directly influencing them (Husain et al., 2002). According to the Arousal and Mood Hypothesis, incorporating a preferred aural background enhances the interest in a learning task and increases learners' arousal levels and attention to the task (Muro and Murray, 2012). As a result, the student processes more information, which improves performance over time (Fedorikhin and Patrick, 2010). This theory is particularly relevant in contexts where learners select their own background music. Self-selected music may be more effective in regulating arousal and mood, as it reflects individual preferences and familiarity, which in turn enhances task engagement and emotional readiness for learning (Homann et al., 2023).

The impact of background music on academic performance

Research examining the impact of background music on task performance has shown enhancement in subjects' long-term memory, in results on intelligence tests, and in tests involving the speed of information processing and efficiency of verbal problem-solving (Bottiroli et al., 2014; de la Mora Velasco et al., 2023; Sala and Gobet, 2017). Listening to music can effectively aid concentration and focus, as students concentrating on the auditory stimulus apparently maintain high levels of motivation, interest, and engagement in lesson content (Portowitz et al., 2009; de la Mora Velasco and Hirumi, 2020). Individuals use self-selected background music to regulate their mood and to be more relaxed during various daily situations such as driving or traveling (Dibben and Williamson, 2007; Greasley and Lamont, 2011; Heye and Lamont, 2010; Rastogi and Silver, 2014).

A systematic review (de la Mora Velasco and Hirumi, 2020) on the effects of background music on learning reveals contradictory results, including positive, negative, or no effect. Few studies have explored the effects of background music on conceptual and procedural knowledge, problem-solving, and metacognitive skills (de la Mora Velasco and Hirumi, 2020; de la Mora Velasco et al., 2023). For example,(Bellier et al., 2020) study on medical students revealed that students who studied for an anatomy test with background music scored higher than those who studied without it. Another study (Stramkale and Timermane, 2020) involving first- and second-grade students compared their performance in reading comprehension tasks with and without background music. The findings demonstrated an improvement in the students' performance when music was played in the background as opposed to when it was absent. Kang and Williamson (2014) investigated the impact of background music on learning a second language. The participants who studied Chinese accompanied by background music achieved significantly higher results than those without it. However, no significant differences were observed between groups that studied Arabic with and without background music.

The beneficial effects of music have been demonstrated in several areas; however, the type of music, the volume at which it is played, and individual preferences all influence this effect (Bellier et al., 2020). As most research on the subject has focused on the effects of calming instrumental music, it is widely accepted that slow-tempo music (between 60 and 80 beats per minute) or classical music are most closely linked to these outcomes, especially when it is played quietly (Anyanwu et al., 2016; Bellier et al., 2020). Previous studies also addressed the positive effect of fast-tempo background music on students' performance and cognitive engagement. For example, EEG-based findings suggested that faster music increases inter-regional brain connectivity, indicating heightened cognitive and emotional engagement (Yang et al., 2025). Finally, fast music (around 140 beats per minute; BPM) has been shown to boost physical performance and reduce perceived fatigue during activity (Almeida et al., 2015).

Self-selected music appears to offer unique advantages over predetermined music in learning environments due to its emotional, cognitive, and motivational impact (Bidelman and Feng, 2025; Cheah et al., 2022). Research demonstrates that when individuals have autonomy in choosing the background music they listen to, they experience enhanced emotional engagement, increased focus, and reduced stress (Homann et al., 2023). For example, participants in a pulmonary rehabilitation study found that self-selected music enhanced their mood, relaxation, and enjoyment, which led to greater engagement in the training task (Lee et al., 2023).

Self-selected background music can help sustain optimal arousal and reduce mind-wandering, thereby lowering extraneous cognitive load and supporting task focus (Homann et al., 2023; Kiss and Linnell, 2021). In a study that utilized eye-tracking during reading tasks, students with high English proficiency or habitual background music usage showed reduced cognitive strain when listening to self-selected music, in contrast to those subjected to generic music (Que et al., 2023). Kiss and Linnell (2021) showed that preferred music increases task-focused attentional states, while Homann et al. (2023) found that it helps maintain engagement and reduces variability in performance across tasks of varying difficulty. However, overly complex or distracting music may increase cognitive load and impair performance, with effects influenced by task complexity, individual differences, and music preference.

The impact of background music on mathematics learning

Only a few studies have examined the contribution of background music to mathematics learning. Some of these studies revealed a positive effect of background music on arithmetic tasks (Hallam et al., 2002; Miller and Schyb, 1989). For example, Taylor and Rowe (2012) study revealed that students in trigonometry classes did statistically significantly better on a mathematics outcome assessment while listening to Mozart. Other studies revealed no significant differences in participants' task performance between music and no-music conditions (Chew et al., 2016). Some studies argued that background music can be a distractive element during tasks, particularly those demanding high concentration and involving multiple avenues of action, such as solving complex mathematical problems (Bottiroli et al., 2014). In such cases, background music may delay complex learning processes. In other words, the more complex the learning process, the greater the distracting and detrimental effect of background music.

Few studies have explored the impact of background music on enhancing mathematics performance to address some of the challenges faced by students with learning disabilities or difficulties (e.g., Gustavson et al., 2021). One study examined how auditory stimulation affects the arithmetic performance of children (ages 7.5–13) with and without attention-deficit/hyperactivity disorder (ADHD). The study revealed that including background music in tests led to improved results for children with ADHD (Abikoff et al., 1996). Another study investigated whether incorporating classical background music could enhance the behavior and academic achievements of children with behavioral and emotional issues. The findings indicated that integrating classical background music into lessons significantly improved students' performance in math assignments (Hallam and Price, 1998). Moreover, a study involving sixth-grade children with learning disabilities, attention disorders, and math difficulties found that incorporating classical background music during learning sessions contributed to improved students achievements (McKeever, 2017).

The literature review presented herein suggests that background music may impact academic performance, particularly when it is self-selected and aligned with individual preferences and task characteristics. However, as the specific effects of background music on mathematics learning remain underexplored, further research is needed to better understand its potential in this domain.

Purpose of the study

The purpose of the current study was two-fold: (a) to examine the effect of playing background music on the mathematics performance of high-school students with difficulties in mathematics; and (b) to examine the impact of preferred background music on students' mathematical performance.

Research questions and hypotheses

- What is the effect of background music on students' mathematics performance?

  We hypothesized that playing music in the background while solving mathematics tasks will enhance students' performance compared to solving mathematics tasks without any background music.
- To what extent is background music preferred compared to predetermined or no background music in terms of students' performance on mathematics tasks?

  We hypothesized that solving mathematics tasks while listening to self-selected music (i.e., their preferred music) in the background will enhance students' mathematical performance compared to solving mathematics tasks with predetermined background music or without any background music.

Method

Participants

The study was conducted in two large high schools of middle socioeconomic status, ranking 5 (on a scale of 1–10) on the School Nurturing Index[1] used by the Ministry of Education. Each of these schools had two classes of 10th-grade students enrolled in the 3-unit mathematics course level for instruction. Students study math in homogeneous course levels based on academic ability to prepare them for the mathematics matriculation examinations of 3–5 units, where the 3-unit class is the lowest course level. Each class comprised 28 to 34 students. The sample consisted of 65 10th-grade students aged 15–17 years (M = 15.55, SD = 0.56) with difficulties in mathematics. The students' mean score in mathematics was 67.54 (on a scale ranging from 0 to 100). All students confirmed that they had no learning disorders.

The students were randomly assigned to two study groups: an experimental group and a control group. The experimental group comprised 35 students (18 boys and 17 girls), and the control group comprised 30 students (15 boys and 15 girls). The students were divided into research groups in a balanced manner to ensure an approximately equal distribution, ensuring a balanced sample across the different classes and schools. The random assignment was performed only among students who had provided consent, and it was done manually using a simple randomization procedure within each class separately. Table 1 summarizes the number of students who agreed to participate in each class and how they were randomly assigned to the experimental group and control groups.

1 The school Nurturing Index is a socio-economic classification system used by the Ministry of Education to assess the socio-economic background of students in public schools. The index is based on several indicators, including parental education levels, income, employment status, and access to educational resources at home. It is typically presented on a scale from 1 to 10, where 1 indicates the lowest socio-economic status and 10 the highest

TABLE 1 Distribution of participants in experimental and control groups.

Class	Students who agreed to participate	Control group	Experimental group
School 1			
A	16 out of 30	8	8
B	18 out of 35	8	10
School 2			
C	14 out of 28	6	8
D	15 out of 29	8	9
Total		$N = 30$	$N = 35$

Tools

Demographic questionnaire

At the beginning of the study, students completed a demographic questionnaire to provide information about their age, gender, and academic scores in mathematics and language arts. Additionally, the participants were asked two questions regarding their music listening habits: (a) Do you listen to music during daily tasks? (b) Do you usually listen to music while doing homework and studying for school exams?

Raven's progressive matrices

Raven's Standard Progressive Matrix (The Raven's Test; Raven et al., 2000) involves a sequence of shapes, with one shape missing. Participants are required to select the correct shape from several options to complete the sequence. The test contains 60 items, comprising a series of diagrams or designs with a part missing. Items are presented in black ink on a page with a white background and become increasingly more challenging to solve as the participant progresses through each set. The time limit is 40 min. The score for each correct answer is one point, and for incorrect answers, zero points. The Raven's Test is a common component in IQ tests and is used to measure fluid intelligence, namely, the capacity to think logically and solve problems in novel situations, independent of acquired knowledge (Hunt, 2010).

Mathematics algebraic knowledge test

For the current study, three mathematics algebraic knowledge tests were administered to the participants. The questions were based on the high school algebra curriculum. The questions were sourced from tests and textbooks commonly employed in the instruction of algebra for high school students. Each test included five algebraic equations designed with the same level of difficulty. The questions' level of complexity increased as the participants progressed through each set of algebraic equations. The division of the math questions into three tests of equal difficulty was done by consulting four experts in mathematics: two academic professionals and two high school mathematics teachers. For each question in Test 1, a corresponding question was placed at the same difficulty level in Test 2 and Test 3, with only slight numerical alterations. The tests were administered to the participants with no time limit (Figure 1).

One-way repeated measures analyses of variance (ANOVA) were conducted to validate the three math tests and ensure they represented similar knowledge. The analyses revealed no significant differences between the three mathematics tests administered to participants in the control group, $F_{(2, 58)} = 0.24$, $p = 0.785$, $\eta_p{}^2 = 0.01$; $F_{(2, 58)} = 0.05$, $p = 0.953$, $\eta_p{}^2 = 0.00$. These findings validated the mathematics tests and indicated that the three tests were of a similar level. Cronbach's alpha reliability of the math tests was high ($\alpha = 0.73$). The test-retest reliability of the math tests ranged from $r = 0.57$ to $r = 0.65$ ($p < 0.001$).

Procedure

First, the researcher obtained approval from the school staff to conduct the study. Next, the school's mathematics teachers told the students about the study and asked them to participate voluntarily. The students were assured that their math scores at school would not suffer if they chose not to participate in the study. Furthermore, students could decide to withdraw from the study at any time. The students who wanted to participate asked their parents to sign a consent letter.

The researcher scheduled meetings with each student after school hours. The students were told that the purpose of the study was to test their algebraic knowledge and that their achievements would not be disclosed to any members of the school staff.

The study took place in four phases, after school hours. The first phase involved administering the Demographics Questionnaire and the Raven's Test. The second phase, Time Point 1 (T1), consisted of the pre-test, in which the participants were instructed to complete the math test without background music. In the third phase, Time Point 2 (T2), the students from the experimental group were asked to complete another test with background music predetermined by the researcher. The students in the control group completed the same test without background music. In the fourth phase, Time Point 3 (T3), the students from the experimental group were asked to complete another test with self-selected background music; namely, each participant chose and listened to music they liked. The control group students completed the same test without background music. The trials took place in a quiet classroom.

The volume of the music was set to the same medium level for all participants. The music was played at a uniform volume on a JBL® speaker connected to Spotify (Spotify Technology S.A., 2006).

The background music played in the second study phase was of high tempo—149 beats per minute (BPM)—and was in English. The music tempo was chosen following previous studies (i.e., Kämpfe et al., 2011; Yang et al., 2025), indicating that high-tempo background music has a positive effect on employee productivity. In the third phase, the self-selected music chosen by the students had an average tempo of 91 BPM. The music chosen by most of the students was rock, pop, and/or rap/hip-hop. Only one student chose jazz music.

Results

Preliminary analysis

No significant differences in the gender distribution were found between the two groups, $\chi^2_{(1)} = 0.01$, $p = 0.909$. T-tests for two independent samples indicated that the two study groups did not differ in age, $t_{(63)} = 0.61$, $p = 0.543$. The students' scores in mathematics and language arts at school were collected. No differences in students' scores were found between the two groups: math: $t_{(63)} = 1.07$; $p = 0.287$; language arts: $t_{(63)} = 0.20$; $p = 0.840$. Additionally, to make sure that the participants' general intelligence scores were normal, the Raven's Test was administered to the students. The scores were normal, ranging from 85 to 122 ($M = 102.75$, $SD = 10.34$). No significant differences in students' general intelligence scores were found between the two groups $t_{(63)} = 1.35$, $p = 0.183$. The general intelligence scores of participants in the experimental group ($M = 100.90$, $SD = 8.58$) were similar to those in the control group ($M = 104.34$, $SD = 11.52$; see Table 2). The effect sizes were calculated according to Cohen's (1988) *d*, and were interpreted according to conventional benchmarks, where values of 0.20, 0.50, and 0.80 represent small, medium, and large effects, respectively (Cohen, 1988).

A chi-square test of independence was performed to examine differences in the distribution of music listening habits between the two study groups. Table 3 shows that no significant differences were found in the distribution of music listening habits between the two study groups.

Shapiro-Wilk tests were conducted for each study group to examine whether the study measures were normally distributed prior to examining the research questions and hypotheses. The results indicated that the dependent variables (i.e., accuracy, performance time, and efficiency) in each study group deviated significantly from a normal distribution ($p < 0.05$). Therefore, we conducted non-parametric and parametric analyses. We used the Mann-Whitney and Wilcoxon tests as the non-parametric analyses. The Mann-Whitney test examined the differences between the two study groups in each study measure. The Wilcoxon test examined the differences between the two levels of mathematical problems in each study group.

As the findings and the significance level of the non-parametric analyses matched the findings of the parametric analyses, we presented the ANOVA findings and reported the mean and standard deviation instead of the mean and sum rank among each group. Moreover, the main effects of study group and time point (i.e., T1, T2, T3), as well as the significant results regarding the interaction between these two variables, were presented using the parametric analysis.

Effect sizes were calculated as partial eta squared (η^2_p) and interpreted using conventional thresholds: η^2_p values of 0.01, 0.06, and 0.14 indicate small, medium, and large effects, respectively (Lakens, 2013; Cohen, 1988).

$6(4\text{-}x)\text{-}(6\text{-}x) = 3x$ $\qquad \frac{4x}{15} + \frac{3x}{10} = 1$ $\qquad \frac{1}{2} - \frac{x}{x-1} = 0$ $\qquad \begin{cases} 5x - 2y = -2 \\ x + 4y = 4 \end{cases}$ $\qquad \begin{cases} 4x = 3y - 29 \\ 5y = 9 - 13x \end{cases}$

FIGURE 1
Examples of algebraic tasks.

TABLE 2 Mean, SD, and T-test values of students' age, general-intelligence, and school scores.

Measures	Control ($n = 30$)		Experimental ($n = 35$)		*t* values		
	M	*SD*	*M*	*SD*	*t*	*p*	*d*
Age	15.60	0.50	15.51	0.61	0.61	.543	0.16
General intelligence	100.90	8.58	104.34	11.52	1.35	.183	0.34
Mathematics score	66.67	4.01	68.29	7.37	1.07	.287	0.27
Language arts score	73.17	8.35	72.71	9.42	0.20	.840	0.05

d = Cohen's *d*.

Differences in accuracy, performance time, and efficiency in solving mathematics tests

Before examining the research questions and hypotheses, we examined whether there were significant differences between the two study groups in accuracy, performance time, and performance efficiency of the mathematics tests at the first time point (T1). As indicated in Table 4, two independent sample *t*-tests were performed to examine the differences between intervention and control groups of students in terms of accuracy, performance time, and efficiency. No significant differences were found between the two groups at T1, $t_{(63)} = 0.81, 0.82, 0.06$; $p = 0.421, 0.417, 0.955$, on accuracy, performance time, and efficiency, respectively.

Table 5 presents the results of the performance on mathematics tests of the two study groups. A two-way (3 × 2) mixed ANOVA was conducted on data from 65 participants (35 in the experimental group and 30 in the control group), with the group (experimental and control) as the between-subject factor and the time point (i.e., T1, T2, T3) as the within-subject factor. The results indicated significant main effects of group for accuracy, performance time, and efficiency. Bonferroni *post-hoc* analyses indicated that the accuracy, performance time, and efficiency scores of students in the experimental group were significantly higher than those of the control group at T2 and T3 compared to T1 ($p < 0.001$). As can be seen in Table 5, two-way interactions of group and time point were significant for accuracy, performance time, and efficiency.

The interaction between time point and group was significant, $F_{(3, 54)} = 11.28$, $p < 0.001$; $\eta_p{}^2 = 0.38$ (indicating a large effect size) of background music varied between groups. A one-way repeated measures ANOVA was conducted to examine the source of significant interaction between study groups and time point on the accuracy score, performance time, and efficiency for each study group. Examining the simple effects of the accuracy level in each group and at each time point indicated that among students from the control group, no significant differences were found in accuracy among the three math tests, $F_{(2, 58)} = 0.24$, $p = 0.785$, $\eta_p{}^2 = 0.01$ (indicating a small effect size). However, among the experimental group students, the differences in accuracy between the three tests were significant, $F_{(2, 68)} = 24.54$, $p < 0.001$, $\eta_p{}^2 = 0.42$ (indicating a large effect size). Bonferroni *post hoc* pairwise comparisons indicated that the accuracy scores of experimental group students were significantly higher at T2 compared to T1 (when they solved the test without music; $p < 0.001$). In addition, the accuracy score of the experimental group students was significantly higher at T3, in which they solved the test with the self-selected background music, compared to T1 and T2 ($p < 0.001$). In contrast, the control group's accuracy score remained stable ($p = 0.443$; see Figure 2).

The results regarding the simple effects of the students' performance time in each group and at each time point indicated that among students from the control group, no significant differences were found in performance time between the three math tests, $F_{(2, 58)} = 0.05$, $p = 0.953$, $\eta_p{}^2 = 0.00$ (indicating a small effect size). However, among the experimental group students, the differences in performance time between the three tests were significant, $F_{(2, 68)} = 19.32$, $p < 0.001$, $\eta_p{}^2 = 0.36$ (indicating a large effect size). Bonferroni *post hoc* pairwise comparisons indicated that the performance times of experimental group students were significantly shorter at T2 compared to T1, in which they solved the test without music ($p < 0.001$). In addition, the performance time of the experimental group students was significantly shorter at T3 when they solved the test with self-selected background music compared to T1 and T2 ($p < 0.001$). In contrast, the control group's performance time remained stable ($p = 0.443$; see Figure 3).

The results regarding the simple effects of the students' efficiency score in each group and at each time point indicated that among students from the control group, no significant differences were found in the efficiency score between the three math tests, $F_{(2, 58)} = 0.44$, $p = 0.647$, $\eta_p{}^2 = 0.01$ (indicating a small effect size). However, among the experimental group students, the differences in performance time between the three tests were significant, $F_{(2, 68)} = 13.19$, $p < 0.001$, $\eta_p{}^2 = 0.28$ (indicating a large effect size). Bonferroni *post hoc* pairwise comparisons indicated that the efficiency score of the experimental group students was significantly higher at T2 compared to T1, in which they solved the test without music ($p < 0.001$). In addition, the efficiency score of the experimental group students was significantly higher at T3 when they solved the test with self-selected background music compared

TABLE 3 Distribution of the participants' listening to music habits.

Listening to music habits	Response	Total ($n = 65$)	Experimental ($n = 35$)	Control ($n = 30$)	χ^2	p
During daily tasks	No	18 (27.7%)	7 (23.3%)	11 (31.4%)	0.53	.467
	Yes	47 (72.3%)	23 (76.7%)	24 (68.6%)		
Homework & studying for tests	No	18 (27.7%)	9 (30.0%)	9 (25.7%)	0.15	.700
	Yes	47 (72.3%) 47	21 (70.0%)	26 (74.3%)		

TABLE 4 Mean, SD, and *t*-values of students' scores on mathematics tests at T1.

Measures	Experimental		Control		*t* values		
	M	*SD*	*M*	*SD*	*t*	*p*	*d*
Accuracy (in %)	61.05	22.91	58.11	16.06	0.81	.421	0.21
Performance time (in seconds)	538.40	74.51	513.31	162.35	0.82	.417	0.20
Efficiency	199.47	60.99	197.80	152.97	0.06	.955	0.01

d = Cohen's *d*.

to T1 and T2 ($p < 0.001$). In contrast, the control group's efficiency score remained stable, ($p = 0.443$; see Figure 4).

We also examined the correlation between the BPM gap at T2 and T3, and the achievements gap at T2 and T3. No significant correlation was found, $r_{(33)} = -0.03$, $p = 0.872$. This confirms that the differences in students' performance between time points were not related to the BPM gap.

Discussion

The current study examined the effect of playing background music on the mathematics performance of high school students with difficulties in mathematics, and the impact of preferred background music on students' mathematical performance.

This study is unique, as only a few studies have explored the impact of background music on students' mathematical achievements, with most of the studies examining reading comprehension and other cognitive tasks (Bellier et al., 2020; Bottiroli et al., 2014; Chen and Wen, 2013; Hallam et al., 2002; Kang and Williamson, 2014; Patston and Tippett, 2011). No previous studies have investigated the impact of background music on students with difficulties in mathematics. Additionally, no direct studies have examined the impact of preferred background music on students' mathematical achievements. To investigate the research questions, a comparative analysis was conducted, comparing students' achievements in solving algebraic equations under three conditions: without background music, with background music selected for them, and with background music chosen by the students. Three algebra tests were administered to the students under the three study conditions.

The impact of background music on students mathematics performance

Consistent with the first hypothesis, the findings revealed that playing music in the background resulted in a significant increase in adolescents' performance on mathematics tasks. The results of this study are in line with previous research that considered music to be an important precursor for learning (Mohan and Thomas, 2020; Sahebdel and Khodadust, 2014). Previous studies also indicated that students who engage in mathematical and reading comprehension tasks while listening to background music outperform their peers in control groups (Abikoff et al., 1996; Hallam and Price, 1998; Madjar et al., 2020; Portowitz et al., 2009). These results can be explained by the Arousal and Mood Hypothesis (Thompson et al., 2011), which asserts that background music leads to increased psychophysiological arousal levels, in turn leading to a positive impact on the associated cognitive task. Our study suggests that the background music increased the students' levels of pleasure and enjoyment, subsequently leading to higher levels of accuracy in completing the algebraic tests.

Our study revealed that the performance time and efficiency scores of students in the experimental group were higher and more effective compared to those in the control group who completed the mathematics tests without music. These findings align with a previous study (Bottiroli et al., 2014) on the effects of background music on the task performance of adults, which indicated that the presence of upbeat as well as downbeat background music positively and significantly influences both performance and participants' mood. Our results also corroborate earlier studies showing the beneficial effects of listening to music on work productivity (Lesiuk, 2005; Lisa and Dwiyanti, 2022). Kämpfe et al.'s (2011) study revealed that activities carried out while listening to background music are influenced by the tempo of the music. The current study's findings contribute to existing theoretical knowledge by addressing the mathematics domain.

The findings of the current study support theoretical models that explain the mechanisms through which background music impacts learning processes. Our study results align with Hallam and MacDonald's (2016) framework, as the background music appeared to match the cognitive demands of the task and students' needs, thereby enhancing engagement in the mathematics tasks. Furthermore, our study supports de la Mora Velasco and Moreno's (2025) model, which emphasizes the importance of aligning background music characteristics with task demands and individual learner variables. It seems that the relatively low

TABLE 5 Mean, SD, and F-values of students' performance on mathematics tests.

Measures	Control		Experimental		F values (η_p^2)		
Time point	*M*	*SD*	*M*	*SD*	Time	Group	Interaction
Accuracy (in%)							
T1	58.00	16.06	61.02	22.91	13.12*** (0.17)	11.66*** (0.16)	8.57*** (0.12)
T2	60.00	21.00	72.30	23.22			
T3	60.00	20.34	77.94	21.90			
Performance time (in seconds)							
T1	538.40	74.51	513.31	162.35	14.26*** (0.19)	27.38*** (0.30)	12.79*** (0.17)
T2	536.23	63.28	417.77	101.99			
T3	534.40	56.30	370.23	102.08			
Efficiency							
T1	199.47	60.99	197.80	152.97	5.24** (0.08)	13.75*** (0.18)	8.58**(0.12)
T2	218.27	141.69	121.34	48.13			
T3	208.63	112.20	95.29	34.72			

**$p < 0.01$.
* * *$p < 0.001$.
η^2_p = partial eta squared; T1 = Time Point 1; T2 = Time Point 2; T3 = Time Point 3.

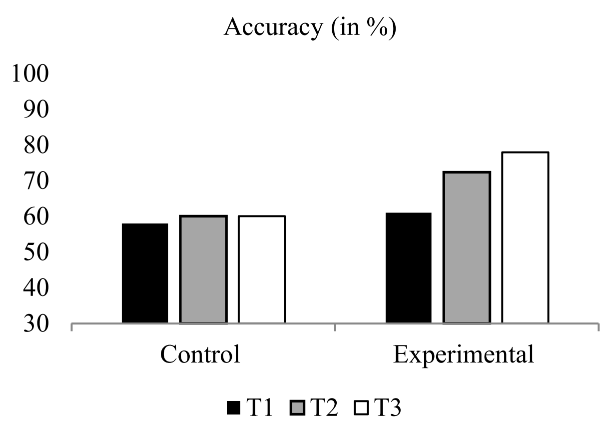

FIGURE 2
Accuracy (in %) on math tests by group and time point.

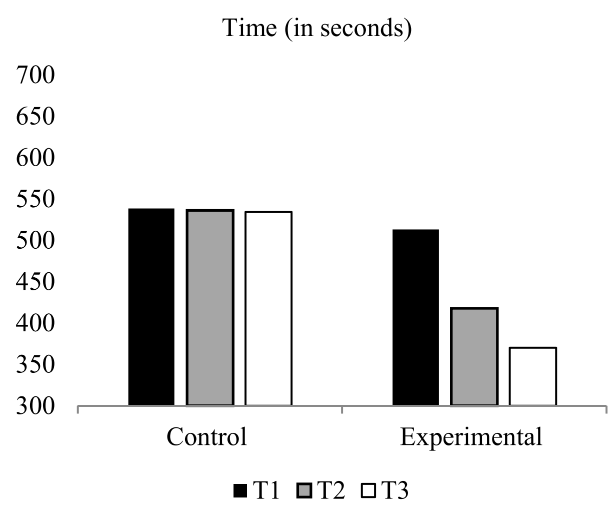

FIGURE 3
Performance time (in seconds) on math tests by group and time point.

cognitive demands of the equation-solving tasks used in our study, combined with the use of familiar and preferred music, created an optimal combination of external and internal factors, which likely contributed to students' enhanced performance. Finally, the improved task performance without apparent interference suggests that the background music did not impose excessive cognitive load, consistent with Cognitive Load Theory (Sweller et al., 2011), and may have helped reduce extraneous load, allowing learners to focus more effectively on the mathematics tasks.

The current study focused on students with mathematics difficulties, revealing that background music can be beneficial for these students. These findings align with some studies conducted among students with learning difficulties (Abikoff et al., 1996; Gustavson et al., 2021). Madjar et al.'s (2020) study revealed that 10-year-old children with ADHD benefit from reading while listening to background music. Children were assigned to one of four conditions (no music, calm music without lyrics, calm music with lyrics, and rhythmic music with lyrics). The results revealed that in the music conditions, accuracy significantly improved in the ADHD group, but decreased in the control group. The effects were greatest when listening to calm music with or without lyrics compared to rhythmic and more arousing music. The authors, therefore, suggested that background music has the potential to improve reading comprehension abilities in children with ADHD.

FIGURE 4
Efficiency (in seconds) on math tests by group and time point.

Our study's findings contradict those of Madjar et al. (2020) in that the rhythmic music in our study apparently assisted the students with difficulties in mathematics. As the current study examined students' performance on algebraic equations that usually do not demand high concentration, we suggest that further studies examine the impact of high-tempo background music on students' mathematics performance in other mathematics domains, such as complex mathematical problems.

The impact of self-selected background music on students' mathematics performance

The results supported our second hypothesis, indicating that solving mathematics tasks while listening to self-selected background music enhances students' mathematical performance compared to solving mathematics tasks with predetermined background music or without any background music. These results align with previous studies demonstrating improved performance among subjects who had the opportunity to select the type of background music accompanying their tasks compared to those who had music selected for them by others (Cassidy and MacDonald, 2009; Que et al., 2023).

The element of choice is significant in the present study, with findings clearly demonstrating that students benefit from the freedom to choose. It can be posited that offering students the opportunity to select their preferred music to accompany mathematics exercises reduces their anxiety and enhances their motivation. This hypothesis is supported by previous studies (Brigham, 1979; Mills and Krantz, 1979; Stotland and Blumenthal, 1964) indicating that the provision of choice and control over a decision diminishes stress and anxiety compared to situations where there are no options from which to choose. The findings also align with those of Keinan and Zeidner (1987), who examined the impact of choice on anxiety and achievement, finding that subjects provided with a decisional choice exhibited reduced anxiety levels and higher performance on a math test compared to subjects who had no choice. Brandt and Columba (2022) also corroborated these findings in a study showing the positive impact of the choice component on students' motivation levels. These findings could potentially be explained by Miller's (1979) theory, suggesting that choice enhances an individual's perceived sense of control over the source of stress. As the emotional aspect of music's effect on students' achievements was not specifically addressed in this study, further research might examine the contribution and impact of students' choice of music on mathematics anxiety.

Limitations, implications, and suggestions for future research

Several limitations should be considered. First, the study was conducted in two schools, and the sample size was relatively small. Future studies could examine the research questions with a larger sample size and should conduct a priori power analysis to determine the optimal sample size needed to detect significant effects, thereby better revealing the impact of background music on mathematics performance.

A second limitation of the study relates to the focus on a specific mathematical domain, namely algebraic equations. Algebra represents an abstract structural representation of numerical relationships that build upon arithmetic principles (Knops et al., 2006; Tolar et al., 2009). Mathematics encompasses various domains (i.e., algebra, geometry, word problems) that require different cognitive skills. For example, different results will likely be measured in a test involving verbal abilities that are necessary when solving word problems. In order to deepen the understanding of background music's impact on students' mathematics learning, future studies should focus on different domains of mathematical knowledge.

Gaining a clearer understanding of the contribution of background music to mathematics performance can be achieved by examining students' problem-solving strategies and their emotional experiences. In addition, exploring the long-term effects of background music during mathematics learning and problem-solving may provide valuable insights into its lasting impact on learning outcomes.

Another avenue for extensive research would involve eye-tracking technology, which can shed light on the cognitive processes involved in problem-solving tasks as they occur with and without background music (i.e., Que et al., 2023). Such studies can potentially contribute to developing intervention programs.

Finally, the present study evaluated the mathematics achievements of students exposed to rhythmic music. We suggest that future studies investigate the impact of different types of background music, such as calm or rhythmic classical music, with and without lyrics, as well as disentangle the effects of genre and tempo to better understand their respective roles. Furthermore, individual differences in music sensitivity and in how students process auditory stimuli during mathematical tasks may moderate the effects of background music and should be explored in future research.

The findings from this study provide important insights regarding the role of background music in mathematics. For practical purposes, the findings should be taken into consideration by mathematics educators in their discourse on students' mathematics learning in class. The results can be utilized in a school setting by using self-selected background music to help students practice mathematics. Furthermore, our findings can also be utilized for adaptive and personalized learning environments that respond to diverse learner needs and preferences. Allowing students to choose whether or not to listen to background music during learning may offer a flexible strategy that supports students' engagement and performance. We also suggest designing an intervention program for in-service educators on the use of music during mathematics learning, especially for students with difficulties. The program could serve as an innovative platform for students, providing a familiar and relaxing learning environment that may reduce the stress often associated with mathematics learning.

Data availability statement

The anonymized datasets generated during the current study are available from the corresponding author on reasonable request. Requests to access the datasets should be directed to nurit.paz@biu.ac.il.

Ethics statement

The study involving humans were approved by Human Subjects Institutional Review Board (HSIRB) at Bar-Ilan University. The study 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

AM: Validation, Data curation, Conceptualization, Project administration, Investigation, Writing – review & editing, Writing – original draft. NP-B: Writing – original draft, Writing – review & editing, Conceptualization, Project administration, Validation, Formal analysis, Methodology, Supervision.

Funding

The author(s) declare that no financial support was received for the research 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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