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Efficacy of music listening on mathematical performance

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Abstract. Although numerous studies have shown that background music improves the academic performance of adolescents, few have contrasted results based on their musical preferences or Mozart's compositions. A total of 185 adolescents between the ages of 12 and 17 (M = 13.63; SD = 1.26), 52.4% of whom were girls, participated in the study. The main objective of this study was to determine which styles have the most beneficial effect on mathematical performance in a sample of adolescent students. The groups were randomly assigned to one of two conditions: listening to their musical preference or to compositions by Mozart, while performing a mathematics test. The results show that boys perform significantly better in mathematics than girls. Likewise, there was a decrease in the time taken to perform mathematical tasks and the lower-performing students obtained greater benefit from music. Likewise, in the group that listened to their musical preference, there was a greater improvement in the girls and in contrast, in the group that listened to Mozart's music, this was manifested in the boys. It is considered that the optimization of arousal levels has improved attentional focus, which in turn has increased processing speed, enhancing efficiency in selecting information and finding more accurate answers, thus improving mathematical performance. Likewise, special attention is given to the fact that listening to music while performing mathematical tasks has helped students with poor mathematical performance to a greater extent. Due to its importance, this article expresses a position in favor of a greater recognition and presence of music at the curricular level in Compulsory Secondary Education.
Keywords: music listening; adolescents; mathematics; musical preferences; Mozart.

[sp] Eficacia de la escucha musical en el rendimiento matemático

Resumen. Si bien numerosos estudios han mostrado que la música de fondo mejora el rendimiento académico de adolescentes, pocos han contrastado resultados a partir de sus preferencias musicales o de composiciones de Mozart. Participaron en el estudio 185 adolescentes pertenecientes a los cursos de 1º a 4º de Educación Secundaria Obligatoria con edades comprendidas entre 12 y 17 años (M = 13,63; DE = 1,26) de las cuales el 52,4% eran chicas. El objetivo principal de este estudio fue el de conocer qué estilos de música tienen un efecto más beneficioso sobre el rendimiento matemático en una muestra de alumnado adolescente. Se realizó una asignación aleatoria de los grupos a una de dos condiciones: escuchar su preferencia musical o composiciones de Mozart mientras desarrollaban una prueba matemática. Los resultados muestran que los chicos obtienen significativamente mejores resultados en matemáticas que las chicas. Asimismo, se aprecia una disminución en el tiempo de ejecución de tareas matemáticas y que los estudiantes con rendimiento más bajo obtienen mayor beneficio con música. Igualmente, en el grupo que escuchó su preferencia musical se produjo una mayor mejora en las chicas y en cambio, en el que escuchó música de Mozart esta se manifestó en los chicos. Se considera que la optimización de los niveles de excitación ha mejorado el enfoque atencional, lo que a su vez ha incrementado la velocidad de procesamiento haciendo que aumentara la eficiencia para seleccionar información y encontrar respuestas más acertadas, redundando, de este modo, en el rendimiento matemático. Asimismo, se presta especial atención a que la escucha de música durante el desempeño de tareas matemáticas ha ayudado en mayor medida al alumnado con un pobre rendimiento matemático. A través de este artículo se manifiesta, debido a su importancia, una posición en pro de un mayor reconocimiento y presencia musical a nivel curricular en Educación Secundaria Obligatoria.
Palabras clave: escucha musical; adolescentes; matemáticas; preferencias musicales; Mozart.

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1. Introduction

The influence of music listening on academic performance has been extensively studied. When approaching this area, two well-founded areas of study should be reported: the use of musical preferences and that of Mozart's music. On this, we find an open debate in which some research shows that musical preferences improve academic outcomes by optimizing mood and arousal (Perham and Sykora, 2012), while others suggest that musical preference does not affect academic performance (Perham and Vizard, 2011). Likewise, some studies indicate that listening to Mozart's music helps to improve academic performance (Perlovsky et al., 2013), and increases the capacity for abstract (Rauscher et al., 1993) and spatial reasoning (Newman et al., 1995), since activating brain areas relevant to the performance of spatiotemporal activities improves learning (Jausovec et al., 2006) and temporal attention (Ho et al., 2007). In this regard, Husain et al. (2002) consider that the Mozart effect is generated by changes in arousal and mood. In fact, this music could be used as a background listening strategy, as it can favor optimal levels of both physiological and mood arousal, not requiring deep or conscious engagement with it (Schäfer et al., 2013). However, other authors have observed no change in IQ or reasoning ability in general, and that the effects that are seen affect performance in a specific type of cognitive tasks (Steele et al., 1999).

Seeking to expand knowledge in this area, this research is proposed as a chronometric study based on the time spent in solving mathematical tasks and on the accuracy of such performance, considering that both indicators can be useful to reveal differences in performance depending on the type of music that has been listened to during the resolution of arithmetic tasks. In this sense, processing speed is understood as the time in which a person can abstract and integrate knowledge to solve a problem (Kail, 1991) or as the skill in executing cognitive tasks in a fast and fluid way with sustained and focused attention (Schrank and Wendling, 2018). Similarly, sustained attention highly correlates with reasoning (Buehner et al., 2006). In the same way, processing speed is a predictor of reasoning (Kail et al., 2015) and one of the most determinant factors in the acquisition of mathematical skills (Floyd et al., 2003), which have a strong relationship with both performance in this subject and in computational automaticity (Taub et al., 2008). Besides, people with musical studies show significantly higher scores in fluid cognition than those without them, fluid intelligence being understood as the ability to think abstractly and to solve problems (Meyer et al., 2020).

Based on these findings, numerous studies have shown that background music improves performance in various academic disciplines, including mathematics. However, to the best of our knowledge, no studies have been conducted to contrast results based on the musical preferences of adolescents or on certain compositions by Mozart. In this sense, this article aims to address some of the gaps in the literature by exploring the effect of background music on adolescents' mathematical performance.

1.1. Perception and Music

Enjoyment of music varies nonlinearly as a function of the uncertainty experienced by the listener when anticipating a musical event, as well as the perceived surprise when it deviates from the expectations generated therein (Cheung et al., 2019). This idea suggests that much of the potential of music comes from the predictions it encompasses and develops in listeners (Huron, 2008). For example, when music with a given musical structure allows for relatively certain predictions, it turns out to be pleasurable (Salimpoor et al., 2011). More specifically, the pleasure of listening to music is linked to two interactions: uncertainty and surprise (Huron, 2019). According to Schmidhuber (2008), artistic beauty shares a common cognitive process with scientific knowledge, which consists in the successful encoding and decoding of compressible patterns. Thus, human beings understand the world through patterns, finding particularly pleasing those that are neither too simple nor too complex (Hudson, 2011). Particularly in the case of music, moderately complex fragments are preferred (Radocy, 1982). In this regard, Hudson (2011) considers that musical beauty, as in the deepest mathematical knowledge, can be found in pieces which turn out to be apparently complex, but are perceived as simple. In this sense, intermediate musical challenges are highly motivating and pleasurable, which favors the improvement of learning and attention in task performance (Brydevall et al., 2018).

Therefore, it appears that Mozart's music is shaped by an architecture of optimal complexity that stimulates and comforts the listener, allowing them to develop complex brain functions (Manca et al., 2020). Thus, listening to Mozart's music can increase sympathetic tone (Lin et al., 2014), activate cortical neural circuits related to attentional and cognitive functions (Verrusio et al., 2015), and decrease negative moods (Schäfer et al., 2013; Thompson et al., 2001). From this perspective, Thompson et al. (2001) consider that the underlying mechanism of the effects of listening to Mozart's music on academic performance takes place through increased arousal, which in turn leads to improved cognitive performance. In this sense, the term arousal usually refers to the level of physiological arousal or the degree of intensity of an emotional response (Sloboda & Juslin, 2001). Arousal and mood are factors that are related to the emotional response to a stimulus. Likewise, arousal and mood are known to positively affect cognition (Husain et al., 2002). More precisely, the influence of music on arousal and mood has been extensively studied (García-Rodríguez et al., 2021a; Gabrielsson, 2001; Peretz, 2001; Sloboda & Juslin, 2001). Consequently, the level of arousal and mood experienced when listening to music are determinants that influence cognitive skill performance (Husain et al., 2002). Hence, listening to music involves a broad spectrum of sensorimotor, cognitive, and emotional processes whose effects have significant implications in improving motor, affective or attentional disturbances (Vuilleumier & Trost, 2015). In this way, the neurobiological effects of listening to music point to the fact that auditory stimulation evokes emotions that are related to a higher level of arousal, resulting in better temporal performance in multiple cognitive domains (Pauwels et al., 2014). In contrast, other research indicates that the presence of background music acts as a distractor that negatively influences academic performance (Furnham & Strbac, 2002). Particularly, some research considers that pop music (Furnham & Bradley, 1997) or garage style (Dobbs et al., 2011) generate a distracting effect that negatively affects the performance of various cognitive tasks.

1.2. Music and Mathematics

Music and mathematics have a very close relationship and, over time, the numerous connections between these subjects have been emphasized. Both disciplines use specific notation systems (Wollenberg, 2006). Kashyap (2020) considers music and mathematics as two dialects of the same language, where the presence of musical elements such as pitch or volume in mathematics support the relationship between these two disciplines (Shea & Remington, 2018). Moreover, the analysis of symbolic and pattern representation present in music and mathematics provides insight into the close structural affinity existing between both disciplines (Bahr & Christensen, 2000). From this perspective, it is plausible to consider that the transfer of skills between two closely related areas can be successful. For this reason, Moreno et al. (2011) showed that thanks to music, it is possible to carry out the transfer of an untrained high-level cognitive skill, since this transfer occurs because of a deep structural similarity of domains (Bahr & Christensen, 2000). Moreover, other studies show the effectiveness of musical training in improving general intelligence (Rickard et al., 2012) and mathematics (Mehr et al., 2013) in children and young adolescents (Rickard et al., 2012). Similarly, musical practice reveals an improvement in general cognitive capacity including memory, attention, and executive functions (Meyer et al., 2020). Following this line of analysis, Blasco-Magraner et al. (2021) conclude that music should be used in the school environment, not only because of its importance, but also as a transversal tool in other subjects.

Similarly, the positive influence of music listening on certain factors during academic performance has been widely documented. In this sense, it has been reported that music listening significantly improves behavior and mathematical performance (Hallam & Price, 1998). Schellenberg and Hallam (2005) found that the positive effects of music listening on cognitive skills are more evident when the listener enjoys the music. In addition, listening to background music before performing a task facilitates cognitive processes such as attention and memory, through the mechanism of increased arousal and positive mood (Perham & Vizard, 2011). In like manner, listening to music perceived as pleasant helps students manage stress and perform complex tasks (Cabanac et al., 2013). Following this argumentation, some research indicates that background music can calm and focus children (Črnčec et al., 2006), thus enhancing learning (Cabanac et al., 2013; Črnčec et al., 2006). Specifically, listening to music perceived as calming and relaxing produces better results in arithmetic performance (Hallam et al., 2002

1.3. Mathematical performance and gender

Another important aspect to take into consideration is the gender variable with respect to academic performance. Studies such as Hyde's (2005), maintain the hypothesis about gender similarities in relation to academic skills. In line with this research, Kiuru et al. (2009) found no significant differences between the academic performance of adolescent boys and girls. However, numerous studies have found gender differences that show that girls, in general, show better academic performance (García-Rodríguez et al., 2021b; Hernando et al., 2012), with results decreasing in both sexes throughout adolescence, although more markedly among boys (Hernando et al., 2012). Concerning mathematical performance, some research did not find gender differences in this area (Hyde, 2005; Rodríguez et al., 2020) although another did find better performance in arithmetic tasks by girls (Ramírez et al., 2016). Nevertheless, another large group of studies show higher performance in mathematics by boys (Ceci et al., 2009; Gridley, 2006).

Thus, the main objective of this study was to find out which music styles have a more beneficial effect on academic performance in a sample of adolescent students. For this purpose, individual and group performance environments and gender differences were considered. Also, in accordance with the results of previous research in mathematical performance and music listening, the following hypotheses were posed:

- H1: Music listening increases the level of arousal and thus may act as an activator that would improve performance.
- H2: The level of arousal is lower in students with poor mathematical performance, so music could affect these people to a greater extent with a higher increase in their performance.

H3: Mozart's music is less distracting than adolescents' musical preferences, and therefore should have a greater positive impact on mathematical performance.
H4: Girls perform worse in mathematics, so listening to music during academic tasks would affect their mathematical performance more positively than that of boys.

2. Materials and method

2.1. Participants

A total of 185 adolescents with typical development participated in the study, without applying any exclusion criteria, belonging to grades 1 to 4 of ESO, aged between 12 and 17, with a mean age of 13.63 (*SD* = 1.26), of whom 52.4% (97) were girls. It should be noted that all 4th year ESO students who participated in the study took the same type of mathematics at the curricular level, regardless of the elective subjects they were taking at that time.

2.2. Ethical approval

Following the indications of the educational center, informed consent was obtained from all the adults responsible for the adolescents prior to the start of the study. This research was carried out in accordance with the ethical standards established in the Declaration of Helsinki (W.M.A., 2001) and was approved by the Ethics Committee of the Faculty of Psychology of the Complutense University of Madrid (Pr_2019_20_045).

2.3. Procedure

Before participating in the study, teachers, students, and families were informed (according to the indications of the educational center) about the content, non-binding academic nature and procedure of this research. Subsequently, the academic results in mathematics during the first two terms of the 2020/2021 school year were analyzed. Students were randomly assigned to one of two conditions. The first group (Group A [Class A]) listened to their musical preferences while the second group (Group B [Class B]) listened to Mozart's compositions in the order listed in Table 1. The students in Group A listened with headphones to their musical preferences included in a playlist that they freely selected based on their musical tastes (BSO [Original Soundtracks], Indie, Electronic Music, Latin Music, Pop, Rap, Reggaeton, Rock or Trap) while in Group B all the students listened to the selected Mozart's pieces as background music. In addition, all students remained in their reference class groups regardless of their level of performance in mathematics or gender. Data collection was carried out in a single session and during school hours. The tests were conducted one week after the conclusion of the second term final exams with the intention of avoiding the negative influence that stress or fatigue can generate on academic performance (Paloș et al., 2019). Similarly, since it is known that time pressure can function as a stressor able to trigger anxiety during the execution of academic tasks as well as influence optimal strategy selection and, consequently, lower mathematical performance (Caviola et al., 2017), no time limit was established for the resolution of the tasks posed. Finally, before taking the test, participants were reminded that their collaboration was voluntary and that anonymity and confidentiality of both their identity and their results would be maintained, as well as the possibility of giving up the test if at any time they considered it appropriate.

2.1. Stimuli and measures

Musical stimuli. The Mozart music selected for the participants in this research was as detailed below in Table 1.

Table 1. Mozart's pieces heard during the test (Group B)

Work	Tempo	Tonality	Instrumentation	Duration
Andante of the concerto for piano and orchestra nº 21 in C Major K. 467	Andante	F Major	Solo piano, strings, a flute, two oboes, two bassoons, two horns and timpani	6.05 min
Adagio of divertimento nº 15 in B flat Major K. 287	Adagio	Eb Major	Strings and two horns	7.20 min
Adagio for violin and orchestra K. 261	Adagio	E Major	Solo violin, strings, two flutes and two horns	7.19 min

The characteristics of these musical excerpts were selected in consideration of previous research findings indicating that the tempo factor in music influences arousal (Gagnon & Peretz, 2003; Kuribayashi & Nittono, 2015; Liu et al., 2018), specifically that fast tempos increase arousal and reduce enjoyment (Garrido et al., 2019) or that performance is superior when music is in major keys (Husain et al., 2002). Next, the musical styles that the students in Group A voluntarily chose to listen to are detailed in Table 2.

Table 2. Musical preferences heard during the test (Group A)

Musical style	*Frequency*	*Percentage*
BSO (Original Soundtracks)	5	5,2
Indie	1	1,0
Electronic music	2	2,1
Latin Music	3	3,1
Pop	34	35,4
Rap	11	11,5
Reggaeton	16	16,6
Rock	6	6,3
Trap	18	18,8
Total	96	100,0

Measures of academic performance. As measures of academic performance, the official grades in the subject of mathematics obtained by the research participants in the first two terms were used. Likewise, four tests of mathematical ability were developed ad hoc, adjusted to the contents taught at each level during those periods of the 2020/2021 academic year. It is important to note that the contents of both the official tests and the one conducted with music correspond to the official contents established in the programs of each course. Finally, the tests designed for the study were validated in relation to the content by a system of judges formed by teachers of the subject of mathematics, who verified the suitability of the contents of each ESO course, the formulation of the questions and the accuracy of the statements.

3. Analysis and Results

Figure 1 below shows significant improvement in the results obtained in the mathematics tests that were performed while listening to music in relation to those that were performed silently in the first and second terms.

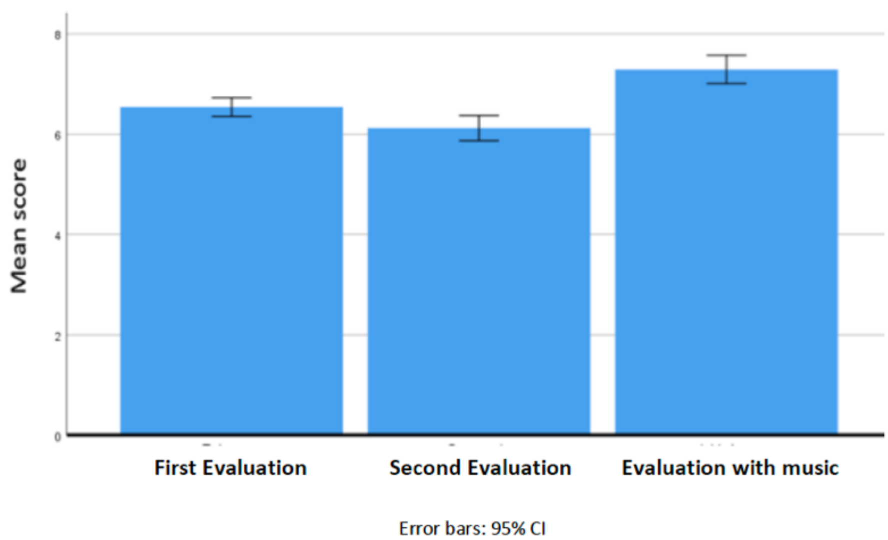

Figure 1. Comparative results of the different mathematics tests

Likewise, analyzing the data shown in Figure 2, it is observed that students with low performance (lower academic grades), both in groups A and B, are those who obtain an advantage when taking the test with music. In the same way, high-performing students maintain their level of performance, without being affected either positively or negatively by music.

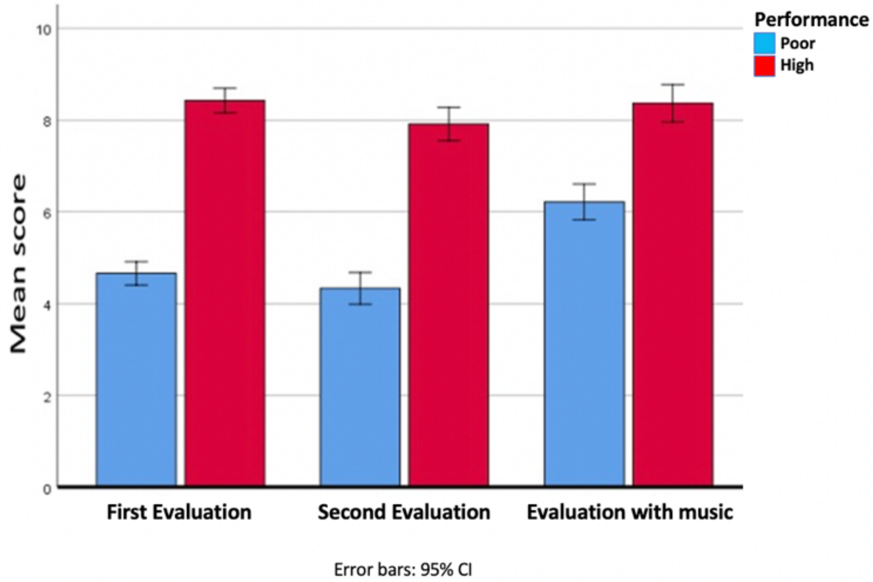

Figure 2. Comparative results of the different mathematics exams of the first and second terms, and of the test carried out with music

Next, a repeated measure analysis of variance (ANOVA) was performed for the dependent variable (mathematical performance) of three exams during the 2020/2021 academic year, T1 (1st term exam), T2 (2nd term exam) and T3 (test with music). In this case, the independent variables were gender and group. At the beginning of the research, the groups were assigned to two random conditions: Group A, who chose the music they would listen to during the test and Group B, which listened to Mozart's music. Finally, the covariate was taken as the time in minutes that they used to perform the mathematics test. The results of the ANOVA are shown in Tables 2 and 3.

Table 3. Multivariate test results for mathematics

Effect	Value	F	df1	df2	p	Etap2
Mathematics	0.109	10.997	2	179	<0,001	0.109
Mathematics*Time	0.083	8.088	2	179	<0,001	0.083
Math*Sex	0.014	1.261	2	179	0.286	0.014
Mathematics*Group	0.016	1.492	2	179	0.228	0.016
Mathematics*Sex* Group	0.037	3,461	2	179	0.034	0.037

Note: The results correspond to the Pillai Trace statistic, although the significance was identical for wilks' Lambda, Hotelling's Trace and Roy's Major Root statistics.

Table 2 shows that there were statistically significant differences (p <.001) between the three mathematics assessments and that this effect interacted with performance time (p <.001). There was no interaction between mathematical performance by gender or by music assignment group (A and B). However, in Table 3, in relation to the overall intrasubject effects in the three assessments, differences were observed in relation to sex. In addition, a triple interaction was observed, which will be discussed later after the analysis of the intrasubject effects.

Table 4. ANOVA results of inter-subject effects tests

Origin	Type III Sum of Squares	df	Mean Squares	F	p	Etap2
Time (min.)	230.000	1	230.000	30.024	<0,001	0.143
Sex	42.581	1	42.581	5.559	0.019	0.030
Group	8.592	1	8.592	1.122	0.291	0.006
Sex*Group	0.088	1	0.088	0.011	0.915	<0,001
Error	1378.891	180	7.661			

The intersubject effects show that randomly assigned groups A and B showed similar performance in mathematics, with a measure with a mean of 6.5 in group A vs. 6.4 in group B (p =.29), with performance by gender being statistically significant, with girls' mean of 6. 1 versus 6.7 for boys (p =.019) and with a large effect size ($\eta 2p$ > 0.140), the effect of music on performance time was statistically significant (p <.001) with a one-point improvement between the silent assessment and the assessment with music. Similarly, the correlation between mathematical performance and execution time (time in minutes) was -.356 (p <.001), which would explain almost 12.67% of its variance.

Finally, regarding the triple correlation in the multivariate test's mathematical performance x sex x group (p =.034), we observe that while in Group A (those who used their musical preferences) the improvement only occurs in girls, in Group B (Mozart's music) the improvement is more intense in boys with a gain of almost one point (from 7 to 8 points). On the other hand, if we analyze the correlation patterns with respect to processing time, the high negative correlation between time and mathematical performance would be influenced by gender, being very strong in the case of boys r = -.522 (p <.001) and much weaker for girls r = -.222 (p =.038).

3. Discussion

This study has deepened our understanding of the use of musical preferences, or Mozart's music, in association with the mathematical performance of adolescents aged between 12 and 17, as well as the possible moderating role of gender in relation to performance in this subject. With respect to the first hypothesis (Listening to music increases the level of arousal and therefore may act as an activator that would improve performance), it is confirmed since a significant improvement is observed in the results obtained through the mathematics tests that have been performed listening to music, in relation to those that were performed in silence. Thus, our results agree with those studies which reviewed that listening to music helps students to perform complex tasks (Cabanac et al., 2013) and facilitates the focus of attention during task performance (Črnčec et al., 2006), improving learning (Cabanac et al., 2013; Črnčec et al., 2006); particularly in the performance of arithmetic performance (Hallam & Price, 1998; Hallam et al., 2002).

Likewise, the second hypothesis (The level of arousal is lower in students with poor mathematical performance, so music could affect these people to a greater extent) is confirmed, since listening to music has mainly helped students with lower mathematical performance. On this particular, it is plausible to consider that background music listening has facilitated the improvement of attention (Perham and Vizard, 2011; Vuilleumier and Trost, 2015) and memory thanks to mechanisms such as increased arousal and positive mood (Perham & Vizard, 2011), and that such positive auditory stimulation would influence a higher level of arousal, resulting in better temporal performance in a specific cognitive domain such as mathematics problem solving (Pauwels et al., 2014; Thompson et al., 2001). On this basis, in consideration with the literature consulted, we consider that the characteristics of the selected musical excerpts by Mozart, mainly the tempo, have been a key factor in the results achieved as it is likely that they positively affected arousal regulation (Gagnon & Peretz, 2003; Kuribayashi & Nittono, 2015; Liu et al., 2018) or that, in addition, the academic performance has been superior because the music was composed in major keys (Husain et al., 2002). In this regard, the modality of music has been studied as a reliable indicator of mood (Husain et al., 2002; Thompson et al., 2001). Similarly, it is known that tempo can induce changes in arousal and is thus related to different levels of arousal (Gabrielsson & Lindström, 2001). In short, from our results we consider that when music listening generates in listeners a moderate level of arousal, which could be achieved with Mozart's music, it positively influences cognition in low-achieving students in mathematics. However, we believe it is necessary to continue research in this area to delimit precisely which factors are those that fundamentally determine the level of arousal or mood in listeners and, in turn, which of them are more effective in cognitive performance.

However, the third hypothesis (Mozart's music is less distracting than adolescents' musical preferences and therefore should have a greater positive impact on mathematical performance) is partially confirmed. In this sense, and based on the results achieved, we consider that, indeed, the music by Mozart used in this study has offered adolescents highly motivating intermediate musical challenges that have favored the improvement of attention in the execution of specific tasks (Brydevall et al., 2018) by students with lower mathematical performance. In this regard, and in line with other research, we consider that certain musical works by Mozart are formed by an ideal degree of structural complexity that stimulates and allows the development of complex brain functions (Manca et al., 2020), improves academic performance (Perlovsky et al., 2013) and increases the capacity for abstract (Rauscher et al., 1993) and spatial reasoning (Husain et al., 2002; Newman et al., 1995). In this sense, it is also praiseworthy to consider that Mozart's music enhances the activation of relevant brain areas linked to the performance of spatiotemporal activities (Jausovec et al., 2006) and temporal attention (Ho et al., 2007). In like manner, we understand that the selected pieces by Mozart have generated changes in the levels of arousal and mood (Husain et al., 2002; Schäfer et al., 2013) of adolescents and that this, in turn, has had a positive impact on concentration and improved academic performance. Thus, we consider that the inclusion of Mozart's music could be an educational strategy during the development of certain academic activities. Regarding listening to musical preferences while performing mathematical tasks, the results of the present study do not support those of other research showing that the presence of background music acts as a distracting element that negatively influences academic performance (Furnham & Strbac, 2002); specifically, with those studies indicating that certain styles of music, frequently listened to by adolescents, generate a distracting effect that negatively affects the performance of various cognitive tasks (Dobbs et al., 2011; Furnham & Bradley, 1997). In short, in accordance with other studies, from our results as well as Perham and Vizard's (2011), we have not found that musical preference negatively affects academic performance. Although the difference between the groups is not significant, however, the interaction with the sex variable is significant. In this sense, we believe that this finding, as far as we know, is novel and very important because it allows us to realize how musical styles can affect girls and boys differently.

Specifically, when we compare male and female participants with respect to the fourth hypothesis (Girls perform worse in mathematics so listening to music during academic performance tasks would affect their mathematical performance more positively than boys), it is also confirmed since although some of the research consulted either found no gender differences in this area (Hyde, 2005; Rodríguez et al., 2020) or did so in favor of better mathematical performance by girls (Ramírez et al., 2016), our results correlate with those of studies showing better results by boys (Ceci et al., 2009; Gridley, 2006).

In short, performing mathematics exercises in the presence of music has a positive effect that is evidenced both in better results and in shorter execution time. These findings agree with those of other studies that consider that it is indeed possible to carry out the transfer of high-level, untrained cognitive skills between two closely related areas, as in the case of music and mathematics (Kashyap, 2020; Shea & Remington, 2018; Wollenberg, 2006), thanks to an important structural similarity of domains (Bahr & Christensen, 2000; Moreno et al., 2011). Consequently, knowing which musical styles favor the development of mathematical skills and abilities in adolescents can provide valuable information to understand the influence of music in this domain. In this sense, we consider that increasing the understanding of this association, music, and mathematics, during adolescence and how this may differ between genres may be important to promote educational strategies that allow a positive adjustment in the mathematical performance of adolescents. In summary, we consider that other studies that specify the different musical genres and their influence on mathematical performance can be derived from this research.

Although this research, to the best of our knowledge, contributes novel data to the literature, it has some limitations. One of them was the design, as it did not include specific non-music control groups. In future research, it is essential to replicate this type of study both with students with functional diversity and in larger samples and with a wider age range that will allow us to know the influence of Mozart's music to understand the possible transfers in mathematical performance. Similarly, since previous studies have reported that the relationship between the demographic variable age and mathematical performance is weak, and that this variable contributes modestly to the prediction of adolescent mathematical skills, it is considered important to replicate this study longitudinally.

As it is well known, although educational research in natural contexts provides greater ecological validity than experimental studies conducted in laboratories, it does not allow complete control of contaminating variables, which in this case have raised new research questions or secondary hypotheses to be investigated in future studies. For example, the tests were conducted one week after the conclusion of the second term final exams with the intention of avoiding the negative influence that stress or fatigue can generate on academic performance (Paloș et al., 2019). Moreover, given that time pressure can be a stressor able to trigger anxiety during the execution of academic tasks, influencing optimal strategy selection and, consequently, causing lower mathematical performance (Caviola et al., 2017), in this study a time limit for the tests was not established. In addition, the non-binding academic nature of the test with music could have made the student body face the test with less stress and more adjusted levels of arousal, and this redounded positively to the results. Similarly, to contrast the results of the study, the official assessment scores were used as a measure of performance. In this sense, it is known that, in addition to exam grades, teachers use other grading criteria (daily work, attitude, notebook, etc.) that can increase the final grades. Taking all these considerations into account, it is plausible to suppose that the results achieved have been even more significant since in the exercises performed with music there was no other factor that could have increased the final grade. On the other hand, the results obtained show that the gender variable seems to be an important factor on which to continue investigating the relationship between the use of different music styles while performing mathematical tasks in educational contexts. To sum up, in addition to the music used, these variables could perhaps have influenced the results of the study, so we believe that further research is needed in this area.

In conclusion, from this study we argue that music can be used in educational contexts not only for its own intrinsic value, but also as a highly effective resource that can be used transversally in other subjects (Blasco-Magraner et al., 2021). As reinforcement to these arguments, we appeal to the results of previous research showing that musical training improves the general intelligence of adolescents (Rickard et al., 2012) and mathematics (Mehr et al., 2013). Ultimately, we believe that the music employed, including adolescents' musical preferences, has had a role in increasing sustained attention, processing speed, and fluid cognition, which have in turn favored mathematical performance (Buehner et al., 2006; Floyd et al., 2003; Kail et al., 2015; Meyer et al., 2020; Schrank & Wendling, 2018; Taub et al., 2008). Furthermore, from these results, we support the hypothesis of Thompson et al. (2001) that the underlying mechanism of the effects of music listening on academic performance is due to increased arousal, which then leads to improved cognitive performance. This is particularly true in the case of Mozart's music.

From this perspective, we consider that listening to music while solving mathematical problems has generated a series of concatenated effects that have positively redounded to performance in this subject. In this sense, we believe that this process has occurred thanks to the fact that optimizing the levels of arousal has improved attentional focus, which in turn has increased the speed of processing, raising efficiency in selecting information and finding the most accurate answers, thus enhancing mathematical performance. Finally, we would like to pay special attention to the fact that listening to music while performing mathematical tasks has helped students with poor mathematical performance to a greater extent. Regarding the triple correlation between mathematical performance, sex, and musical preference, in the group that listened to their musical preferences (Group A), the improvement only occurred in girls, while in the group that listened to Mozart's music (Group B), it was more intense in boys. On the other hand, the correlation patterns with respect to processing time, the high negative correlation between time and mathematical performance would be influenced by gender, being very strong in the case of boys. From these results, it is plausible to consider that this difference shows indications about the differentiating patterns between girls and boys regarding the type of music that correlates with the different states of activation: higher in boys than in girls, so that the benefit would be greater in girls, especially when they choose music of their preference, causing a more relevant activating effect. In the same way, we consider that the use of music listening during academic tasks can benefit both the regulation of arousal levels and the attentional focus of students with specific educational support needs or with certain disorders such as, for example, ADD or ADHD. All in all, we would like to express a position in favor of a greater recognition and presence of both music listening and instrumental practice at the curricular level in Compulsory Secondary Education.

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