Sensitivity to Social Reward in Music Behavior Changes After Music Training in Preadolescence

Mariangela Lippolis[1], Giulio Carraturo[1], Laura Ferreri[3], Peter Vuust[2], Daniel Müllensiefen[4], Benedetta Matarrelli[1, 2], and Elvira Brattico[1, 2]

[1] Department of Education, Psychology, Communication, University of Bari Aldo Moro, Bari, Italy

[2] Center for Music in the Brain (MIB), Department of Clinical Medicine, Aarhus University & The Royal Academy of Music Aarhus/Aalborg, Aarhus, Denmark

[3] Department of Brain & Behavioral Sciences, University of Pavia, Pavia, Italy

[4] Goldsmiths, University of London, Department of Psychology, London, UK

ABSTRACT

During the last decades, a growing body of research on musical pleasure has shed light on individual differences and mechanisms underlying music reward sensitivity. Music training has been identified as a factor able to affect the rewarding experience associated with music, although in the existing literature, evidence on children is scarce. The current study focused on the effects of music training and individual musical engagement on sensitivity to music reward in preadolescence. One hundred and forty-two students (aged 10-14 years) at three different Italian music middle schools were tested three times over a period of one year and a half. Eighty two children belonged to a music curriculum within the school and 60 belonged to a standard curriculum. The Barcelona Music Reward Questionnaire (BMRQ), a multi-dimensional assessment tool to measure music reward sensitivity, was used, and pre-existing differences in music sophistication were controlled for. Moreover, in addition to the between-group comparison, highlighting the formal music training variable, the actual amount of musical activities and engagement both in and out of school was also taken into account. Several positive effects in terms of music social reward were found for students with a high level of musical engagement. Also, results showed a main effect of gender, with girls showing higher scores than boys in total BMRQ score and in several subdomains. Taken together, these data provide new evidence for the special role played by collective musical activities and suggest that music training may be able to promote social connection in preadolescence.

OPEN DATA

KEYWORDS

music reward
music training
preadolescence
musical abilities
social development

Music is one of the greatest human pleasures (Vuust & Kringelbach, 2010; Zatorre, 2015). It has accompanied human beings since ancient times and from childhood throughout their lifespan, providing people with an assortment of possibilities to feel joy and fulfillment in everyday life (Brattico et al., 2013; Brattico & Pearce, 2013; Juslin, 2016; North & Hargreaves, 2004). The rewarding experience associated with music ranges from individual listening to music or playing a musical instrument (e.g., Mas-Herrero et al., 2012), to all the opportunities for social gathering such as dancing, attending a concert, or singing in a choir and/or playing in a group (Cross, 2001; Koelsch, 2014).

Thanks to its intrinsic power to induce emotions and aesthetic judgments in people, notably, enjoyment and liking, music has often been associated with enhanced mood, cognitive abilities, happiness, and quality of life (Brattico & Varankaitė, 2019; Daykin et al., 2018; Matarrelli et al., 2023) in both healthy and pathological populations (DeNora, 2016). This explains why people use music to regulate their mood and why music listening is one of their most common activities (Cook et al., 2019; Huron, 2008; Reybrouck et al., 2021). Furthermore, music is able to promote emotions of social connection, particularly interpersonal trust and bonding (Koelsch, 2014; 2020; Moss et al., 2018), leading some authors to argue that the social dimension of music is the prime reason why we find music enjoyable (Nummenmaa et al., 2021).

In sum, music reward is a heterogeneous and multifaceted construct, largely varying among individuals. The Barcelona Music Reward Questionnaire (BMRQ; Mas-Herrero et al., 2012) is a tool designed to measure individual sensitivity to music reward and all its forms. It assesses individuals' musical reward sensitivity through five subscales, determining the global BMRQ score: musical seeking, emotion evocation, mood regulation, sensory-motor behavior, and social reward. In the last decade, the introduction of the BMRQ significantly contributed to promoting interest and empirical investigations on individual differences and mechanisms underlying

Corresponding author: Mariangela Lippolis, University of Bari Aldo Moro, Department of Education, Psychology, Communication, Piazza Umberto I, 70121 Bari, Italy. E-mail: m.lippolis9@studenti.uniba.it

DOI • 10.5709/acp-0409-z

musical reward sensitivity. This tool provides a fine-grained description of reward sensitivity, ranging from individuals presenting high reward sensitivity values to others showing an inability to experience pleasure, a phenomenon known as musical anhedonia (Zatorre, 2015).

Studies employing BMRQ have revealed that music reward sensitivity is associated with several psychological variables, such as empathy, age, personality traits, and gender (Carraturo et al., 2022; Fuentes-Sánchez et al., 2021; Mas-Herrero et al., 2012; Wang et al., 2021) as well as with physiological (skin conductance) and neural (mainly dopaminergic mesolimbic reward system) outcomes (see e.g., Martínez-Molina et al., 2016; Mas-Herrero et al., 2014).

In addition, a consistent body of research suggests that the large interindividual variability observed in musical reward sensitivity may be associated with music training. Music training is connected to several cognitive, emotional, and social functions (Biasutti & Mangiacotti, 2021; D'Ausilio et al., 2015; Miendlarzewska & Trost, 2014; Yurgil et al., 2020). For example, musical expertise has been shown to enhance emotion recognition accuracy (Castro & Lima, 2014; Virtala & Tervaniemi, 2017) and even musical preference and its related brain correlates (Brattico et al., 2016). Gold et al. (2013) suggested that the level of music training is linked to pleasurable experience when listening to music. This might be ascribed to listening style in musicians and to the involvement of the musically activated reward system, also implicated in reinforcement learning (Salimpoor et al., 2015; Zatorre & Salimpoor, 2013).

Higher musical expertise is also related to enhanced reward responses to music (Chabin et al., 2020), and higher connectivity of the cerebral regions involved in the experience of pleasure and reward (Alluri et al., 2015; Brattico et al., 2016). Consistently, this tendency is reflected in higher BMRQ total scores observed in musicians compared to non-musicians (Hernández et al., 2019; Mas-Herrero et al., 2012; Fuentes-Sánchez et al., 2021).

However, the role of music training on musical reward sensitivity in childhood and adolescence is underrepresented in existing research. Mas-Herrero et al. (2012) and Belfi et al. (2022) suggested that musical reward sensitivity declines with age, although their studies did not include children. In a developmental study, Carraturo et al. (2022) found that children's musical abilities were not significantly associated with BMRQ scores. However, in this latter study musical abilities were measured with the MET (Musical Ear Test; Wallentin et al., 2010) and MiniMET (Musical Ear Test for children; Derdau Sørensen, 2020), which are both musical working memory tests not taking into account participants' amount of music training.

Other studies hypothesized that the rewarding aspect of music training would be tied to enhanced auditory skills in children and adolescents, although without providing empirical evidence (Kraus et al., 2014; Kraus & White-Schwoch, 2015; Tierney et al., 2015). Furthermore, some authors have argued that the interaction of music training and reward may be at its peak during late childhood and adolescence, when brain structures and mechanisms associated with motivation are developing rapidly (Penhune, 2020; Fasano, Cabral et al., 2023).

Research investigating music listening among teenagers and preadolescents show that the search for a way to deal with emotions is strongly correlated with music listening for teenagers (Hargreaves et al., 2015; McFerran, 2019; Thomas, 2016). Moreover, reward activities like music listening play a significant role in emotional regulation, having the potential to elicit strong emotional responses from listeners (Juslin & Laukka, 2003; Juslin & Sloboda, 2001; Miranda & Claes, 2008).

In a recent study by Fasano, Cabral et al. (2023) with preadolescents, functional magnetic resonance imaging (fMRI) during music listening was used together with the BMRQ to measure individual musical reward sensitivity. Results showed the recruitment of the orbitofrontal cortex, involved in hedonic processing in the early adolescent brain cortex during music listening, supporting the view of using music listening as a coping strategy for emotion regulation in preadolescence. Other studies have also shown the beneficial effects of music exposure in children and adolescents (Agarwal et al., 2022; Kim & Stegemann, 2016; Morinville et al., 2013).

Adolescence is a delicate phase of life characterized by an increment of reward-seeking behaviors (Arnett, 1991; Vuust et al., 2010), which may lead to the increase of risky behaviors due to the strong need to be accepted by peers and the increase in social reward (Ambrosia et al., 2018; Foulkes & Blakemore, 2016). In this sense, it is worth noting that music is a determinant of socialization and integration with peers, with implications for solving developmental goals and psychosocial functioning (Dys et al., 2017; Lamont & Hargreaves, 2019; Miranda, 2019). For instance, studies on adolescents reported that this age group develops a strong connection with music and clear musical preferences that serve as an identifier and a way to share their values and personality with others (Franken et al., 2017).

Similarly, analogies in music preferences have been found in early adolescent mutual friendships (Selfhout et al., 2009). In this perspective, considering the vulnerability of this transition period of life, the impact of music training on the brain reward network (Fasano, Cabral et al., 2023) may have potential important implications for music as a tool to support fulfilling the psychosocial tasks required in this delicate window of development. Specifically, preadolescence can be considered a sensitive period for prevention of risky behaviors, as it is a pivotal stage characterized by crucial needs to be satisfied in order to optimally prepare for adolescence and adulthood (Fasano, Cabral et al., 2023; Moore & Theokas, 2008).

To date, no study investigating the effect of curricular musical training on reward sensitivity in preadolescence has been conducted. As for adult populations, studies have indicated an effect of gender on rewarding experiences associated with music. For example, in a study by Fuentes-Sánchez (2021), women rated unpleasant excerpts with higher energy and fear scores compared to men whereas men rated the same excerpts with higher values for valence, happiness, and tenderness, as well as rated neutral excerpts with higher values of happiness and tenderness than women. Wang et al. (2021) found that female participants scored higher than male participants on the BMRQ subscales of emotional evocation, mood regulation, sensory-motor and social reward, while there was no significant gender difference between scores for musical seeking.

This is in line with the findings reported by Mas-Herrero et al. (2012) suggesting that women showed more intense emotional reactions to music than men, and that women used music more frequently than men to control their emotions. Also, women were found to listen to music to a higher degree than men and to be more socially rewarded (Derdau Sørensen, 2020). In sum, these results suggest that, in the adult population, women are likely to be more responsive to musical reward and its subdomains than men, whereas no evidence has been presented for the preadolescent population.

THE CURRENT STUDY

The current study aimed to investigate the role of music training on music reward in preadolescents (10-14 years-old). Moreover, it was part of our "MiddleMusic" project, which was launched with the goal of gathering observational data over the years on performative, emotional, and cognitive abilities as well as self-efficacy and overall quality of life of students enrolled in Italian music middle schools. The "MiddleMusic" project is still ongoing and longitudinal data will be collected from the same children over the coming years (initial findings are published in Lippolis et al., 2022).

Italian musical middle schools were created in the seventies but started to be officially regulated by law in 2000. These schools offer the possibility to study a musical instrument for free and are, therefore, able to reach children of all social classes and constitute a precious resource for the community. Within them, students can choose whether to apply for the music curriculum (MC) or the standard curriculum (SC). Students of both curricula follow the same lessons in the morning according to the national plan for lower secondary schools. In addition, the MC students attend musical instrument, theory, and ensemble music or orchestra afternoon lessons.

Access to the musical curriculum takes place through previous aptitude exams aimed at investigating general musical predispositions, such as rhythmic, melodic, and pitch recognition tests. Furthermore, in music middle schools, like in all Italian schools, in the afternoon, several extra-curricular activities are organized for all students within the National Operational Plan of the Italian Ministry of Education (PON). The PON is funded by the European Social Fund and the European Regional Development Fund and includes courses for strengthening basic school subjects, foreign language courses, computer labs, sports, artistic programs etc. (for more details, see Lippolis et al., 2022).

The scientific evidence on music training carried out as a curricular activity is scarce. Most research has focused on music training as a leisure activity and found effects on intrinsic motivational engagement in music and academic achievement (Guo et al., 2022; Metsäpelto & Pulkkinen, 2012; Pitts, 2007). One might wonder whether curricular training is also strongly related to motivation.

In the BMRQ, the motivational facet of music reward is represented by the musical seeking subscale. Mas-Herrero et al. (2012) define the BMRQ musical seeking as pursuing, sharing, and seeking information regarding specific music pieces, composers, performers, or other information related to music; an interest in "knowing about music" that can be reflected in many situations and everyday activities, for example, attending live concerts, spending money on music-related items, talking about one's favorite music, seeking formal knowledge about music (e.g., classes or conferences), trying to learn to play an instrument, or simply increasing the amount of time devoted to music listening. It is plausible to think that those who study music, whether as a recreational or curricular activity, are driven by curiosity to learn more about it.

Music middle schools offer a stimulating and dynamic learning environment to preadolescents, as well as numerous opportunities for sharing music and socializing through concerts, school plays, and musical competitions throughout the school year. Indeed, music training constitutes one of the greatest opportunities for socialization (Koelsch, 2014; Savage, 2021). Instrumental group practice implies a form of nonverbal communication, and thus constitutes a prototype of social interaction where the ensemble aims to convey musical meaning to a listener through continuous predictions and adaptive processes to satisfy the real-time requirements of interpersonal coordination (D'Ausilio et al., 2015).

Therefore, it is not surprising that several studies show a positive correlation between music training and prosocial skills in children, indicating music-related activity as an adaptive behavior able to foster social cohesion, empathy, cooperation, and a prosocial orientation (Alemán et al. 2017; Fasano et al. 2019; Holochwost et al. 2017; Rabinowitch et al., 2013; Rabinowitch & Meltzoff, 2017; Schellenberg et al., 2015). Besides, in recent years, the aspect of social and emotional sharing of music has been considered as an important, aesthetically rewarding function in humans that may be what makes music so universal and attractive (Nummenmaa et al., 2021; Reybrouck & Brattico, 2022; Reybrouck et al., 2018; Sachs et al., 2016).

Research Questions and Hypotheses

The present study has a quasi-experimental research design, where data were collected three times over a total period of one year and a half. According to the previous literature showing the powerful impact of music on teenage development, what we expected to find was a statistically significant difference between musically trained and untrained preadolescents in the BMRQ scores generally and, specifically, results in favor of MC students due to the selection through aptitude tests that children undergo to be enrolled in the MC. Moreover, we expected only some of the BMRQ subscales to be affected by music training. Particularly, we hypothesized a positive relationship between training and the social and motivational facets of music reward (the social reward and the musical seeking BMRQ subscales).

In the study by Fuentes-Sánchez et al. (2021) comparing trained adult musicians with at least 3 years of training with non-musicians, individual differences were found on the perception of emotions in music using the BMRQ. No statistically significant changes were detected between formally-trained musicians and non-musicians in emotion evocation, while statistically significant effects were found for musical seeking and social reward. Similarly, we expected MC students to score higher than SC students in these two subdomains. In addition to group differences, we also expected a stronger growth in music reward sensitivity after 5 and 18 months for the MC students.

However, some SC students may be engaged in musical activities outside of school. Moreover, variability among music courses exists due to the difference in musical instruments, programs, teachers, and commitment required (Reybrouck et al., 2021; Tervaniemi, 2009). We then also took into account the actual amount of individual and collective music engagement carried out by the students in and out of school besides the curriculum variable (which mainly describes the formal training conducted at school). The aim was to see concretely how committed they were to music regardless of their school curriculum or the music course attended.

Some previous studies reporting the effects of music training on different types of populations had already used actual hours of training as independent variable (e.g., Bergman Nutley et al., 2014; Gordon et al., 2015; Slater et al., 2015; Wesseldijk et al., 2021). Moreover, a study by Brattico's team (Fasano et al., 2021) closely followed the learning process in pianists by means of a questionnaire and showed a statistically significant relation between engagement with studying a musical piece by D. Scarlatti in a 4-week period and the post-learning brain changes in frontostriatal regions. Hence, in the current study, we hypothesized a difference between those with a high and low level of musical engagement over time. This latter hypothesis would not be a definite proof yet of the positive effects of music training, as factors like predisposition to music reward should be considered. However, it could result in a concrete hypothesis that might then be answered with further longitudinal studies in the future.

Regarding gender, we expected to find significant differences in overall music reward and subdomains in favor of girls, consistent with previous literature. Finally, as the BMRQ is not a validated tool for preadolescents, we hypothesized that this measurement instrument applied to preadolescents would be comparable to the original version.

METHODS

Participants

The original sample included 337 preadolescents (range = 10-14 years; M_{age} = 12.3; *SD* = 0.94; 157 girls and 180 boys) selected from 21 classes of three music-focused middle schools in the Bari area (Puglia, Italy): De Amicis-Dizonno (Triggiano, suburban community), Alighieri-Tanzi (Mola di Bari, suburban community), and Massari-Galilei (Bari, city center) in three very different socioeconomic areas. Italian middle schools consist of three grades following the fifth grade of primary school, hence, the children are around 11-13 years old. Children belonged either to the MC (*n* = 194) or to the SC (*n* = 130). All participants agreed to participate in the study on a voluntary basis, and a consent form signed by their parents was obtained for each participant. Anonymity was assured through the creation of codes for each participant. The research procedure was approved by the Ethics Committee of the Department of Education, Psychology and Communication of the University of Bari "Aldo Moro" (reference: ET-21-15).

The MC children were compared with their SC schoolmates. As previously explained, MC children are enrolled based on aptitude assessments regarding imitation and perception of rhythm, melody, and pitch, and for this reason, we have statistically accounted for individual differences in musicality. The two groups of students with higher or lower level of actual musical engagement were also compared. Indeed, children may carry out individual and/or group music activities regardless of whether they are enrolled in the music curriculum in middle school. Alternatively, it is possible that not all MC students are engaged in music to the same extent.

As 3rd grade students left middle school in 2022 to enter high school and could no longer be tested, our final sample for the longitudinal analysis consisted of 142 students. Of these 142 children, 74 (52.1%) were boys and 68 (47.9%) were girls belonging to MC (*n* = 82) or SC (*n* = 60). Descriptives for both groups are reported in Table 1A.

The age of the participants ranged between 10 and 14 years. In the final sample, only six students presented diagnoses of mild cognitive disabilities or learning impairments (3 of them were MC and 3 were SC). However, their scores appear to be similar to those obtained by the rest of the participants. Children in the SC were exposed to general music lessons 2 hours/week with no additional afternoon lessons.

TABLE 1A.
Descriptives for Groups Over Time

	Group	Time	*n*	*M* (*SD*)
Age	MC	1	82	11.72 (0.64)
		2	82	12.13 (0.56)
		3	82	13.11 (0.65)
	SC	1	60	11.54 (0.57)
		2	60	11.94 (0.56)
		3	60	12.90 (0.63)

Note. Time 1 = December 2021; Time 2 = May 2022; Time 3 = April- June, 2023. MC = music curriculum; SC = standard curriculum.

TABLE 1B.
Descriptives for Groups Crossed With Concurrent Musical Activities Levels Over Time

Group	CCM	Time	*n*
MC	Low	1	27
		2	29
		3	12
	High	1	50
		2	48
		3	68
SC	Low	1	50
		2	43
		3	48
	High	1	8
		2	16
		3	10

Note. Time 1 = December 2021; Time 2 = May 2022; Time 3 = April- June, 2023. MC = music curriculum; SC = standard curriculum; CCM = concurrent musical activities.

Children in the MC followed the same classes plus additional 2 hours in 1st grades and 3 hours in 2nd and 3rd grades. The main musical activities consisted of 1 hour of individual instrument lessons and/or in small groups, 1 hour of collective lessons of music theory and music reading, and 1 hour of group music lessons (orchestra and instrumental ensemble).

Materials

Participants were asked to complete a demographic questionnaire (i.e., age, gender, language spoken).

Individual sensitivity to musical reward was assessed using the BMRQ (Mas-Herrero et al., 2012) in its Italian version previously employed by Carraturo et al. (2022). The BMRQ questionnaire includes five subscales: musical seeking, mood regulation, emotion evocation, sensory-motor, and social reward. Each subscale presents fours items for a total of 20 items. The subscale of musical seeking describes a desire to "know about music" and engage in regular musical activities (e.g., attending live concerts, spending money on music-related items, seeking information associated with the music they listen to). The emotional effect that music has on the listener is assessed by the subscale of emotion evocation. The capacity of the listener to utilize music to modify their emotions is assessed by the mood regulation subscale. The social reward subscale is connected to how music affects both people and communities in terms of cohesiveness. Finally, the ability of music to elicit basic or complicated motions, such as toe-tapping or dancing, is assessed by the subscale of sensory-motor behavior.

Ratings are provided on a 5-point Likert-type scale (*totally disagree—absolutely agree*). A numerical value acquired after completing the survey is used to quantify the importance of each aspect to the overall music reward experience. Additionally, a score for general musical sensitivity is calculated as the weighted average of participant scores (i.e., factor score). Both for the global sensitivity to music reward and the subscales, the mean value is 50 and the SD is 10. Therefore, the range of standard values is between 40 and 60. Sum scores below 40 represent low levels, while those above 60 represent high levels for a particular facet (see http://brainvitge.org/).

In order to assess music sophistication and background and to investigate whether this is associated with music reward sensitivity (Gold, Mas-Herrero et al., 2019; Gold, Pearce et al., 2019b; Vuvan et al., 2020) participants also completed the Goldsmith Music Sophistication Index (Gold-MSI, Müllensiefen et al., 2014), a 39-item self-report scale assessing the multifactorial construct of individual musical ability including five subscales in a hierarchical factor structure (active musical engagement, perceptual abilities, musical training, singing abilities, and emotional engagement with music) and one general factor (general musical sophistication, GMS; Müllensiefen et al., 2014). The GMS index is the mean of a diverse range of 18 items chosen from all five Gold-MSI subscales, with a pronounced majority of items from the musical training and the singing abilities subscales. The GMS was also found to correlate highly with self-reported music training (Müllensiefen et al., 2014).

Initially developed for use with adults, the factor structure and internal reliability of the Gold-MSI have been replicated for its German translation by Schaal et al. (2014) and validated for use with secondary school pupils in a large German sample of 11–19-year-olds (Fiedler & Müllensiefen, 2015). The Gold-MSI was translated into Italian with the method of the back translation (similar to the method described in Lin et al., 2021): two parallel translations were carried out and the two versions of the same test, translated from English to Italian and from Italian to English, were then compared by a native speaker.

The Concurrent Musical Activities Questionnaire (CCM, Müllensiefen et al., 2015) was also used to measure the level of musical engagement. The CCM is a self-report inventory developed based on data on the range of musical activities of secondary school students. It assesses the degree of active music making carried out over the previous three months, providing a snapshot of the current amount of musical activity, differently from Gold-MSI which aims to cover longer periods. The CCM consists of five binary items asking about musical activities like playing with friends or on special events, playing in an orchestra/band and current group and/or individual music lessons, as well as two rating scale items that collect information on the current amount of music practice per day and the current total amount of music activities per week (including rehearsals and classes). From the responses to these items, an overall score is then obtained, indicating the degree of concurrent musical activities.

The BMRQ was administered on an online form which can be accessed through a link, while both Gold-MSI and CCM were administered through a specific online platform implemented by the LongGold group (see https://longgold.org/tests/).

Procedure

Data collection took place inside the school buildings, and the whole process was guided by the experimenters. The questionnaires were administered during class hours for a total duration of two hours after prior agreements with principals and teachers. As this study was part of a larger project, further tests were administered in addition to BMRQ and Gold-MSI. The battery of tests was split into two parts and administered in two sessions on two different days, generally at a distance of 2 or 3 days according to the availability of the classes and to the school timetable. This was done in order to avoid cognitive overload and fatigue possibly hindering the performance.

The first round of data collection involved 324 participants and took place mostly in December 2021. Only a small group attending second and third years of middle school was tested in January 2022. For the second round, data were collected after 5 months, in the second half of May 2022, and 337 children participated. Finally, the same second and third grade participants were last tested between April and June 2023. The three measurement times are referred to as Time 1, Time 2, and Time 3. The first administration cannot be considered as a pre-test. Due to logistical difficulties caused by the COVID-19 pandemic, the first testing session was carried out in December 2021, when MC students had already undergone three months of music training.

DATA ANALYSIS

Statistical analyses were performed using the Jamovi software (version 2.4, 2023; Epskamp, 2017; Kerby, 2014; R Core Team, 2021; Rosseel et al., 2018). A confirmatory factor analysis (CFA) was performed using the SEMLj package (Gallucci & Jentschke, 2021), while the *GAMLj* package (Gallucci, 2019) was used to perform a mixed-models analysis. The *ESCI* module for Jamovi (Cumming & Calin-Jageman, 2016) was employed to estimate effect sizes.

First of all, as there is no validated version of the BMRQ for Italian preadolescents, a multigroup CFA was performed. The aim was to test if a relationship exists between the five dimensions and their underlying constructs and to compare the results across the three time measurements. To conduct this comparison, we carried out the chi-square difference ($\Delta\chi^2$) test between two models with and without constraints, where obtaining a statistically nonsignificant value indicated invariance.

In addition, we considered other measures like the ratio of the change in χ^2 to the change in degrees of freedom between the two models ($\Delta\chi^2/\Delta df$) where a value of ≤ 5 indicated invariance, and the difference in root mean square error of approximation (RMSEA) and comparative fit index (CFI) values, where a difference of ≤ 0.015 and $\leq .01$, respectively, indicated invariance (Cheung & Rensvold, 2002).

Subsequently, the variability measures for CCM scores were computed to verify whether the amount of musical engagement measured with the CCM inventory was suitable to be used as an independent variable.

Given the positive results of these assumption checks, Welch's tests and independent-samples *t* tests were performed to verify whether there are differences already at Time 1 on the GMS and BMRQ in the first graders, which would depend on the pre-selection of the MC students. The same was verified between students with a higher or lower amount of current music training, again in relation to the GMS and BMRQ. After that, we tested our main hypothesis on the impact of music training on general music reward and its subscales.

To this purpose, we performed two series of six mixed-models for general music reward and for each one of the five BMRQ subscales used as dependent variables: musical seeking, emotion evocation, mood regulation, sensory-motor, and social rewards. The two series of mixed models were identical except for a single major difference in the fixed factor setup. We defined the mixed models by setting time, group (in the first series), or CCM (in the second series), and gender as fixed factors. The aim was to test the hypothesis predicting significant differences between the categories of students (MC compared to SC students and students with high compared to those with low levels of current music training). At the same time, we aimed to carry out an analysis within the sample over time using the starting GMS scores as a covariate.

As regards clustering (grouping) variables, in addition to the importance of interindividual variability, we selected schools, due to their diverse backgrounds, and also classes. A nested model was created by modeling random intercepts for each student, nested in each class, nested in each school. We used likelihood ratio tests to obtain p values for the mixed effect model coefficients that are the default in Jamovi and the underlying lmer()-function in *R*. Moreover, Jamovi uses the *R* formulation of random effects as implemented by the *lme4 R* package (Bates et al., 2015).

Finally, post hoc analyses were carried out with the statistically significant results, and Bonferroni correction was used to account for false positives deriving from multiple comparisons.

RESULTS

Our Italian version of BMRQ administered to children was confirmed comparable with the original version (Mas-Herrero et al., 2012) by a CFA showing good fit indices with the original five-factor model: $\chi^2(480) = 876.33$, $p < 0001$, CFI = 0.89, TLI = 0.87, RMSEA = 0.08, 95% CI [0.07, 0.08]. Item correlation coefficients were greater than 0.3 in Time 1, 2, and 3 (see Figure 1 and the Supplementary Materials).

To verify whether the factor loadings of the items were the same across the time points, measurement invariance was tested using the chi-square difference ($\Delta\chi^2$) test. The model with constrained loadings, χ^2 (510) = 909,94, was found to not be statistically significantly different from the model without equality constraints, χ^2 (480) = 876.33; $\Delta\chi^2 = 31.63$, $\Delta df = 30$, $p = .38$, indicating invariance between model comparison. Moreover, results from other tests such as $\Delta\chi^2/\Delta df = 1.12$, ΔRMSEA = - 0.01 and ΔCFI = 0 also indicated invariance (see the Supplementary Materials).

After verifying the validity of the Italian version of the BMRQ, we tested whether it made sense to use the CCM as an independent variable. First, we looked at the amount of musical activities carried out by both MC and SC students. In Table 1B, descriptives for groups crossed with the current music training amount over time are reported, showing the majority of MC students as the most engaged in musical activities in all the three time points. However, a small group of SC students was found to be highly engaged in musical activities. We then realized that the mere distinction into groups was not sufficient as an explanatory music training variable. After that, we looked at the descriptives for CCM scores and its variability measures (i.e. variance, range, interquartile range, and *SD*) of students from both curricula over the three measurement points. These descriptives are summarized in Tables 2A and 2B, and Figure 2. In general, a certain degree of variability was found for the groups and across the three time points as variances and SDs were far from 0. Hence, it appeared plausible to use the CCM as an independent variable. In the current analysis, CCM was treated as a categorical variable divided into two levels: high and low music engagement level, situated above and below the median value of the distribution (2.20), respectively. For the CCM, scores for a total of 17 participants were found to be missing in the dataset.

The BMRQ descriptives for the different curricula and CCM levels are reported in Tables 3A and 3B, showing a general advantage in almost all dimensions for the MC group and for those students with a high current amount of music training. Four outliers were removed from the dataset through the interquartile range (IQR, i.e.,

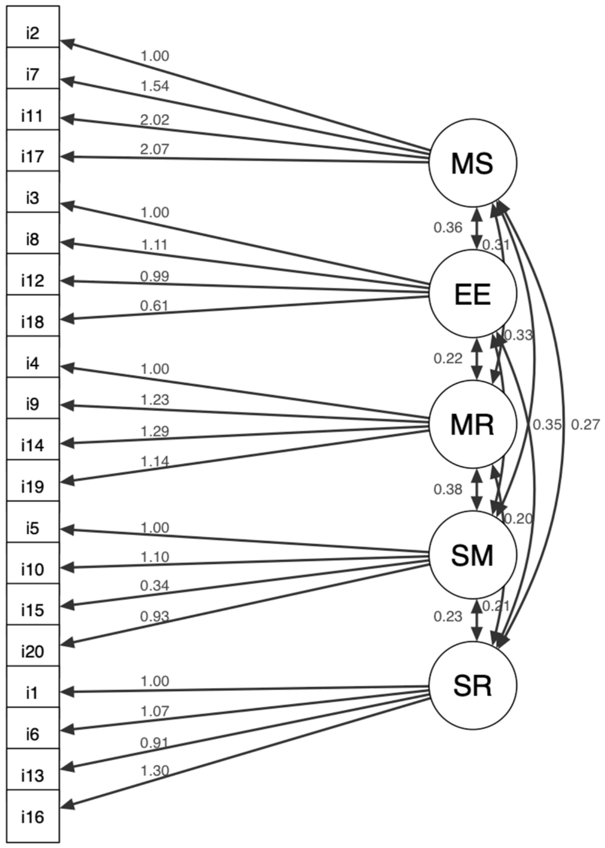

FIGURE 1.

Correlation coefficients in confirmatory factor analysis (Time 3) to test the original BMRQ five-factor model developed by Mas-Herrero et al. (2012). Coefficients for Time 1 and Time 2 are available in the supplementary information. MS = musical seeking; EE = emotion evocation; MR = mood regulation; SM = sensory-motor; SR = social reward.

observations that fall below Q1 – 1.5 IQR or above Q3 + 1.5 IQR here were identified as outliers).

Subsequently, Welch's test revealed a statistically significant starting difference between the MC and SC groups in the GMS, as assessed by the general Gold-MSI score in first graders at Time 1: $t(79.7) = 4.22$; $p < .001$. The statistically significant result turned out to be in favor of the MC group given its higher mean score (4.33) than the SC group (3.64). The same applied for CCM, as a statistically significant difference was found already at Time 1 between 1st graders with high and low amounts of training in the GMS: $t(54.7) = -5.32$; $p < .001$. The related mean scores revealed the advantage of the high CCM level (4.56) compared to the low level (3.67). For this reason, we decided to use the GMS scores as covariate in the following analyses.

Moreover, an independent-samples t test revealed the absence of group differences at Time 1 in first graders for general music reward and the BMRQ subscales except for social reward: $t(84.0) = -2.10$; $p = .039$. Between the two CCM levels, a statistically significant difference was found for musical seeking, $t(81.0) = -3.05$; $p = .003$, and social reward $t(81.0) = -2.16$; $p = .034$. In general, both the MC group and the high CCM level were the categories exhibiting the highest scores (see Tables 4A and 4B).

For testing the effects of music curriculum and amount of music training on music reward, we used two series of mixed models whose main effects are summarized in Table 5. Fixed effects parameter estimates and estimated marginal means, as well as additional analyses and the assumption of normality of residuals verified with the Kolmogorov-Smirnov normality test are available in the Supplementary Materials.

The Omnibus F test from the first series of mixed models, including curricula among the fixed factors, showed no statistically significant differences between the MC and SC groups except for the sensory-motor subscale. As reported by estimated marginal means, the sensory-motor subscale was the only one where SC students scored higher. For mood regulation, a statistically significant decrease was found over time.

Omnibus F test results from the second series of mixed models, including CCM among the fixed factors, showed social reward to be the only subscale with significant CCM × Time interaction effects (see Figure 3): $F = 3.39$; $df = 323.20$; $p = .035$. In order to confirm the nature and direction of the statistically significant interaction effect obtained, a simple effect analysis within the same model was performed. The Omnibus F test (see Table 6A) showed a statistically significant increase only for the high CCM level over time (F = 5.11; df = 297.96; p = .007) and parameter estimates (see Table 6B) showed statistically significant effects in the comparison between Time 2 and Time 1 as well as between Time 3 and Time 1.

Cohen's d (indicated as ds) related to the effect on social reward of group and CCM levels intersected with the time variable are reported in the Supplementary Material. A small-medium effect size was found for the high CCM level over 5 months (0.32) and over one year and a half (0.28). For the low CCM level, the effect sizes were almost null for both time intervals of 5 months (0.02) and 18 months (-0.05). As regards the group variable, small effects were found for both MC (0.20) and SC (0.17) groups over 5 months. Over a period of 18 months, a medium effect was found for the MC group (0.33) and a small effect for the SC group (0.09). All mean differences, interval, and effect estimates, as well as plots of the effects of CCM and group intersected with time are also available in the Supplementary Materials.

In addition, other statistically significant results were found for gender on the social reward subscale (see Table 5). Both from the first and second series of mixed models, strong results arose for musical seeking, emotional evocation, sensory-motor and general music reward. Moreover, a statistically significant interaction effect of CCM × gender was found for musical seeking (F =5.09; df = 402.631; p = 0.025). All gender results (summarized in Figure 4) showed girls to have higher BMRQ scores compared to boys.

After applying the Bonferroni correction to the common significance level of α = 0.05 (i.e. 0.05/6 = 0.00833), the effect of group in sensory-motor, for CCM in social reward, and for gender in emotional evocation, sensory-motor, and general music reward stayed statistically significant (see Table 5). Post hoc pairwise comparisons with Bonferroni correction (see the Supplementary Materials) revealed a significant difference between girls and boys with high CCM level in favor of females and, for social reward, several statistically significant differences between the two CCM levels at all three measurement points, once again in favor of the higher level.

DISCUSSION

The aim of the current study was to evaluate the relationship between music training and music reward in preadolescent children either following or not following music curricular activities in middle school. In addition, the effects on music reward deriving from the children's actual amount of musical engagement in and out of school were also tested regardless of their school curriculum. The additional analyses with musical engagement and concurrent musical activities as a predictor were performed due to the differences among the curricular music courses in terms of instrument features and degree of commitment and orchestral practices required. Also, a few students enrolled in the SC curriculum showed to be highly engaged in musical activities in their leisure time.

An Italian version of the BMRQ (Mas-Herrero et al., 2012), validated with a CFA, was employed to investigate possible differences between the two groups of children (MC vs. SC) and between those with a higher or lower level of musical engagement, measured with the CCM (Müllensiefen et al., 2015). At the same time, longitudinal analyses were carried out over three measurement points from the same children within a total period of one year and a half.

Furthermore, we controlled for initial differences in musical background of participants through the Gold-MSI GMS index score (Müllensiefen et al., 2014). This was done because a starting difference was found between the groups in GMS, probably related to the preselection through aptitude tests into the MC. The same starting difference was found between the two CCM groups in favor of the higher level, possibly because almost all students highly involved in musical activities were enrolled in the MC.

TABLE 2A.
Overview for the Concurrent Musical Activities Variable

Variable	M	Mdn	s	Minimum	Maximum	25th percentile	75th percentile	N	Missing
CCM	2.18	2.20	2.46	−2.54	8.71	0.42	3.87	409	17

Note. M = mean; Mdn = median; s = standard deviation of the sample.

TABLE 2B.
Variability Measures of CCM Scores for Groups and Over the Three Measurement Points

Group	Time	*n*	Missing	*M* (*SD*)	Median	Variance	IQR	Range	25th percentile	50th percentile	75th percentile
MC	1	77	5	3.13 (1.99)	2.83	3.97	2.40	10.26	1.77	2.83	4.17
	2	77	5	3.16 (2.05)	3.09	4.18	2.60	8.79	1.77	3.09	4.37
	3	80	2	3.94 (1.68)	3.99	2.83	2.10	8.29	2.83	3.99	4.93
SC	1	58	2	0.30 (1.90)	0.11	3.61	2.61	7.98	−1.2	0.11	1.41
	2	59	1	1.02 (1.98)	0.84	3.91	2.83	8.81	−0.4	0.84	2.42
	3	58	2	0.21 (2.24)	0.01	5.02	2.85	9.91	−1.4	0.01	1.46

Note. MC = music curriculum; SC = standard curriculum.

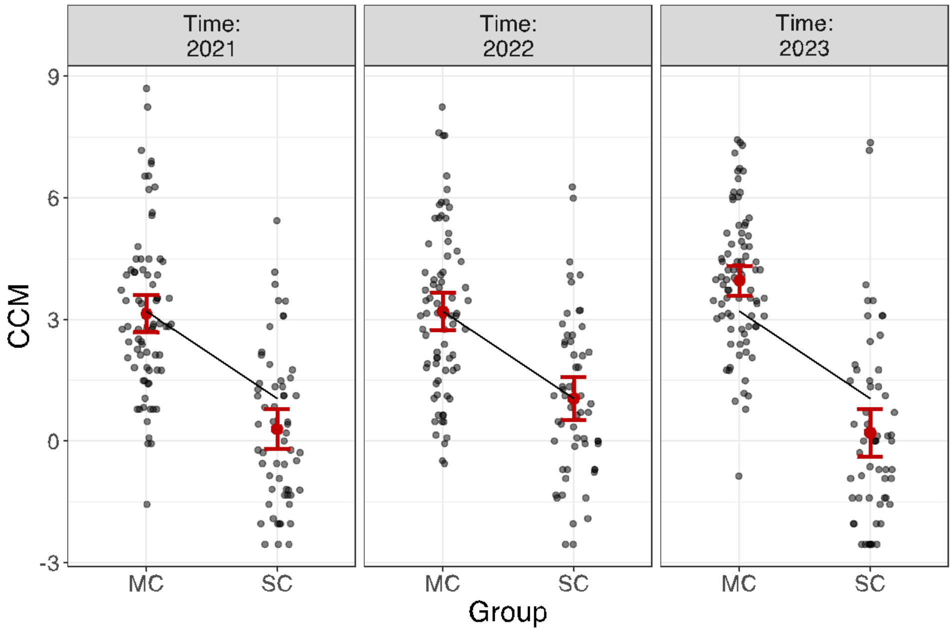

FIGURE 2.

Concurrent musical activities (CCM) score variability for groups and over the measurement points. MC = music curriculum; SC = standard curriculum.

TABLE 3A.

Mean (SD) for General Music Reward and BMRQ Subscales at Three Different Time Points Grouped by Music Curriculum (MC) and Standard Curriculum (SC)

Group	Time	Musical seeking	Emotional evocation	Mood regulation	Sensory motor	Social reward	Music reward
MC	1	47.93 (11.5)	39.83 (16.4)	49.55 (12.9)	40.67 (13.9)	47.55 (10.8)	42.64 (12.9)
	2	48.60 (11.0)	39.33 (17.4)	45.80 (13.5)	41.22 (12.4)	49.53 (10.3)	42.07 (12.9)
	3	48.77 (10.6)	41.23 (15.0)	46.55 (11.9)	42.58 (12.5)	51.54 (11.7)	43.84 (12.3)
SC	1	45.03 (12.6)	38.27 (17.2)	46.08 (15.2)	42.47 (12.9)	42.28 (11.0)	39.63 (14.6)
	2	44.97 (12.8)	36.02 (20.0)	43.77 (15.6)	40.95 (14.4)	43.17 (12.1)	37.88 (17.1)
	3	46.62 (12.6)	38.33 (19.2)	47.35 (14.5)	42.77 (13.3)	43.27 (11.2)	40.68 (15.4)

Note. Time 1 = December 2021; Time 2 = May 2022; Time 3 = April- June, 2023.

TABLE 3B.

Mean (SD) for General Music Reward and BMRQ Subscales at Three Different Time Points Grouped by Levels of Amount of Music Training (CCM)

CCM	Time	Musical seeking	Emotional evocation	Mood regulation	Sensory motor	Social reward	Music reward
Low	1	42.78 (12.2)	36.31 (16.5)	45.95 (15.3)	40.96 (12.9)	42.21 (10.6)	37.88 (13.4)
	2	44.32 (12.5)	35.86 (19.1)	42.12 (15.4)	39.26 (13.5)	41.64 (10.7)	36.32 (15.7)
	3	45.45 (11.8)	36.80 (18.5)	46.03 (15.1)	41.42 (13.2)	41.80 (11.1)	38.75 (14.7)
High	1	51.56 (9.7)	41.90 (17.2)	50.32 (12.1)	42.76 (14.3)	49.75 (10.6)	45.64 (13.5)
	2	50.19 (10.7)	40.53 (17.9)	48.53 (12.8)	43.84 (12.7)	53.00 (9.5)	45.31 (12.9)
	3	49.53 (11.0)	43.05 (15.2)	47.82 (15.2)	43.57 (12.6)	52.90 (11.1)	45.63 (12.5)

Note. Time 1 = December 2021; Time 2 = May 2022; Time 3 = April- June, 2023.

TABLE 4A.

Independent Samples t Test and Welch's Test for General Music Sophistication, General Music Reward and Subscales in First Graders (Group)

		Statistic	df	*p*	Group	*M*	*SD*
Musical seeking	Student's *t*	1.30	84.00	.196	MC	46.00	11.83
	Welch's *t*	1.30	83.53	.196	SC	42.79	10.98
Emotional evocation	Student's *t*	1.39	84.00	.169	MC	39.44	17.08
	Welch's *t*	1.39	83.56	.169	SC	34.51	15.89
Mood regulation	Student's *t*	1.64	84.00	.105	MC	49.72	12.61
	Welch's *t*	1.64	80.78	.106	SC	44.74	15.44
Sensory motor	Student's *t*	0.34	84.00	.731	MC	42.23	13.43
	Welch's *t*	0.34	83.83	.731	SC	41.26	12.85
Social reward	Student's *t*	2.10	84.00	.039	MC	46.00	11.10
	Welch's *t*	2.10	83.50	.039	SC	41.16	10.27
Music reward	Student's *t*	1.98	84.00	.051	MC	42.16	12.52
	Welch's *t*	1.98	83.98	.051	SC	36.77	12.70
GMS	Student's *t*	4.23	83.00	< .001	MC	4.33	0.81
	Welch's *t*	4.22	79.75	< .001	SC	3.64	0.68

Note. $H_a \mu_{MC} \neq \mu_{SC}$ MC = music curriculum; SC = standard curriculum.

TABLE 4B.

Independent Samples t Test and Welch's Test for General Music Sophistication, General Music Reward and Subscales in First Graders (Concurrent Musical Activities, CCM)

		Statistic	df	*p*	CCM	*M*	*SD*
Musical seeking	Student's *t*	−3.05	81.00	.003	Low	41.67	11.50
	Welch's *t*	−3.18	64.31	.002	High	49.41	10.07
Emotional evocation	Student's *t*	−1.28	81.00	.204	Low	34.87	15.22
	Welch's *t*	−1.20	47.33	.238	High	39.79	19.15
Mood regulation	Student's *t*	−0.55	81.00	.587	Low	46.35	15.21
	Welch's *t*	−0.57	65.58	.569	High	48.17	13.00
Sensory motor	Student's *t*	−0.46	81.00	.644	Low	41.33	12.23
	Welch's *t*	−0.44	50.00	.660	High	42.72	14.38
Social reward	Student's *t*	−2.16	81.00	.034	Low	41.80	10.56
	Welch's *t*	−2.14	56.51	.036	High	47.07	10.75
Music reward	Student's *t*	−1.98	81.00	.051	Low	37.26	11.79
	Welch's *t*	−1.86	48.48	.069	High	43.07	14.40
GMS	Student's *t*	−5.42	81.00	< .001	Low	3.67	0.70
	Welch's *t*	−5.32	54.71	< .001	High	4.56	0.74

Note. $H_a \mu_{MC} \neq \mu_{SC}$

We used a back-translated Italian version of the BMRQ questionnaire for children which turned out to be interpreted in a similar manner by respondents in all three measurement points. Only one previous study was conducted with this scale in school-age children, showing relevant differences with adult participants in the relation between musical reward sensitivity and empathy (Carraturo et al., 2022). To our knowledge, no other study investigated this construct in a preadolescent population. Moreover, the BMRQ, while being increasingly adopted in music psychology and neuroscience research (cf., e.g., Ferreri & Rodriguez-Fornells, 2017; Ferreri et al., 2019; Ferreri, Mas-Herrero et al., 2021; Martínez-Molina et al., 2016), still lacks validation in the Italian language. Considering the main role of BMRQ scores in modulating participants' behavior in music cognition tasks, our study contributes to the Italian validation, thus promoting its administration to the Italian population.

Our findings did not show any differences among groups in terms of general individual sensitivity to music reward (i.e., general musical hedonia BMRQ score). However, and interestingly, we found that the social reward subscale of the BMRQ had the most statistically significant results, even when controlling for pre-existing individual differences in GMS. For this subscale, a strong difference arose between CCM groups in favor of the high level, which stayed

TABLE 5.
Fixed Effects Omnibus Test

	Model 1 (Group)	Model 2 (CCM)	*F*	Num df	Den df	*p*
Social reward	Gender		4.88	1	142.06	.029
		Gender	4.55	1	145.63	.035
		CCM	12.42	1	398.76	<.001*
		CCM X Time	3.39	2	323.20	.035
Emotional evocation	Gender		17.42	1	140.34	<.001*
		Gender	15.95	1	142.39	<.001*
Mood regulation	Time		3.21	2	278.34	.042
Sensory-motor	Group		5.36	1	141.72	.022
	Gender		15.41	1	141.39	<.001*
		Gender	15.96	1	143.04	<.001*
General music reward	Gender		20.40	1	141.82	<.001*
		Gender	19.41	1	143.786	<.001*
Musical seeking	Gender		4.81	1	136.52	<.030
		Gender	4.34	1	137.83	.039
		CCM X Gender	4.81	1	391.07	.029

Note. Satterthwaite method for degrees of freedom. The reported results come from two series of six mixed models, one of them including Group, Time and Gender as fixed factors and the second one including the amount of music training (CCM), Time and Gender as fixed factors. p values marked with * stayed significant after Bonferroni correction. Statistically insignificant results are reported in the Supplementary Materials.

TABLE 6A.
Simple Effects of Time: Omnibus Tests

Moderator levels				
CCM	F	Num df	Den df	*p*
Low	0.31	2.00	292.51	.736
High	5.11	2.00	297.96	.007

Note. CCM = Concurrent musical activities.

TABLE 6B.
Simple effects of Time: Parameter Estimates

Moderator levels								
CCM	Contrast	Estimate	SE	95% CI Lower	95% CI Upper	df	t	p
Low	2022 - 2021	−0.99	1.39	−3.73	1.75	300.02	−0.71	.479
	2023 - 2021	−0.05	1.44	−2.90	2.79	292.51	−0.04	.970
High	2022 - 2021	4.10	1.52	1.11	7.09	306.44	2.70	.007
	2023 - 2021	4.28	1.45	1.42	7.13	297.96	2.95	.003

Note. Simple effects are estimated keeping constant other independent variable(s) in the modelCCM = Concurrent musical activities.

statistically significant even after Bonferroni correction. Moreover, the strongest result was the significant growth for those highly engaged in music activities after only five months from the first data collection, a result that remained stable after one year and a half.

Likewise, gender results for sensory-motor, emotional evocation, and general music reward turned out to be strong with girls in all cases scoring higher than boys. Another statistically significant interaction of CCM × Gender was found for musical seeking. That is, girls with higher engagement in musical activities showed higher scores on the musical seeking subscale.

Taken together, our results support the hypotheses that musical training in preadolescence can affect specific facets of the musical reward experience, in our case, the social one. Indeed, the main findings distinguishing children with a higher and lower amount of time spent in individual and collective music training were concentrated on the social reward subscale of BMRQ. Of course, given the initial difference in social reward between the groups, it is possible that the predisposition to enjoy social experiences may be an incentive for engaging in musical activities. However, no statistically significant interactions of CCM × time were found for the other subscales,

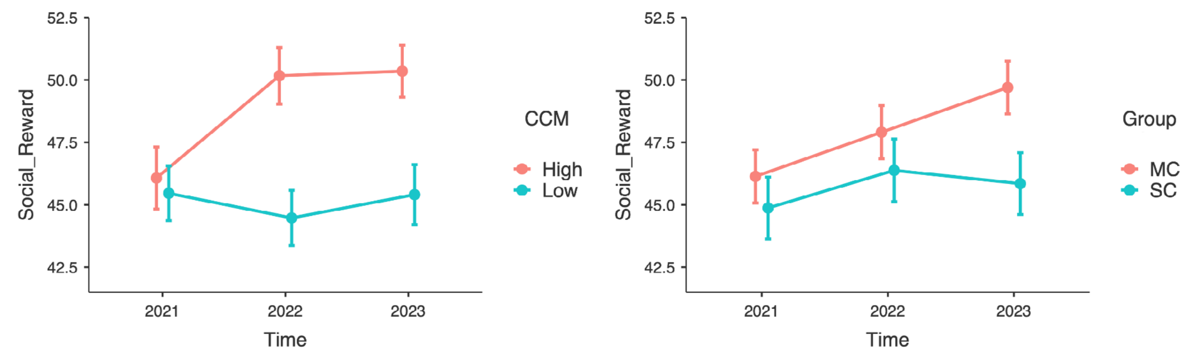

FIGURE 3.

Social reward grows significantly over time for those carrying out a higher amount of music training measured with the Concurrent Musical Activities Questionnaire (CCM), while the growth over time was found to be nonsignificant for the two groups. Error bars indicate standard error of the mean. MC = music curriculum; SC = standard curriculum.

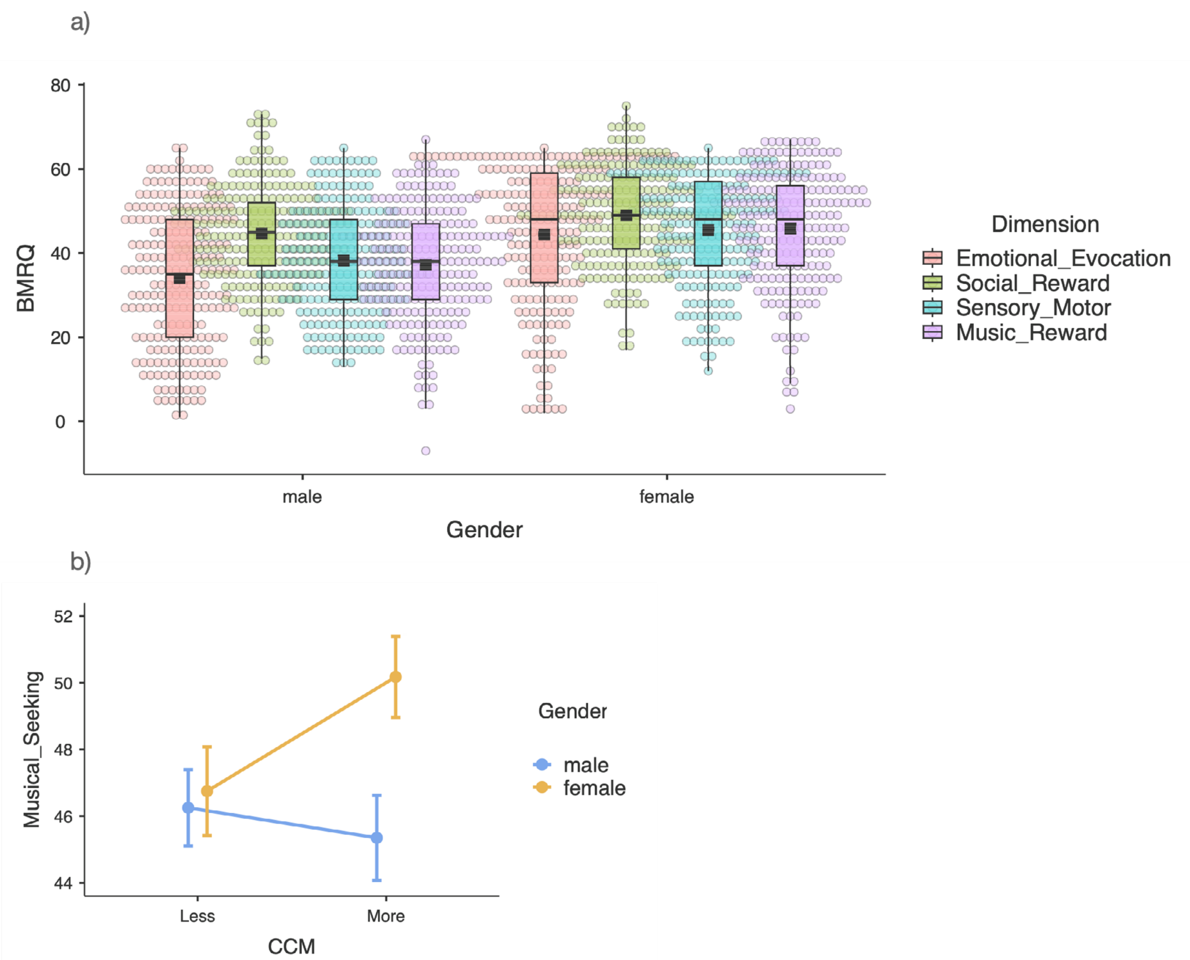

FIGURE 4.

Significant differences between genders for emotional evocation, social reward, sensory-motor and general music reward (a) and significant CCM x gender interaction effects for musical seeking (b). Error bars indicate standard error of themean.

meaning that music training allows only the social facet of reward to grow over time.

Even musical seeking, that is, the motivational aspect of musical reward we had initially assumed to be stronger in the MC group and in the high CCM group, turned out to be statistically significant only when considering the interaction with gender. A possible justifying reason for this result may lie in the fact that preadolescents generally do not own money to spend on items or activities related to music, nor the independence to go to concerts unless they are accompanied by parents. This should be addressed in future studies through the exploration of other variables including the sociodemographic conditions and the musical background of the children's families. In addition, it is important to consider that within the two-year period 2020-2021 the COVID-19 pandemic caused the call-off of most cultural events and music performances (Denk et al., 2022).

Sensory-motor was the only subscale where SC children exhibited higher scores. This could partly be linked to the curricular feature of music training: music middle school training is a proper curricular subject, evaluated like all other school subjects, that requires hours of study and sufficient preparation to pass the exams. By consequence, MC children would be more likely to conceive of music as a subject of study rather than as a reason to have fun. Such a conclusion is consistent with previous findings revealing that expert musicians show a more negative correlation with music conceived of as entertainment or a leisure activity (Juniu et al., 1996; Saarikallio et al., 2013).

Children enrolled in the MC are, for the greatest part, those who are most engaged in both individual and collective musical activities. In fact, in addition to the individual lessons, music curriculum as conceived in music middle schools offers the possibility to regularly practice music in small groups or in an orchestra, and students are also provided with numerous opportunities to perform publicly in concerts, competitions, and school plays. Hence, MC children have an effective and continuous chance for social connection with their peers, and so, practicing music constitutes a way to connect with others' interests and create interpersonal bidirectional exchanges.

However, it is possible that, due to specific features of the various music courses and instruments, MC students are not required to provide the same level of effort or of engagement in collective activities. It was already shown, in fact, that the different musical instruments produce different results on the musician's brain and skills (e.g., Burunat et al., 2015; Tervaniemi, 2009). Moreover, some SC students independently pursue musical interests outside of school. All this may explain why no statistically significant growth in the MC group over time was found in the current study. Although scores indicated a trend of the curricular music program in fostering social reward, the effect was relevant only for those more musically engaged (see Figure 3).

This reflects the need to be careful when defining the music training variable, a topic on which the current literature is scarce. In our case, the variable that had the strongest predictive power was CCM, which includes items asking for the actual amount of training, similarly to previous studies (e.g., Bergman Nutley et al., 2014; Fasano et al., 2021; Slater et al., 2015; Wesseldijk et al., 2021). The overall effect sizes between student categories and over time were, in fact, larger when considering CCM as an explanatory variable instead of the school curriculum (see the Supplementary Materials). Moreover, CCM includes a range of both curricular and informal musical activities. It is not surprising, then, to find effects if we consider that other authors already suggested that carrying out formal as well as less formal musical activities can shape the brain and lead to developing skills (Putkinen et al., 2013; Putkinen et al., 2015).

The CCM assesses both the amount of individual and collective musical activities currently carried out. It may be difficult to determine whether it is the music training alone that influences our results or the joint music making, as the two go normally hand in hand. However, it would be appropriate to consider these two aspects as interconnected, since playing together requires many hours of individual instrumental practice. Therefore, more hours of individual study are needed before playing in a group, as musicians need to learn how their musical part intersects with the others.

During an ensemble performance, musicians are constantly connected to others: it is necessary for a group of musicians, in order to play together, to intentionally orient their attention to the other, to the intentions and emotions residing in the expressive movements inherent of playing an instrument. The collective musical experience is characterized by a "shared affective motion experience" built through a process of "embodied simulation" allowing the emergence of a real empathic act, a sharing and meaningful understanding of what the other expresses (Molnar-Szakacs et al., 2011). Indeed, accumulating empirical evidence indicates that musical training and joint music making might elicit a strong reward in children to music-social experience (see Fasano, Brattico et al., 2023), and this distinctive social feature of the musical experience may explain, at least partially, our results.

It is known that social and musical processing share some of the same brain subsystems which go beyond the sensory and associative cortices. An overlap is observed in the auditory cortices, but also in posterior temporal multisensory areas, motor cortex, thalamus, amygdala, midcingulate cortex, anterior insula, and ventral striatum (Nummenmaa et al., 2021). In addition, several studies with both adults and children showed that musical beat can stimulate our social brains by providing a feeling of synchrony with others (Glowinski et al., 2013; Kirschner & Tomasello, 2009; Novembre et al., 2019; Stupacher et al., 2017; Trainor & Cirelli, 2015; Vesper et al., 2011). A meta-analysis by Koelsch (2020) indicated that music, and specifically motor and emotional synchronization, causes hippocampal activations not only due to cognitive, but rather emotional processes associated with attachment-related emotions and social bonding. In line with this, another recent meta-analysis by Criscuolo et al. (2022) showed significantly larger volumes and activity in adult music experts as opposed to nonexperts in brain areas related not only to auditory cognition but also to interoception and reward, such as the insula and striatum.

Our findings are in line with other authors' claims about music as a way to come into contact with others and be able to engage social cognition, involve nonverbal communication skills, foster interpersonal coordination and synchronization, and promote group cohesion (Koelsch, 2014; Stark et al., 2018). They also support the claim that social involvement is related to transcendental aesthetic feelings. This happens because the neurocognitive network involved in social cognition, the default mode network, is also involved in aesthetic contemplation (Cardona et al., 2022; Cela-Conde et al., 2013; Nair et al., 2020; Xie et al., 2016). Furthermore, our findings for social reward stand upon prior research demonstrating the significance of the social component within the emotional experience related to musical activities (Saarikallio et al., 2019).

In recent times, evidence is accumulating on music's positive role for both men and women. However, music listening was found to produce more intense physiological reactions in women and be more related to reduction in negative affect and enhancement of positive affect in women than men (Gupta & Gupta, 2016). In the current study, the results clearly reveal a superior sensitivity to musical reward in girls in several reward subdomains and in general music reward, consistent with previous evidence on gender-dependent affect (e.g., Fuentes-Sánchez et al., 2021).

These results are in line with other studies showing that women reported experiencing a greater degree of emotional arousal than men when listening to music (Hernández et al., 2019; Mas-Herrero et al., 2012; Mas-Herrero et al., 2018; Wang et al., 2021). The higher scores reported in this study by preadolescent girls in musical reward sensitivity can be considered a striking sign of a more advanced maturation by girls typical of the preadolescent age, consistent with the literature on the biological, cognitive, and psychosocial gap that occurs between preadolescent boys and girls (Duckworth & Seligman, 2006; Lenroot & Giedd, 2010; Van der Graaff et al., 2014).

To conclude, social needs appear to be particularly crucial and need to be fostered during the sensitive developmental period of preadolescence. As is known, the default mode network develops substantially between the ages of 10 and 13 (Mars et al., 2012; Sherman et al., 2014), and the involvement of this brain circuit is related to the importance of music for the formation of self, identity and cultural belongingness (Reybrouck et al. 2018). Preadolescents' neural maturation is accompanied by developments in the social and cognitive domains, so that they experience a sort of social readjustment, becoming more sensitive to social dynamics and peer interactions. Thus, it is essential to put an emphasis on social learning through a range of activities for the youngest.

Thanks to its capacity to elicit emotions and aesthetic judgments in people, art can be one of these activities, as it is a source of aesthetic entertainment endowed with multiple values, such as pleasure and functionality for life (Shusterman, 2003). Specifically, music can elicit an eudaimonic sense of pleasure based, among other things, on feeling interconnected (Stark et al., 2018). A fitting example was concretely seen during the COVID-19 pandemic, when a wide use of music for virtual sharing during the period of isolation brought out the intrinsic social feature of music able to regulate stress and strengthen collective resilience by providing a good substitute for many of the daily social interactions that individuals were lacking (Hansen, 2021; Ferreri, Singer et al., 2021).

Social contact would be then mediated by the inherent pleasure of sharing music-related activities like concerts, music preferences, cultural events, and dancing. As an activity involving many social interactions, music-making also meets this human need with experiences of fulfillment, pleasure, enjoyment, and happiness (Savage et al., 2021). This is the reason why music can be so effective in promoting social reward during development, as shown by the results of the current study.

LIMITATIONS OF THE STUDY

The current study is subject to several limitations. First, the BMRQ is not a questionnaire originally designed for preadolescents: items like "I spend quite a bit of money on music and related items" are clearly meant for adults. Nevertheless, the results of the factor analysis showed a relationship between the observed variables for the BMRQ's five dimensions and the underlying constructs and thus, that BMRQ is suitable for the pre-adolescent population.

Moreover, despite the longitudinal study design, participants were not randomly assigned to the conditions. Therefore, GMS appeared to be more enhanced in the MC group from the outset. It is known that random assignment is particularly important when determining the causality of music training as well as the presence of an active control group (Tierney & Kraus, 2013). But, in the particular case of the current study, random assignment was not ethically nor practically conceivable, as it is not possible to control the enrollment of students to a school curriculum. However, when adequate randomization is not possible, it is essential to determine group equivalence. In the current study, children were equally distributed between the conditions.

Another disturbing element may consist in having arranged two out of three data collections at the end of the school year. A student's life is full of stressful moments and challenges to face, and this may be even more true in the last part of the school year, when final tests and exams are near, and fatigue reaches its peak before the start of the summer holidays. This could explain the score decrease in mood regulation over time.

Finally, important variables such as differences between the various curricular music courses and leisure time activities of children from both groups were not controlled for in the current study. Future research on music middle schools should take these variables into account to better evaluate the effects of music training carried out at school and obtain clearer results when comparing the two curricula.

CONCLUSIONS

In the current study, the statistically significant scores found for social reward revealed that those who participate in music training derive more pleasure from sharing musical events with other people. Moreover, our results seem to suggest the necessity to consider the contribution of gender when studying the processing of emotions associated with music, in addition to the general construct of music reward. Altogether, these results obtained in a sample with such a varied social background make us consider music training as a valuable resource that may foster meaningful, positive, and developmentally useful social interactions in preadolescence. In addition, music middle school appears to be a positive developmental context for preadolescents, but more research is needed in order to deepen this topic. To further explore the effect of music training, future research involving children should investigate the role of intrapersonal factors, such as musical reward sensitivity and openness to experience, which was found to be particularly related to responsiveness to music. This would help to clarify the role of pre-existing attitudes for musical reward in the developmental stage and to add evidence to the already promising data of this study.

ACKNOWLEDGEMENTS

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.

Center for Music in the Brain (MIB) is funded by the Danish National Research Foundation (DNRF117).

We are grateful to the directors, teachers, students and their families of the schools De Amicis-Dizonno (Triggiano), Alighieri-Tanzi (Mola di Bari) and Massari-Galilei (Bari) for collaborating on this project. The project also profited from the precious help provided at different stages of data collection and analysis by the following Bachelor's students from University of Bari Aldo Moro: Gaia Fratepietro, Giuseppe Fuggiano, Alessia Bianco, Roberta Capuano, Luigi Di Blasio, Adriana Dagnello, Giorgia Mazzone and Alessandro Liguigli.

DATA AVAILABILITY

The dataset analyzed for this study can be found in the Zenodo digital repository at https://doi.org/10.5281/zenodo.10001724

SUPPLEMENTARY MATERIALS

REFERENCES

Agarwal, T., Singh, B., Kapadnis, C., Bhonsale, I., & Jabade, S. (2022). Effects of music listening on coping strategies and multiple intelligence in music-experienced and music-nonexperience adolescents. *Journal of Positive School Psychology*, *6*(6), 4002–4011

Alemán, X., Duryea, S., Guerra, N. G., McEwan, P. J., Muñoz, R., Stampini, M., & Williamson, A. A. (2017). The effects of musical training on child development: A randomized trial of El Sistema in Venezuela. *Prevention Science*, *18*(7), 865–878. https://doi.org/10.1007/s11121-016-0727-3

Alluri, V., Brattico, E., Toiviainen, P., Burunat, I., Bogert, B., Numminen, J., & Kliuchko, M. (2015). Musical expertise modulates functional connectivity of limbic regions during continuous music listening. *Psychomusicology: Music, Mind, and Brain*, *25*(4), 443–454. https://doi.org/10.1037/pmu0000124

Ambrosia, M., Eckstrand, K. L., Morgan, J. K., Allen, N. B., Jones, N. P., Sheeber, L., ... & Forbes, E. E. (2018). Temptations of friends: adolescents' neural and behavioral responses to best friends predict risky behavior. *Social Cognitive and Affective Neuroscience, 13*(5), 483–491. https://doi.org/ 10.1093/scan/nsy028

Arnett, J. (1991). Heavy metal music and reckless behavior among adolescents. *Journal of Youth and Adolescence, 20*(6), 573–592. https://doi.org/10.1007/BF01537363

Bates, D., Maechler, M., Bolker, B., Walker, S., Christensen, R. H., Singmann, H., & Dai, B. (2015). lme4: Linear mixed-effects models using Eigen and S4. R package version 1.1–7. 2014.

Belfi, A. M., Moreno, G. L., Gugliano, M., & Neill, C. (2022). Musical reward across the lifespan. *Aging and Mental Health, 26*(5), 932–939. https://doi.org/ 10.1080/13607863.2021.1871881

Bergman Nutley, S., Darki, F., & Klingberg, T. (2014). Music practice is associated with development of working memory during childhood and adolescence. *Frontiers in Human Neuroscience, 7*, 926. https://doi.org/10.3389/fnhum.2013.00926

Biasutti, M., & Mangiacotti, A. (2021). Music training improves depressed mood symptoms in elderly people: a randomized controlled trial. *The International Journal of Aging and Human Development, 92*(1), 115–133. https://doi.org/ 10.1177/0091415019893988

Brattico, E., Bogert, B., Alluri, V., Tervaniemi, M., Eerola, T., & Jacobsen, T. (2016). It's sad but I like it: The neural dissociation between musical emotions and liking in experts and laypersons. *Frontiers in Human Neuroscience, 9*, 676. https://doi.org/10.3389/fnhum.2015.00676

Brattico, E., Bogert, B., & Jacobsen, T. (2013). Toward a neural chronometry for the aesthetic experience of music. *Frontiers in Psychology, 4*, 206. https://doi.org/10.3389/fpsyg.2013.00206

Brattico, E., & Pearce, M. (2013). The neuroaesthetics of music. *Psychology of Aesthetics, Creativity, and the Arts, 7*(1), 48–61. https://doi.org/ 10.1037/a0031624

Brattico, E., & Varankaitė, U. (2019). Aesthetic empowerment through music. *Musicae Scientiae, 23*(3), 285–303. https://doi.org/10.1177/1029864919850606

Burunat, I., Brattico, E., Puoliväli, T., Ristaniemi, T., Sams, M., & Toiviainen, P. (2015). Action in perception: Prominent visuo-motor functional symmetry in musicians during music listening. *PloS One, 10*(9), e0138238. https://doi.org/10.1371/journal.pone.0138238

Cardona, G., Ferreri, L., Lorenzo-Seva, U., Russo, F. A., & Rodriguez-Fornells, A. (2022). The forgotten role of absorption in music reward. *Annals of the New York Academy of Sciences, 1514*, 142–154. https://doi.org/10.1111/nyas.14790

Carraturo, G., Ferreri, L., Vuust, P., Matera, F., & Brattico, E. (2022). Empathy but not musicality is at the root of musical reward: A behavioral study with adults and children. *Psychology of Music, 50*(6), 2001–2020. https://doi.org/10.1177/03057356221081168

Castro, S. L., & Lima, C. F. (2014). Age and musical expertise influence emotion recognition in music. *Music Perception: An Interdisciplinary Journal, 32*(2), 125–142. Https://doi.org/ 10.1525/MP.2014.32.2.125

Cela-Conde, C. J., García-Prieto, J., Ramasco, J. J., Mirasso, C. R., Bajo, R., Munar, E., ... & Maestú, F. (2013). Dynamics of brain networks in the aesthetic appreciation. *Proceedings of the National Academy* of Sciences, *110*(supplement_2), 10454–10461. https://doi.org/10.1073/pnas.1302855110

Chabin, T., Gabriel, D., Chansophonkul, T., Michelant, L., Joucla, C., Haffen, E., ... & Pazart, L. (2020). Cortical patterns of pleasurable musical chills revealed by high-density EEG. *Frontiers in Neuroscience, 14*, 1114. https://doi.org/10.3389/fnins.2020.565815

Cheung, G. W., & Rensvold, R. B. (2002). Evaluating goodness-of-fit indexes for testing measurement invariance. *Structural Equation Modeling, 9*(2), 233–255. https://doi.org/10.1207/S15328007SEM0902_5

Cook, T., Roy, A. R., & Welker, K. M. (2019). Music as an emotion regulation strategy: An examination of genres of music and their roles in emotion regulation. *Psychology of Music, 47*(1), 144–154. https://doi.org/10.1177/0305735617734627

Criscuolo, A., Pando-Naude, V., Bonetti, L., Vuust, P., & Brattico, E. (2022). An ALE meta-analytic review of musical expertise. *Scientific Reports, 12*(1), 1–17. https://doi.org/10.1038/s41598-022-14959-4

Cross, I. (2001). Music, cognition, culture, and evolution. *Annals of the New York Academy of Sciences, 930*(1), 28–42. https://doi.org/10.1111/j.1749-6632.2001.tb05723.x

Cumming, G., & Calin-Jageman, R. (2016). *Introduction to the new statistics: Estimation, open science, and beyond*. Routledge.

D'Ausilio, A., Novembre, G., Fadiga, L., & Keller, P. E. (2015). What can music tell us about social interaction? *Trends in Cognitive Sciences, 19*(3), 111–114. https://doi.org/ 10.1016/j.tics.2015.01.005

Daykin, N., Mansfield, L., Meads, C., Julier, G., Tomlinson, A., Payne, A., … & Victor, C. (2018). What works for wellbeing? A systematic review of wellbeing outcomes for music and singing in adults. *Perspectives in Public Health, 138*(1), 39–46. https://doi.org/10.1177/1757913917740391

Denk J, Burmester A, Kandziora M, Clement M (2022) The impact of COVID-19 on music consumption and music spending. *PLoS One, 17*(5), e0267640. https://doi.org/10.1371/journal.pone.0267640

DeNora, T. (2016). *Music asylums: Wellbeing through music in everyday life*. Routledge.

Derdau Sorensen, S. (2020). *How musical are children? A nationwide cross-sectional study of individual differences in musical competence and working memory in Danish school children* [Doctoral dissertation], Aarhus, Denmark. Aarhus University.

Duckworth, A. L., & Seligman, M. E. (2006). Self-discipline gives girls the edge: Gender in self-discipline, grades, and achievement test scores. *Journal of Educational Psychology, 98*(1), 198–208. https://doi.org/10.1037/0022-0663.98.1.198

Dys, S. P., Schellenberg, G., & McLean, K. C. (2017). Musical identities, music preferences, and individual differences. In R. A. R. MacDonald, D. J. Hargreaves, & D. Miell (Eds.), *Handbook of musical identities* (pp. 247–266). https://doi.org/ 10.1093/acprof:oso/9780199679485.003.0014

Epskamp, S. (2017). semPlot: Path Diagrams and Visual Analysis of Various SEM Packages' Output. [R package]. https://cran.r-project.org/package=semPlot

Fasano, M. C., Brattico, E., Lorenzen, I. S., Gargiulo, A., Kringelbach, M. L., Semeraro, C., & Cassibba, R. (2023). The impact of orchestral playing on children's lives. In T. Chemi, E. Brattico, L. O. Fjorback, & L. Harmat (Eds.), *Arts and mindfulness education for human flourishing* (pp. 106–123). Routledge.

Fasano, M. C., Cabral, J., Stevner, A., Vuust, P., Cantou, P., Brattico, E., & Kringelbach, M. L. (2023). The early adolescent brain on music: Analysis of functional dynamics reveals engagement of orbitofrontal cortex reward system. *Human Brain Mapping, 44*(2), 429–446. https://doi.org/10.1002/hbm.26060

Fasano, M. C., Semeraro, C., Cassibba, R., Kringelbach, M. L., Monacis, L., De Palo, V., ... & Brattico, E. (2019). Short-term orchestral music training modulates hyperactivity and inhibitory control in school-age children: A longitudinal behavioural study. *Frontiers in Psychology, 10*, 750. https://doi.org/10.3389/fpsyg.2019.00750

Fasano, M. C., Glerean, E., Gold, B. P., Sheng, D., Sams, M., Vuust, P., ... & Brattico, E. (2021). Inter-subject similarity of brain activity in expert musicians after multimodal learning: A behavioral and neuroimaging study on learning to play a piano sonata. *Neuroscience, 441*, 102–116. Https://doi.org/ 10.1016/j.neuroscience.2020.06.015

Ferreri, L., Bigand, E., & Bugaiska, A. (2015). The positive effect of music on source memory. *Musicae Scientiae, 19*(4), 402–411. https://doi.org/10.1177/1029864915604684

Ferreri, L., Mas-Herrero, E., Cardona, G., Zatorre, R. J., Antonijoan, R. M., Valle, M., ... & Rodriguez-Fornells, A. (2021). Dopamine modulations of reward-driven music memory consolidation. *Annals of the New York Academy of Sciences, 1502*(1), 85–98. https://doi.org/ 10.1111/nyas.14656

Ferreri, L., Mas-Herrero, E., Zatorre, R. J., Ripollés, P., Gomez-Andres, A., Alicart, H., ... & Rodriguez-Fornells, A. (2019). Dopamine modulates the reward experiences elicited by music. *Proceedings of the National Academy of Sciences, 116*(9), 3793–3798. https://doi.org/ 10.1073/pnas.1811878116

Ferreri, L., & Rodriguez-Fornells, A. (2017). Music-related reward responses predict episodic memory performance. *Experimental Brain Research, 235*(12), 3721–3731. https://doi.org/ 10.1007/s00221-017-5095-0

Ferreri, L., Singer, N., McPhee, M., Ripollés, P., Zatorre, R. J., & Mas-Herrero, E. (2021). Engagement in music-related activities during the COVID-19 pandemic as a mirror of individual differences in musical reward and coping strategies. *Frontiers in Psychology, 2504*. https://doi.org/10.3389/fpsyg.2021.673772

Fiedler, D., & Müllensiefen, D. (2015). Validation of the Gold-MSI questionnaire to measure musical sophistication of German students at secondary education schools. *Musikpädagogische Forschung/Research in Music Education, 36*, 199–219

Foulkes, L., & Blakemore, S. J. (2016). Is there heightened sensitivity to social reward in adolescence? *Current Opinion in Neurobiology, 40*, 81–85. Https://doi.org/ 10.1016/j.conb.2016.06.016

Franken, A., Keijsers, L., Dijkstra, J. K., & Ter Bogt, T. (2017). Music preferences, friendship, and externalizing behavior in early adolescence: A SIENA examination of the music marker theory using the SNARE study. *Journal of Youth and Adolescence, 46*(8), 1839–1850. Https://doi.org/ 10.1007/s10964-017-0633-4

Fuentes-Sánchez, N., Pastor, M. C., Eerola, T., & Pastor, R. (2021). Individual differences in music reward sensitivity influence the perception of emotions represented by music. *Musicae Scientiae, 27*(2), 313–331. https://doi.org/10.1177/10298649211060028

Gallucci, M. (2019). GAMLj: General analyses for linear models. [jamovi module]. https://gamlj.github.io/

Gallucci, M., Jentschke, S. (2021). SEMLj: jamovi SEM Analysis. [jamovi module]. https://semlj.github.io/

Glowinski, D., Mancini, M., Cowie, R., Camurri, A., Chiorri, C., & Doherty, C. (2013). The movements made by performers in a skilled quartet: a distinctive pattern, and the function that it serves. *Frontiers in Psychology, 4,* 841. https://doi.org/10.3389/fpsyg.2013.00841

Gold, B. P., Frank, M. J., Bogert, B., & Brattico, E. (2013). Pleasurable music affects reinforcement learning according to the listener. *Frontiers in Psychology, 4*, 541. https://doi.org/10.3389/fpsyg.2013.00541

Gold, B. P., Mas-Herrero, E., Zeighami, Y., Benovoy, M., Dagher, A., & Zatorre, R. J. (2019). Musical reward prediction errors engage the nucleus accumbens and motivate learning. *Proceedings of the National Academy of Sciences of the United States of America, 116*(8), 3310–3315. https://doi.org/ 10.1073/pnas.1809855116

Gold, B. P., Pearce, M. T., Mas-Herrero, E., Dagher, A., & Zatorre, R. J. (2019). Predictability and uncertainty in the pleasure of music: a reward for learning? *Journal of Neuroscience, 39*(47), 9397–9409. https://doi.org/10.1523/JNEUROSCI.0428-19.2019

Gordon, R. L., Fehd, H. M., & McCandliss, B. D. (2015). Does music training enhance literacy skills? A meta-analysis. *Frontiers in Psychology, 6*, 1777. https://doi.org/10.3389/fpsyg.2015.01777

Guo, H., Yuan, W., Fung, C. V., Chen, F., & Li, Y. (2022). The relationship between extracurricular music activity participation and music and Chinese language academic achievements of primary school students in China. *Psychology of Music, 50*(3), 742–755. Https://doi.org/10.1177/03057356211027642

Gupta, U., & Gupta, B. S. (2016). Gender differences in psychophysiological responses to music listening. *Music and Medicine, 8*(1), 53–64. Https://doi.org/ 10.47513/mmd.v8i1.471

Hansen, N. C. (2021). Music for hedonia and eudemonia during pandemic social isolation. In: T. Chemi, E. Brattico, L.O. Fjorback, & L. Harmat (Eds), *The anthology: Arts and mindfulness education for human flourishing*. Routledge.

Hargreaves, D. J., North, A. C., & Tarrant, M. (2015). How and why do musical preferences change in childhood and adolescence. In G. E. McPherson (Ed.), *The child as musician: A handbook of musical development* (pp. 303–322). Oxford University Press.

Hernández, M., Palomar-García, M. Á., Nohales-Nieto, B., Olcina-Sempere, G., Villar-Rodríguez, E., Pastor, R., ... & Parcet, M. A. (2019). Separate contribution of striatum volume and pitch discrimination to individual differences in music reward. *Psychological Science, 30*(9), 1352–1361. https://doi.org/10.1177/0956797619859

Holochwost, S. J., Propper, C. B., Wolf, D. P., Willoughby, M. T., Fisher, K. R., Kolacz, J., ... & Jaffee, S. R. (2017). Music education, academic achievement, and executive functions. *Psychology of Aesthetics, Creativity, and the Arts, 11*(2), 147–166. https://doi.org/10.1037/aca0000112

Huron, D. (2008). *Sweet anticipation: Music and the psychology of expectation*. MIT Press.

Juniu, S., Tedrick, T., & Boyd, R. (1996). Leisure or work?: Amateur and professional musicians' perception of rehearsal and performance. *Journal of Leisure Research, 28*(1), 44–56. https://doi.org/10.1080/00222216.1996.11949760

Juslin, P. N. (2016). Emotional reactions to music. In S. Hallam, I. Cross, & M. Thaut (Eds.), *The Oxford handbook of music psychology* (pp. 197–213). Oxford University Press.

Juslin, P. N., & Laukka, P. (2003). Communication of emotions in vocal expression and music performance: Different channels, same code? *Psychological Bulletin, 129*(5), 770–814. https://doi.org/10.1037/0033-2909.129.5.770

Juslin, P. N., & Sloboda, J. A. (2001). *Music and emotion. Theory and research.* Oxford University Press.

Kerby, D. S. (2014). The simple difference formula: An approach to teaching nonparametric correlation. *Comprehensive Psychology, 3*, 2165–2228. https://doi.org/ 10.2466/11.IT.3.1

Kim, J., & Stegemann, T. (2016). Music listening for children and adolescents in health care contexts: A systematic review. *The Arts in Psychotherapy, 51*, 72–85. https://doi.org/10.1016/j.aip.2016.08.007

Kirschner, S., & Tomasello, M. (2009). Joint drumming: Social context facilitates synchronization in preschool children. *Journal of Experimental Child Psychology, 102*(3), 299–314. Https://doi.org/10.1016/j.jecp.2008.07.005

Koelsch, S. (2014). Brain correlates of music-evoked emotions. *Nature Reviews Neuroscience, 15*(3), 170–180. https://doi.org/10.1038/nrn3666

Koelsch, S. (2015). Music-evoked emotions: principles, brain correlates, and implications for therapy. *Annals of the New York Academy of Sciences, 1337*(1), 193–201. https://doi.org/10.1111/nyas.12684

Koelsch, S. (2020). A coordinate-based meta-analysis of music-evoked emotions. *NeuroImage, 223*, 117350. https://doi.org/10.1016/j.neuroimage.2020.117350

Kraus, N., Slater, J., Thompson, E. C., Hornickel, J., Strait, D. L., Nicol, T., & White-Schwoch, T. (2014). Auditory learning through active engagement with sound: biological impact of community music lessons in at-risk children. *Frontiers in Neuroscience, 8*, 351. https://doi.org/10.3389/fnins.2014.00351

Kraus, N., & White-Schwoch, T. (2015). Unraveling the biology of auditory learning: A cognitive–sensorimotor–reward framework. *Trends in Cognitive Sciences, 19*(11), 642–654. https://doi.org/10.1016/j.tics.2015.08.017

Lamont, A., & Hargreaves, D. J. (2019). Musical preference and social identity in adolescence. In K. McFerran, P. Derrington, & S. Saarikallio (Eds.), *Handbook of music, adolescents, and wellbeing* (pp. 109-118). Oxford University Press.

Lenroot, R. K., & Giedd, J. N. (2010). Sex differences in the adolescent brain. *Brain and Cognition, 72*(1), 46–55. https://doi.org/10.1016/j.

bandc.2009.10.008

Lin, H. R., Kopiez, R., Müllensiefen, D., & Wolf, A. (2021). The Chinese version of the Gold-MSI: Adaptation and validation of an inventory for the measurement of musical sophistication in a Taiwanese sample. *Musicae Scientiae, 25*(2), 226–251. https://doi.org/10.1177/1029864919871987

Lippolis, M., Müllensiefen, D., Frieler, K., Matarrelli, B., Vuust, P., Cassibba, R., Brattico, E. (2022). Learning to play a musical instrument in the middle school is associated with superior audiovisual working memory and fluid intelligence: A cross-sectional behavioral study. *Frontiers in Psychology, 13,* 982704. https://doi.org/10.3389/fpsyg.2022.982704

Mars, R. B., Neubert, F. X., Noonan, M. P., Sallet, J., Toni, I., & Rushworth, M. F. (2012). On the relationship between the "default mode network" and the "social brain". *Frontiers in Human Neuroscience, 6*, 189. https://doi.org/10.3389/fnhum.2012.00189

Martínez-Molina, N., Mas-Herrero, E., Rodríguez-Fornells, A., Zatorre, R. J., & Marco-Pallarés, J. (2016). Neural correlates of specific musical anhedonia. *Proceedings of the National Academy of Sciences, 113*(46), E7337–E7345. https://doi.org/10.1073/pnas.1611211113

Mas-Herrero, E., Dagher, A., Farrés-Franch, M., & Zatorre, R. J. (2021). Unraveling the temporal dynamics of reward signals in music-induced pleasure with TMS. *Journal of Neuroscience, 41*(17), 3889–3899. https://doi.org/https://doi.org/10.1523/JNEUROSCI.0727-20.2020

Mas-Herrero, E., Dagher, A., & Zatorre, R. J. (2018). Modulating musical reward sensitivity up and down with transcranial magnetic stimulation. *Nature Human Behaviour, 2*(1), 27–32. https://doi.org/10.1038/s41562-017-0241-z

Mas-Herrero, E., Marco-Pallares, J., Lorenzo-Seva, U., Zatorre, R. J., & Rodriguez-Fornells, A. (2012). Individual differences in music reward experiences. *Music Perception: An Interdisciplinary Journal, 31*(2), 118–138. https://doi.org/10.1525/mp.2013.31.2.118

Mas-Herrero, E., Zatorre, R. J., Rodriguez-Fornells, A., & Marco-Pallarés, J. (2014). Dissociation between musical and monetary reward responses in specific musical anhedonia. *Current Biology, 24*(6), 699–704. https://doi.org/ 10.1016/j.cub.2014.01.068

Matarrelli, B., Lippolis, M., & Brattico, E. (2023). Musica per il flourishing individuale e collettivo: le frontiere della ricerca in Psicologia e Neuroscienze della Musica. *Musica per il flourishing individuale e collettivo: le frontiere della ricerca in Psicologia e Neuroscienze della Musica,* 35–55.

McFerran, K. (2019). *Handbook of music, adolescents, and wellbeing.* Oxford University Press.

Metsäpelto, R. L., & Pulkkinen, L. (2012). Socioemotional behavior and school achievement in relation to extracurricular activity participation in middle childhood. *Scandinavian Journal of Educational Research, 56*(2), 167–182. Https://doi.org/10.1080/00313831.2011.581681

Miendlarzewska, E. A., & Trost, W. J. (2014). How musical training affects cognitive development: rhythm, reward and other modulating variables. *Frontiers in Neuroscience, 279*. https://doi.org/10.3389/fnins.2013.00279

Miranda, D. (2019). A review of research on music and coping in adolescence. *Psychomusicology: Music, Mind, and Brain, 29*(1), 1–9. https://doi.org/10.1037/pmu0000229

Miranda, D., & Claes, M. (2008). Personality traits, music preferences and depression in adolescence. *International Journal of Adolescence and Youth, 14*(3), 277–298. https://doi.org/10.1080/02673843.2008.9748008

Molnar-Szakacs, I., Assuied, V. G., & Overy, K. (2011). Shared affective motion experience (SAME) and creative, interactive music therapy. In D. Hargreaves, D. Miell, & R. MacDonald (Eds.), *Musical imaginations: Multidisciplinary perspectives on creativity, performance and perception* (pp. 313–330). Oxford University Press.

Moore, K. A., & Theokas, C. (2008). Conceptualizing a monitoring system for indicators in middle childhood. *Child Indicators Research, 1*, 109–128. https://doi.org/10.1007/s12187-008-9011-9

Morinville, A., Miranda, D., & Gaudreau, P. (2013). Music listening motivation is associated with global happiness in Canadian late adolescents. *Psychology of Aesthetics, Creativity, and the Arts, 7*(4), 384–390. https://doi.org/10.1037/a0034495

Moss, H., Lynch, J., & O'donoghue, J. (2018). Exploring the perceived health benefits of singing in a choir: an international cross-sectional mixed-methods study. *Perspectives in Public Health, 138*(3), 160–168. https://doi.org/ 10.1177/1757913917739652

Müllensiefen, D., Gingras, B., Musil, J., & Stewart, L. (2014). Measuring the facets of musicality: The Goldsmiths Musical Sophistication Index (Gold-MSI). *Personality and Individual Differences, 60*, S35. https://doi.org/10.1016/j.paid.2013.07.081

Müllensiefen, D., Harrison, P., Caprini, F., & Fancourt, A. (2015). Investigating the importance of selftheories of intelligence and musicality for students' academic and musical achievement. *Frontiers in Psychology, 6*, 1702. https://doi.org/10.3389/fpsyg.2015.01702

Nair, A., Jolliffe, M., Lograsso, Y. S. S., & Bearden, C. E. (2020). A review of default mode network connectivity and its association with social cognition in adolescents with autism spectrum disorder and early-onset psychosis. *Frontiers in Psychiatry, 11*, 614. https://doi.org/ 10.3389/fpsyt.2020.00614

North, A. C., Hargreaves, D. J., & Hargreaves, J. J. (2004). Uses of music in everyday life. *Music perception, 22*(1), 41–77. https://doi.org/10.1525/mp.2004.22.1.41

Novembre, G., Mitsopoulos, Z., & Keller, P. E. (2019). Empathic perspective taking promotes interpersonal coordination through music. *Scientific Reports, 9*(1), 1–12. https://doi.org/10.1038/s41598-019-48556-9

Nummenmaa, L., Putkinen, V., & Sams, M. (2021). Social pleasures of music. *Current Opinion in Behavioral Sciences, 39*, 196–202. https://doi.org/10.1016/j.cobeha.2021.03.026

Penhune, V. B. (2020). A gene-maturation-environment model for understanding sensitive period effects in musical training. *Current Opinion in Behavioral Sciences, 36*, 13–22. https://doi.org/10.1016/j.cobeha.2020.05.011

Pitts, S. E. (2007). Anything goes: A case study of extra-curricular musical participation in an English secondary school. *Music Education Research, 9*(1), 145–165. https://doi.org/10.1080/14613800601127627

Putkinen, V., Saarikivi, K., & Tervaniemi, M. (2013). Do informal musical activities shape auditory skill development in preschool-age children? *Frontiers in Psychology, 4*, 572. https://doi.org/10.3389/fpsyg.2013.00572

Putkinen, V., Tervaniemi, M., Saarikivi, K., & Huotilainen, M. (2015). Promises of formal and informal musical activities in advancing neurocognitive development throughout childhood. *Annals of the New York Academy of Sciences, 1337*(1), 153–162. https://doi.org/10.1111/nyas.12656

R Core Team (2021). R: A Language and environment for statistical computing. (Version 4.0) [Computer software]. https://cran.r-project.org

Rabinowitch, T. C., Cross, I., & Burnard, P. (2013). Long-term musical group interaction has a positive influence on empathy in children. *Psychology of Music, 41*(4), 484–498. https://doi.org/10.1177/0305735612440

Rabinowitch, T. C., & Meltzoff, A. N. (2017). Joint rhythmic movement increases 4-year-old children's prosocial sharing and fairness toward peers. *Frontiers in Psychology, 8*, 1050. https://doi.org/10.3389/fpsyg.2017.01050

Reybrouck, M., & Brattico, E. (2022). Music, mindfulness and meditation. In T. Chemi, E. Brattico, L. O. Fjorback, & L. Harmat (Eds.), *Arts and mindfulness education for human flourishing.* Routledge.

Reybrouck, M., Vuust, P., & Brattico, E. (2018). Brain connectivity networks and the aesthetic experience of music. *Brain Sciences, 8*(6), 107. https://doi.org/ 10.3390/brainsci8060107

Reybrouck, M., Vuust, P., & Brattico, E. (2021). Neural correlates of music listening: Does the music matter? *Brain Sciences, 11*(12), 1553. https://doi.org/10.3390/brainsci11121553

Rosseel, Y., Jorgensen, T. D., De Wilde, L., Oberski, D., Byrnes, J. Vanbrabant, L., Savalei, V., Merkle, E., Hallquist, M., Rhemtulla, M., Katsikatsou, M., Barendse, M., Rockwood, N., Scharf, F., Du, H., & Jamil, H.. (2018). lavaan: Latent Variable Analysis. [R package]. https://cran.r-project.org/package=lavaan

Salimpoor, V. N., Zald, D. H., Zatorre, R. J., Dagher, A., & McIntosh, A. R. (2015). Predictions and the brain: how musical sounds become rewarding. *Trends in Cognitive Sciences, 19*(2), 86–91. https://doi.org/ 10.1016/j.tics.2014.12.001

Saarikallio, S. H., Maksimainen, J. P., & Randall, W. M. (2019). Relaxed and connected: Insights into the emotional–motivational constituents of musical pleasure. *Psychology of Music, 47*(5), 644–662. https://doi.org/ 10.1177/0305735618778768

Sachs, M. E., Ellis, R. J., Schlaug, G., & Loui, P. (2016). Brain connectivity reflects human aesthetic responses to music. *Social Cognitive and Affective Neuroscience, 11*(6), 884–891. https://doi.org/10.1093/scan/nsw009

Savage, P. E., Loui, P., Tarr, B., Schachner, A., Glowacki, L., Mithen, S., & Fitch, W. T. (2021). Music as a coevolved system for social bonding. *Behavioral and Brain Sciences, 44,* e59. https://doi.org/10.1017/S0140525X20000333

Schaal, N. K., Bauer, A. K. R., & Müllensiefen, D. (2014). Der Gold-MSI: replikation und validierung eines fragebogeninstrumentes zur messung musikalischer erfahrenheit anhand einer deutschen stichprobe. *Musicae Scientiae, 18*(4), 423–447. https://doi.org/10.1177/1029864914541851

Schellenberg, E. G., Corrigall, K. A., Dys, S. P., & Malti, T. (2015). Group music training and children's prosocial skills. *PLoS One, 10*(10), e0141449. https://doi.org/10.1371/journal.pone.0141449

Selfhout, M. H., Branje, S. J., ter Bogt, T. F., & Meeus, W. H. (2009). The role of music preferences in early adolescents' friendship formation and stability. *Journal of Adolescence, 32*(1), 95–107. https://doi.org/10.1016/j.adolescence.2007.11.004

Sherman, L. E., Rudie, J. D., Pfeifer, J. H., Masten, C. L., McNealy, K., & Dapretto, M. (2014). Development of the default mode and central executive networks across early adolescence: A longitudinal study. *Developmental Cognitive Neuroscience, 10*, 148–159. https://doi.org/10.1016/j.dcn.2014.08.002

Shusterman, R. (2003). Pragmatism between aesthetic experience and aesthetic education. *Studies in Philosophy and Education, 22*(5), 403–412. https://doi.org/10.1023/A:1025127015220

Slater, J., Skoe, E., Strait, D. L., O'Connell, S., Thompson, E., & Kraus, N. (2015). Music training improves speech-in-noise perception: Longitudinal evidence from a community-based music program. *Behavioural Brain Research, 291*, 244–252. Https://doi.org/10.1016/j.bbr.2015.05.026

Stark, E. A., Vuust, P., & Kringelbach, M. L. (2018). Music, dance, and other art forms: New insights into the links between hedonia (pleasure) and eudaimonia (well-being). *Progress in Brain Research, 237*, 129–152. https://doi.org/ 10.1016/bs.pbr.2018.03.019

Stupacher, J., Wood, G., & Witte, M. (2017). Neural entrainment to polyrhythms: a comparison of musicians and non-musicians. *Frontiers in Neuroscience, 11*, 208. https://doi.org/10.3389/fnins.2017.00208

Tervaniemi, M. (2009). Musicians—same or different? *Annals of the New York Academy of Sciences, 1169*(1), 151–156. https://doi.org/10.1111/j.1749-6632.2009.04591.x

The jamovi project (2021). jamovi. (Version 2.2) [Computer Software]. https://www.jamovi.org

Thomas, K. S. (2016). Music preferences and the adolescent brain: A review of literature. *Update: Applications of Research in Music Education, 35*(1), 47–53. https://doi.org/10.1177/8755123315576534

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

Tierney, A. T., Krizman, J., & Kraus, N. (2015). Music training alters the course of adolescent auditory development. *Proceedings of the National Academy of Sciences, 112*(32), 10062–10067. https://doi.org/10.1073/pnas.1505114112

Trainor, L. J., & Cirelli, L. (2015). Rhythm and interpersonal synchrony in early social development. *Annals of the New York Academy of Sciences, 1337*(1), 45–52. https://doi.org/10.1111/nyas.12649

Van der Graaff, J., Branje, S., De Wied, M., Hawk, S., Van Lier, P., & Meeus, W. (2014). Perspective taking and empathic concern in adolescence: gender differences in developmental changes. *Developmental Psychology, 50*(3), 881. https://doi.org/10.1037/a0034325

Vesper, C., Van Der Wel, R. P., Knoblich, G., & Sebanz, N. (2011). Making oneself predictable: Reduced temporal variability facilitates joint action coordination. *Experimental Brain Research, 211*(3), 517–530. https://doi.org/ 10.1007/s00221-011-2706-z

Virtala, P., & Tervaniemi, M. (2017). Neurocognition of major-minor and consonance-dissonance. *Music Perception: An Interdisciplinary Journal, 34*(4), 387–404. https://doi.org/10.1525/mp.2017.34.4.387

Vuust, P., Gebauer, L., Hansen, N. C., Jørgensen, S. R., Møller, A., & Linnet, J. (2010). Personality influences career choice: Sensation seeking in professional musicians. *Music Education Research, 12*(2), 219–230. https://doi.org/ 10.1080/14613801003746584

Vuust, P., & Kringelbach, M. L. (2010). The pleasure of making sense of music. *Interdisciplinary Science Reviews, 35*(2), 166–182. https://doi.org/10.1002/hup.1123

Vuvan, D. T., Simon, E., Baker, D. J., Monzingo, E., & Elliott, E. M. (2020). Musical training mediates the relation between working memory capacity and preference for musical complexity. *Memory & Cognition, 48*(6), 972–981. https://doi.org/ 10.3758/s13421-020-01031-7

Wallentin, M., Nielsen, A. H., Friis-Olivarius, M., Vuust, C., & Vuust, P. (2010). The Musical Ear Test, a new reliable test for measuring musical competence. *Learning and Individual Differences, 20*(3), 188–196. Https://doi.org/ 10.1016/j.lindif.2010.02.004

Wang, J., Xu, M., Jin, Z., Xia, L., Lian, Q., Huyang, S., & Wu, D. (2021). The Chinese version of the Barcelona Music Reward Questionnaire (BMRQ): Associations with personality traits and gender. *Musicae Scientiae, 139*. https://doi.org/ 10.1177/10298649211034547

Wesseldijk, L. W., Gordon, R. L., Mosing, M. A., & Ullén, F. (2021). Music and verbal ability—A twin study of genetic and environmental associations. *Psychology of Aesthetics, Creativity, and the Arts, 17*(6), 675–681. https://doi.org/ 10.1037/aca0000401

Xie, X., Bratec, S. M., Schmid, G., Meng, C., Doll, A., Wohlschläger, A., ... & Sorg, C. (2016). How do you make me feel better? Social cognitive emotion regulation and the default mode network. *NeuroImage, 134*, 270–280. https://doi.org/10.1016/j.neuroimage.2016.04.015

Yurgil, K. A., Velasquez, M. A., Winston, J. L., Reichman, N. B., & Colombo, P. J. (2020). Music training, working memory, and neural oscillations: A review. *Frontiers in Psychology, 11*, 266. https://doi.org/10.3389/fpsyg.2020.00266

Zatorre, R. J. (2015). Musical pleasure and reward: mechanisms and dysfunction. *Annals of the New York Academy of Sciences, 1337*(1), 202–211. https://doi.org/ 10.1111/nyas.12677

Zatorre, R. J., & Salimpoor, V. N. (2013). From perception to pleasure: music and its neural substrates. *Proceedings of the National Academy of Sciences, 110*(supplement_2), 10430–10437. https://doi.org/ 10.1073/pnas.1301228110

RECEIVED 07.10.2023 | ACCEPTED 02.01.2024