



# The Italian version of the extended Barcelona Music Reward Questionnaire (eBMRQ): a validation study and association with age, gender, and musicianship

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## ABSTRACT

**Background.** Music is a primary source of pleasure for humans. Nevertheless, there is large interindividual variability in how individuals experience and derive pleasure from music and music-related activities. With this study we propose and validate the Italian version of the extended Barcelona Music Reward Questionnaire (eBMRQ), the most in-depth and comprehensive tool for investigating the diverse characterization of individual sensitivity to pleasure in music. In addition, we aim to investigate eBMRQ scores as a function of age, gender, and musicianship across Italian population.

**Methods.** For the validation process of the Italian eBMRQ, we first conducted forward and backward translation from the original English eBMRQ version. The new Italian version was then administered to 1,012 participants who were fluent in Italian from the north and the south of Italy through online surveys (age range 18–86 years old;  $M = 34.9$ ,  $SD = 16.9$ , females 74%). Unrestricted confirmatory analysis was computed for both six-factor and single-factor models. The effect of gender, age, and musicianship on eBMRQ scores was analyzed through analysis of variance (ANOVA).

**Results.** The quality assessment of the factor solution indicated that the Italian eBMRQ demonstrated acceptable quality and reliability, making it a valid tool for assessing sensitivity to music reward. All factors were significantly correlated with each other, in line with previous adaptations of the BMRQ. Our findings indicate that females reported higher music reward sensitivity compared to males, except for Social Reward subscale. Moreover, individual reward sensitivity was significantly higher among musicians and amateurs compared to non-musicians, although this trend did not emerge for Sensory-motor and Mood Regulation subscales. Also, overall musical reward sensitivity was negatively associated with age.

**Conclusions.** The results obtained suggest the feasibility of applying the Italian version of eBMRQ as a reliable tool in the field of affective and clinical music-related research. Furthermore, the significant associations we have highlighted between eBMRQ scores,

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gender, age, and musicianship contribute to emphasizing the significant impact of individual factors on music reward sensitivity.

**Subjects** Neuroscience, Cognitive Disorders, Psychiatry and Psychology

**Keywords** Music reward, Music perception, Individual differences, Musical expertise, Musical pleasure

## INTRODUCTION

Music is an art form that has a relevant emotional impact in people's life, as a wide spectrum of emotions may derive from it, including joy, sadness, excitement, and nostalgia (Reybrouck, Vuust & Brattico, 2021; Sachs, Damasio & Habibi, 2015; Vuilleumier & Trost, 2015). Among these, pleasure plays a fundamental role in shaping our musical experiences (Brattico & Pearce, 2013). Pleasant music activates brain regions associated with reward, motivation, and emotion, such as the nucleus accumbens, amygdala, and ventral tegmental area (Blood & Zatorre, 2001), as well as pleasure derived from musical experiences plays a crucial role in strengthening social connections and community cohesion (Tarr, Launay & Dunbar, 2014). According to Juslin & Västfjäll (2008), the experience of pleasure in music arises from the interaction between the listener's expectations, emotional responses, and the perceived qualities of the music itself. The investigation into music-induced pleasure has pointed out that the rewarding response elicited by music share commonalities with the gratification derived from fulfilling fundamental survival-related needs (e.g., food) (for a review see Mas-Herrero et al., 2021). Indeed, neuroimaging studies consistently highlighted the engagement of brain regions associated with dopamine-mediated mesocorticolimbic pathways in the pleasurable experience of music (Blood & Zatorre, 2001; Brattico et al., 2016; Ferreri et al., 2019; Ferreri & Rodriguez-Fornells, 2022; Martínez-Molina et al., 2016). Considering that the release of dopamine is associated with motivation and reinforcement processes (Salimpoor et al., 2011), pleasure might also act as a reinforcer, motivating and promoting continued engagement with music. However, it has been suggested that enjoying music appears to be more complex than experiences evoked by primary rewards. Indeed, the pleasant experience of music seems to depend on the modulation of several neural mechanisms, not only those related to emotion but also to attention and memory (Ferreri et al., 2019; Mas-Herrero et al., 2021). According to these studies, attention enhances engagement and emotional anticipation, while memory retrieval adds depth and personal significance to the musical experience. The integration of these neural mechanisms creates a comprehensive and rewarding musical experience. The reasons why music is considered one of the greatest human pleasures are manifold. Music can facilitate the release of emotions, enhance enjoyment, provide comfort, and alleviate stress, making it a pivotal tool for emotional regulation processes (Ferreri et al., 2021; Van Goethem & Sloboda, 2011). Indeed, the ability of music to regulate mood has been identified among the most essential reasons for engaging in musical activities on a daily basis (for a review see Saarikallio & Erkkilä, 2007). For instance, listening to sad music may be beneficial to sort out negative

feelings and thoughts, resulting in more positive reported feelings (Eerola et al., 2018; Van den Tol & Edwards, 2015).

Another relevant aspect to consider is music potential to act as a social facilitator, fostering human social activities and promoting individuals to bond into groups (Keller, Novembre & Hove, 2014; Nummenmaa, Putkinen & Sams, 2021; Savage et al., 2021). In addition, several individual factors may influence the experience of pleasure in music, such as empathy (Carraturo et al., 2022; Wallmark, Deblieck & Iacoboni, 2018), musical expertise (Brattico et al., 2016), and even fluid intelligence (Bonetti & Costa, 2016), as well as cultural and situational context (Curzel et al., 2024; Curzel et al., 2023; North & Hargreaves, 2000; Soley & Hannon, 2010). This results in a considerable interindividual variability in the experience of musical pleasure, and an inherent complexity in objectively measuring this construct. In the last decade, however, the implementation of the Barcelona Music Reward Questionnaire (BMRQ) (Mas-Herrero et al., 2013) has enabled a profound and comprehensive exploration of how people experience pleasure and reward from music-related activities. The BMRQ, which the original authors validated in both Spanish and English, allows for a fine-grained assessment of individuals' reward sensitivity to musical experiences decomposed into five factors: Musical Seeking, Emotion Evocation, Mood Regulation, Social Reward, and Sensory-Motor. Musical Seeking refers to individuals' tendency to engage in music-related activities, such as attending concerts, or to seek additional information about the music listened (including details about composers); Emotion Evocation relates to music's capacity to induce relevant emotional responses in individuals; Mood Regulation scale provides an evaluation of how music is employed to regulate mood; the ability of music to promote and enhance social interaction is assessed by Social Reward scale; and finally, Sensory-Motor scale assesses the capacity of music to intuitively induce body movements synchronized to a rhythm's beat. Studies employing the BMRQ have pointed out several significant findings. For instance, individual sensitivity to musical reward is higher in females compared to males (Fuentes-Sánchez et al., 2023; Mas-Herrero et al., 2013). Also, music-related pleasure tends to decline with age (Mas-Herrero et al., 2013), as further corroborated in a recent cross-sectional study on adult population (Belfi et al., 2022). As regards the effect of musical expertise on music reward sensitivity, prior evidence revealed that musicians score higher than non-musicians on overall BMRQ (Fuentes-Sánchez et al., 2023; Hernández et al., 2019; Mas-Herrero et al., 2013). Recently, Cardona et al. (2022) proposed and validated an extended version of BMRQ (eBMRQ), adding to the five main factors a sixth facet assessing individuals' experiences of absorption in music listening (Absorption in Music). The additional four items composing the Absorption in Music scale were taken from the Absorption in Music scale (Sandstrom & Russo, 2013), developed in English. The concept of absorption can be described as a willingness to be deeply drawn in by sensory stimuli, experiencing immersion without distraction (Sandstrom & Russo, 2013). It can be considered similar to the concept of flow (Nakamura & Csikszentmihalyi, 2002), hence a profound emotional involvement and connection that a person may experience while listening to or performing music. In other words, the Absorption in Music scale addresses the degree of immersion and how deeply an individual engages in the musical experience, not only on the intensity and quality

of emotions elicited by music (as assessed by Emotional Evocation scale). High scores in trait absorption lead to more intense emotional reactions in response to music (*Kreutz et al., 2008*), as well as a positive relationship has been pointed out between trait absorption and the enjoyment of evoked negative emotions in response to music (*Garrido & Schubert, 2011*). Absorption trait is also associated with listening habits, musical preferences, and overall music experience, as it can affect amount of time spent listening to music every day, the importance of music, and knowledge about preferred music or artists (*Sandstrom & Russo, 2013; Wild, Kuiken & Schopflocher, 1995*). As such, the eBMRQ aims to serve as an even more in-depth and comprehensive tool for investigating the diverse characterization of individual sensitivity to pleasure in music. The main aim of this study is to develop and validate an Italian version of the extended Barcelona Music Reward Questionnaire (eBMRQ), and to assess its psychometric properties, including its factor structure. A further aim of this study is to investigate eBMRQ scores as a function of age, gender, and musicianship across Italian population.

## MATERIALS & METHODS

### Instruments

The original extended version of Barcelona Music Reward Questionnaire (eBMRQ), here used in accordance with a Creative Commons Attribution 4.0 International License (CC BY 4.0), provides a measure of sensitivity to musical reward by describing situations that individuals could experience in their daily life. The questionnaire consists of 24 items divided into six facets (Musical Seeking (MS), Emotion Evocation (EE), Mood Regulation (MR), Social Reward (SR), Sensory-Motor (SM), and Absorption in Music (AM)). Participants are requested to indicate the level of agreement with each statement by using a five-point scale from fully disagree (1) to fully agree (5). ORION reliability of the six subscales ranged from 0.836 to 0.932, whereas the ORION reliability of the overall dimension was 0.952. Please note that, while Cronbach's alpha a measure of internal consistency, that is, how closely related a set of items are as a group, ORION is a reliability index of factor scores that it includes in the estimate of the reliability the inter-factor correlation values (*Ferrando & Lorenzo-Seva, 2016*). The Italian version of the eBMRQ was developed following the forward-backwards translation method (*Brislin, 1970*). First, the original English version of the eBMRQ was independently translated into Italian by two Italian native speakers fluent in English and Spanish. The original Spanish questionnaire served as a point of reference to clarify some wordings. The Italian version obtained was then back-translated into English by an English native speaker fluent in Italian who was blind to the original version. For the translation, greater emphasis was placed on capturing meaning rather than literal translation (see [Appendix A](#) in the [Supplementary Files](#) for the Italian version of the eBMRQ).

### Participants

A total of 1,012 adult participants (74% women,  $34.9 \pm 16.9$  years old) fluent in Italian took part in the study. To enable greater generalizability of the results to the Italian population, participants were recruited from Bari ( $n = 452$ ) in Southern Italy, and from

Milan ( $n = 560$ ) in Northern Italy. For participants in Bari, the study was approved by the local Ethical Committee of the Department of Education, Psychology, Communication at the University of Bari “Aldo Moro” (Ethics reference code: ET-21-06; ET-21-17), while for participants in Milan the study received approval by the Ethics Committee of the Department of Neurological and Behavioral Sciences at the University of Pavia (111/22). Participants from Bari consisted mainly of Bachelor’s and Master’s students in Psychology, Educational Sciences, History, and Philosophy, and questionnaires were administered *via* online surveys from September 2022 to April 2023 as part of multiple projects including eBMRQ. In contrast, the Milan sample consisted of individuals who attended a conference-concert, followed by a scientific experiment (not directly related to the eBMRQ research). The following day, *i.e.*, from their houses, once the event finished, on a voluntary basis, they completed the eBMRQ. An informed written consent was obtained from the participants prior to the experiment. There was no time limit imposed on completion of the questionnaire. Prior to the questionnaire, participants were asked to provide demographic information, as well as to classify themselves based on their musical background as non-musicians, amateurs, or musicians. However, information on musicianship was collected from only 826 participants. This is because the data were gathered from various projects that included the Italian eBMRQ, and a few of these projects did not require specific information on music training. As a result, this information is missing for 186 participants. Among the 826 participants, 506 self-identified as non-musicians, 257 as amateurs, and 63 as musicians. [Table 1](#) describes information on age, gender, and musicianship as a function of location (*i.e.*, Milan *vs.* Bari).

In order to assess the convenience of the sample size to compute factor analysis, we used the Seneca estimate method ([Lorenzo-Seva & Ferrando, 2024](#)). This method estimates the sample size that is needed in order to reproduce the expected population correlation matrix given a precision threshold. We used as threshold a value of .003 for the root mean square of residuals (RMSR) between (1) the observed correlation matrix in the sample and (2) the population correlation matrix. If the sample at hand is close to the value proposed by Seneca Estimate, then the size of the sample is expected to be adequate for the precision proposed.

## Data analysis

### *Unrestricted confirmatory factor analysis*

The examination of the item scores of eBMRQ showed that the distributions were generally skewed. Hence, the item scores were treated as ordered-categorical variables, and the factor analysis based on the polychoric inter-item correlations was the model chosen to fit the data. This model is an alternative parameterization of the multidimensional IRT graded response model ([Ferrando & Lorenzo-Seva, 2013](#)). In order to assess the adequacy of matrix correlation to be factor analyzed, Kaiser-Meyer-Olkin (KMO) test for sampling adequacy was computed ([Kaiser & Rice, 1974](#)). Indices normed-MSA were also inspected for the items in order to decide if some item was not sharing enough communality with the whole set of items: values of normed-MSA below .50 suggest that the item does not measure the same domain as the remaining items in the pool, and so that it should be removed

**Table 1** Age, gender, and musicianship of the participants as a function of the location (Milan & Bari).

<i>Demographics</i>		Milan sample	Bari sample
N		556	456
Gender	Male	229	33
	Female	320	417
	Non-binary/unidentified	7	6
Age	Mean	46.38	20.97
	Standard deviation	14.84	3.0
	Range	18/86	18/46
Musicianship	Non-musicians	287	219
	Amateurs	223	34
	Musicians	45	18

(Lorenzo-Seva & Ferrando, 2021). In order to compute the confirmatory factor analysis, we opted for unrestricted confirmatory factor analysis based on the Objectively Refined Target Matrix method (Lorenzo-Seva & Ferrando, 2020). The unrestricted approach is based on (1) defining the model parameters that are expected to be zero in the population, and (2) allowing these model parameters to fluctuate around zero when fitting the sample model. Nowadays, the unrestricted approach seems more suitable to assess factor models than the classical restricted approach (see for example Nájera, Abad & Sorrel, 2023). We expected a factor model in which each item was related to one of the six facets that conform eBMRQ, and that the six facets are correlated so that an overall score for each individual can be interpreted.

The factor analysis solution was fitted by using Robust FA based on the unweighted least squares (ULS) criterion, and the chi square statistic was scaled using LOSEFER (Lorenzo-Seva & Ferrando, 2023). Currently it is usual to scale the chi square statistic using the mean and variance of the distribution of the statistics, LOSEFER goes a step further and adds the skewness and the kurtosis of the distribution of the statistic. Even if this approach is a computing-intensive task, the value of the scaled chi square is more accurate. In order to assess the goodness-of-fit of the factor model, the following indices were inspected: root mean square error of approximation (RMSEA; values between 0.050 and 0.080 are considered as *fair*), Comparative Fit Index (CFI; values larger than .990 are considered *excellent*), Goodness of Fit Index (GFI; values larger than .990 have been recommended to represent good fit), and root mean square of residuals (RMSR), with a threshold value adapted to each dataset analyzed (Harman, 1976).

The target matrix proposed was defined based on the facets in which each item was expected to load: the expected salient loading value in the corresponding facet was set as a free value in the target matrix, while the other values in the target were set to zero (*i.e.*, we expected the corresponding loading values to show values close to zero in the loading matrix). In order to allow the analysis to refine the proposed target, we used Objectively Refined Target Matrix (RETAM) strategy (see Lorenzo-Seva & Ferrando, 2020, for further details). As a large number of values in the target were set to be close to zero, the RETAM strategy used was “To allow the model to be more complex”. It means that RETAM was

allowed to add free values in the target matrix if necessary. In addition, we also defined the inter-factor correlation values to be free.

While eBMRQ is expected to be composed of six facets, the overall score in the questionnaire is also computed and interpreted. For this reason, we also assessed whether a unidimensional factor model can be expected to be reasonable in the population. In order to assess essential unidimensionality, unidimensional congruence (UNICO), explained common variance (ECV), and mean of item residual absolute loadings (MIREAL) were inspected (Ferrando & Lorenzo-Seva, 2018). Values of UNICO larger than .95, ECV larger than .85 and MIREAL lower than .30 suggest that data can be treated as essentially unidimensional. Finally, as the indices to assess essential unidimensionality suggested that a single dimension could be interpreted, the unidimensional factor solution was also inspected. Unrestricted confirmatory factor analysis was computed using FACTOR software (Lorenzo-Seva & Ferrando, 2006).

### **Quality of factor solution and psychometric proprieties**

In order to estimate factor reliabilities of factor scores, we computed ORION reliability index of factor scores: values above .80 can be considered as acceptable. The quality of the factor solution was inspected using the construct replicability, and the quality of factor scores estimates were assessed with indices H, and sensitivity ratio (SR-index) (Ferrando & Lorenzo-Seva, 2018). The H index evaluates how well a set of items represents a common factor. It is bounded between 0 and 1 and approaches unity as the magnitude of the factor loadings and/or the number of items increase. High H values (>.80) suggest a well-defined latent variable. The SR-index can be interpreted as the number of different factor levels than can be differentiated on the basis of the factor score estimates. If factor scores are to be used for individual assessment, marginal reliabilities above .80, and SR above 2 are recommended.

### **Effect of age, gender, and musicianship**

As additional exploratory analyses, we aimed to investigate the associations between eBMRQ, including subscale scores, gender (females/males) and musicianship (non-musicians, amateurs, and musicians). To this extent, we performed Kruskal–Wallis analysis of variance (ANOVA) due to the non-normal distribution of the data. As for the relationships between the Italian eBMRQ (the six factors and overall scale) and age, we computed Spearman Analyses using age as continuous variable. In addition, considering the wide age range of our sample (18–86 years), we grouped participants based on their age into young (18–30 years,  $n = 536$ ), adults (31–60 years,  $n = 378$ ), and older adults (61 years and older,  $n = 98$ ). This allowed us to perform a Kruskal–Wallis ANOVA to enable a cross-sectional analysis of eBMRQ scores across the lifespan. For multiple comparisons, Dwass-Steel-Critchlow-Fligner (DSCF) *post-hoc* tests were used to explore differences between groups. All analyses concerning eBMRQ subscales were conducted considering the factor scores obtained using FACTOR software (Lorenzo-Seva & Ferrando, 2006), due to the small number of items in each factor. All factor analyses were computed using FACTOR, whereas analyses on age, gender, and musical expertise were conducted using Jamovi 2.3.26. Figures were generated through Jamovi 2.3.26.

## RESULTS

### Sample and correlation matrix assessment

Seneca Estimate proposed that the size of the sample should be 1,129. While our sample was not that large, the difference was small enough to accept that the difference between the sample and the population reproduced correlation matrices must be close to  $RMSR = .003$ .

The inter-item polychoric correlation matrix had good sample  $KMO = .895$  (bootstrap 95% confidence interval .859 and .927). Normed-MSA for items ranged between .736 and .967. The conclusion is that correlation matrix was suitable to be analyzed using factor analysis, and that all the items contributed substantially to the common variance.

### Unrestricted confirmatory factor analysis

The factor analysis solution reached acceptable goodness-of-fit levels:  $RMSEA = .037$ ,  $CFI = .995$ , and  $GFI = .995$ . In addition,  $RMSR = .023$  was lower than Kelley's criterion (0.032). The value of these goodness-of-fit indices allows us to conclude that the model can be expected to be observed in the general population. RETAM introduced four changes in the proposed target matrix. The changes were related to items 2 (MS-) and 20 (MS+): in both items an extra value was set as a free value corresponding to the facet SR. In addition, the two target values related to item 4 (MR) were set as free values: they were the target values related to facets SR and MS.

The loading matrix, shown in [Table 2](#), was inspected in order to assess whether the patterns of items corresponded to the expected solution. While the overall pattern of loadings was as expected, some items have a complex pattern. The only two items that showed a large loading value in an unexpected facet were items 4 (MR) and 19 (SR).

The dimensions were related to a reasonable number of salient loadings (*i.e.*, loadings with absolute value larger than .25): 3 (facet MR), 4 (facets EE and SM), 5 (facets MS and AM) and 6 (facet SR). The facet with the lowest ORION reliability was SR (value of .806), while the other facets showed reliability that ranged from .891 to .959. These outcomes support the hypothesis of a six-dimensional solution. The values of the inter-factor correlation matrix ranged between .245 and .769 (see [Table 3](#)). In addition, all the facets showed at least three correlations larger than .4 with other facets. These large correlation values among facets suggest that a unidimensional factor solution might also be acceptable.

To assess the essential unidimensionality, the values of the indices to assess essential unidimensionality were  $UNICO = .901$  (bootstrap 95% confidence interval .882 and .919),  $ECV = .799$  (bootstrap 95% confidence interval .781 and .816), and  $MIREAL = .226$  (bootstrap 95% confidence interval .205 and .248). These outcomes suggested that a single dimension could also be acceptable for the questionnaire. The factor analysis with a single factor reported the following goodness-of-fit indices:  $RMSEA = .085$ ,  $CFI = .952$ ,  $GFI = .937$ ,  $RMSR = .1058$ . While the fit worsened, it was still acceptable. The absolute loading values in the single factor ranged from .339 to .780. ORION reliability for the factor was .939.

**Table 2** Factor solutions of multidimensional and unidimensional factor analysis.

Items	SR	MS	EE	MR	SM	AM	eBMRQ
1. SR	<b>.283</b>	.231	.160	.077	.143	-.188	.511
2. MS-	<b>.372</b>	<b>-.901</b>	.014	-.095	-.006	.071	-.523
3. EE	-.043	-.049	<b>1.032</b>	-.022	-.019	-.152	.543
4. MR	<b>-.652</b>	<b>1.012</b>	.064	.236	.046	-.013	.666
5. SM-	.065	-.020	.003	.080	<b>-.856</b>	.061	-.347
6. AM	.043	.283	.160	-.011	-.049	<b>.440</b>	.750
7. SR	<b>.539</b>	.172	.044	.180	.135	-.171	.639
8. MS	.234	<b>.562</b>	.013	-.092	-.088	-.006	.519
9. EE	-.121	.102	<b>1.003</b>	-.036	.004	-.094	.649
10. MR	-.052	-.001	-.016	<b>.965</b>	-.002	-.073	.676
11. SM	.060	-.073	-.060	.039	<b>.979</b>	-.039	.488
12. AM	-.091	.039	-.025	.062	.035	<b>.818</b>	.737
13. MS	-.044	<b>.720</b>	-.194	-.035	.067	.149	.577
14. EE	.075	-.172	<b>.555</b>	.021	.083	.212	.586
15. SR	<b>.642</b>	-.038	.023	-.065	.015	-.051	.339
16. MR	.041	-.110	-.066	<b>1.063</b>	-.043	.023	.742
17. SM	.017	.036	.080	.146	<b>.464</b>	-.039	.472
18. AM	-.159	.068	-.021	-.028	-.055	<b>.986</b>	.726
19. SR	.142	.174	.039	.081	.228	.061	.544
20. MS	<b>.473</b>	<b>.346</b>	-.055	-.088	-.174	.073	.462
21. EE	.138	-.113	<b>.473</b>	.057	-.063	<b>.314</b>	.652
22. MR	-.004	.203	.105	<b>.479</b>	-.067	.182	.780
23. SM	-.008	.039	.033	-.141	<b>.756</b>	.178	.529
24. AM	.197	-.234	-.020	.028	.098	<b>.743</b>	.649

**Notes.**

The bold face highlights the loading value that was expected to be the largest one for each item. The loading value in each expected factor are printed in bold face.

**Table 3** Inter-factor correlation matrix among the six dimensions.

Dimensions	SR	MS	EE	MR	SM
MS	.769				
EE	.476	.530			
MR	.420	.678	.592		
SM	.245	.343	.400	.437	
AM	.659	.735	.600	.632	.431

In sum, the unrestricted confirmatory analysis indicated that the six-factor model was acceptable for the eBMRQ, and that a single factor would also be informative in order to compute an overall score in the questionnaire.

**Quality of factor solution and psychometric proprieties**

The indices to assess the quality of the factor solution are showed in [Table 4](#). As previously described in [Cardona et al. \(2022\)](#), H-Latent evaluates how well the factor can be identified

**Table 4** Indices to assess the quality of the factor solution.

Index	SR	MS	EE	MR	SM	AM	eBMRQ
H-Latent	.806	.891	.917	.959	.934	.914	.939
H-Observed	.767	.845	.712	.841	.837	.871	.902
SR-index	2.038	2.860	3.799	4.854	3.762	3.255	3.921

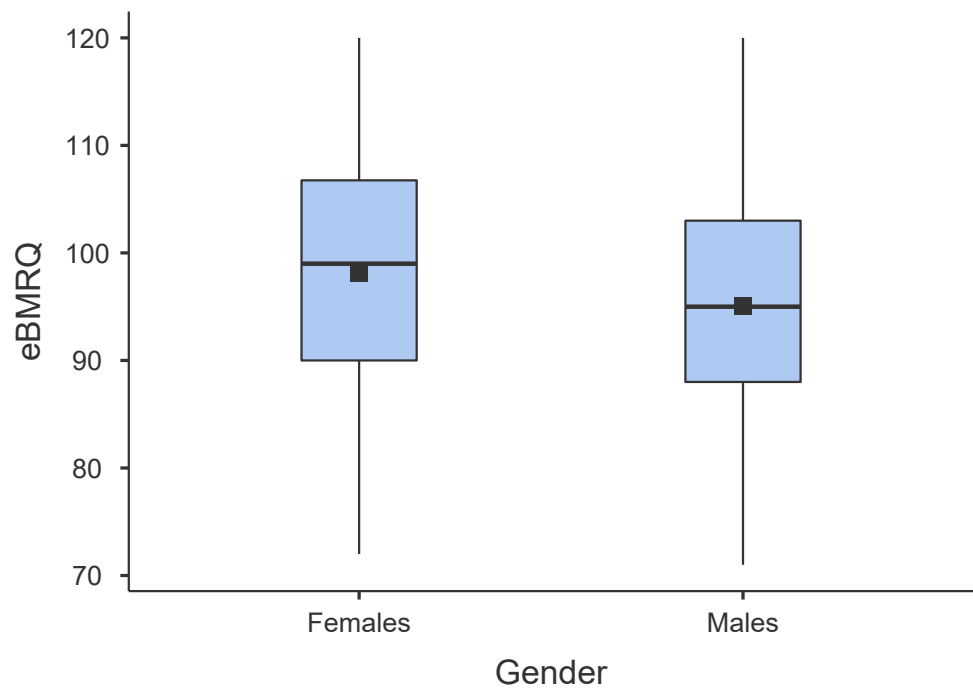
by the continuous latent response variables underlying the observed item scores (*i.e.*, the factor scores estimates), while H-Observed assesses how well it can be identified from the observed item scores (*i.e.*, the raw total of participants' responses to the items). Since the H-Latent values are systematically higher than the corresponding H-Observed values, factor scores should be computed rather than simply adding up the item response. Therefore, instead of simply adding up the responses to items, it is better to compute factor scores to capture the true underlying traits or abilities measured by the test. This approach takes into account the relationships between items and the latent variables they are intended to measure. In the supplementary materials, we provide researchers with an excel file that computes factor scores from participants' responses to the items and raw data are freely available at the Open Science Framework (OSF) (<https://osf.io/ka7xc/>).

The value of the indices indicate that both the six dimensions and the overall dimension exhibit an acceptable quality. The facet with the lowest quality is SR. Overall, the indices for the unidimensional solution are higher than those for the six dimensions. This suggests that the factor score for the overall questionnaire is more reliable and informative than the scores for the individual facets composing the test, as also suggested in *Cardona et al. (2022)*.

For the following sections, we computed eBMRQ factor scores that are the ones related to the unidimensional factor model (*i.e.*, the overall factor score), and the factor scores related to the six dimensions (*i.e.*, Musical Seeking, Emotion Evocation, Mood Regulation, Social Reward, Sensory-Motor, and Absorption in Music). Please note that, as two items did not load in the expected dimensions, the most informative outcome and comparable to the original study is the one related to eBMRQ scores.

### **Relationship between eBMRQ scores and gender**

To assess the putative gender effect on eBMRQ scores we computed a Kruskal–Wallis ANOVA due to abnormal distribution of the data. 13 participants chose not to specify their gender or identify as non-binary and were thus excluded from the analysis. Results revealed that females scored significantly higher than males in the eBMRQ overall scale ( $H(1) = 13.96, p < .001, \varepsilon^2 = 0.013$ ) (see [Fig. 1](#) for a graphical depiction of the results). Specifically, females showed significant higher values in the Emotion Evocation ( $H(1) = 9.10, p = .003, \varepsilon^2 = 0.009$ ), Mood Regulation ( $H(1) = 20.91, p < .001, \varepsilon^2 = 0.020$ ), Sensory-Motor ( $H(1) = 120.17, p < .001, \varepsilon^2$ ), and Absorption in Music scale ( $H(1) = 5.09, p = .024, \varepsilon^2 = 0.005$ ). In contrast, males' scores on Social Reward scale were significantly higher than females ( $H(1) = 13.34, p < .001, \varepsilon^2 = 0.013$ ). No gender difference arose in Musical Seeking scale.



**Figure 1** Box plot illustrating the distribution and means of eBMRQ scores in females and males.

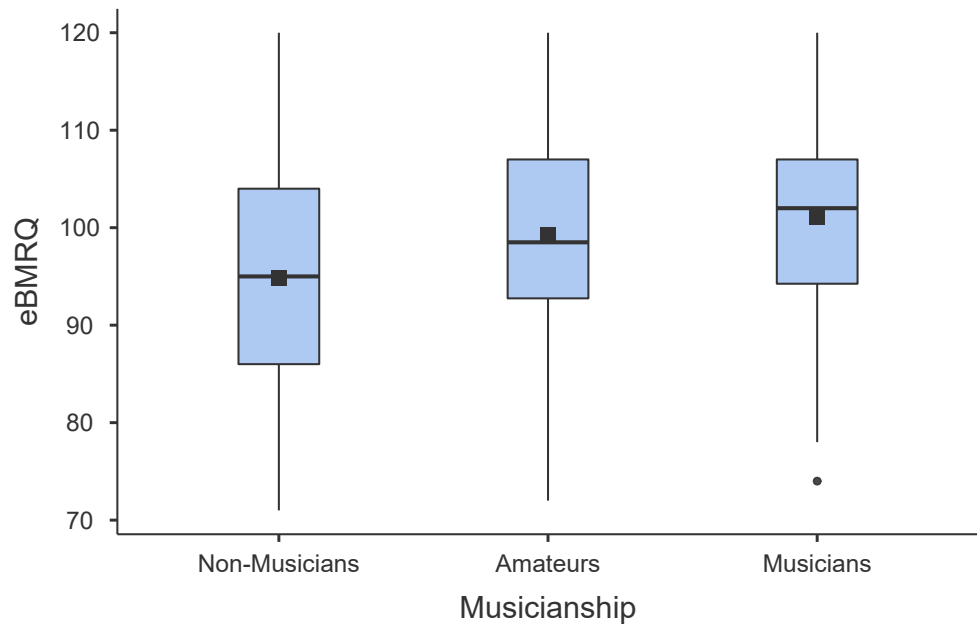
Full-size [DOI: 10.7717/peerj.18403/fig-1](https://doi.org/10.7717/peerj.18403/fig-1)

### Musicianship

To evaluate the effect of musicianship on eBMRQ scores we asked participants to classify themselves as non-musicians, amateurs, or musicians based on their musical background. By computing Kruskal-Wallis ANOVA we found a significant difference between the groups in the eBMRQ overall scale ( $H(2) = 48.06, p < .001, \epsilon^2 = 0.058$ ) (see Fig. 2 for a graphical depiction of the results). Specifically, DSCF pairwise comparisons suggest that musicians and amateurs' overall scores were significantly higher than non-musicians,  $Z = 5.87, p < .001$ , and  $Z = 8.82, p < .001$ , respectively. The effect of musicianship arose in all eBMRQ scales except for Mood Regulation and Sensory-Motor ( $H(2) = 4.87, p = .088$ , and ( $H(2) = 5.48, p = .064$ , respectively). All results are summarized in Tables 5 and 6.

### Age

As data were not normally distributed, the effect of age was first explored by conducting a Spearman rank correlation coefficient analysis between the age of the participants and eBMRQ overall scores. This analysis indicates that eBMRQ overall scores are negatively correlated with age (Spearman's  $\rho = -0.117, p < .001$ ). Significant negative associations with age were specifically observed in Mood Regulation (Spearman's  $\rho = -0.157, p < .001$ ), Sensory-Motor (Spearman's  $\rho = -0.262, p < .001$ ), and absorption scales (Spearman's  $\rho = -0.082, p = .009$ ), whereas for Social Reward scale the correlation with age was significantly positive (Spearman's  $\rho = 0.131, p < .001$ ). To allow for a deeper analysis, these significant associations were further explored using Kruskal-Wallis ANOVA taking into account the participants' age group (young, adults or older adults) (see Fig. 3



**Figure 2** Box plot illustrating the distribution and means of eBMRQ scores in non-musicians, amateurs, and musicians.

Full-size DOI: [10.7717/peerj.18403/fig-2](https://doi.org/10.7717/peerj.18403/fig-2)

**Table 5** Kruskal–Wallis ANOVA as a function of musicianship.

	H <sup>2</sup>	df	P value
eBMRQ (overall sum)	48.06	2	<.001
Social reward	152.09	2	<.001
Musical seeking	76.34	2	<.001
Emotional evocation	37.96	2	<.001
Mood regulation	4.87	2	0.088
Sensory-motor	5.48	2	0.064
Absorption in music	55.11	2	<.001

for a graphical depiction of the results). The results confirmed the significant effect of age on eBMRQ overall scores ( $H(2) = 16.7, p < .001, \varepsilon^2 = .0165$ ), Social Reward ( $H(2) = 20.95, p < .001, \varepsilon^2 = .0207$ ), Mood Regulation ( $H(2) = 24.09, p < .001, \varepsilon^2 = .0238$ ), Sensory-Motor ( $H(2) = 65.81, p < .001, \varepsilon^2 = .0650$ ), Emotion Evocation scale ( $H(2) = 6.04, p .049, \varepsilon^2 = .005$ ), and Absorption in Music scales ( $H(2) = 8.60, p .014, \varepsilon^2 = .008$ ). DSCF pairwise comparisons revealed that eBMRQ overall scores are significantly different between young and older adults ( $Z = -5.74, p < .001, r = -.23$ ), as well as between adults and older adults' groups ( $Z = -4.06, p = .012, r = -.19$ ). The only scale that significantly differed in each age bracket was the Sensory-Motor: young vs. adults ( $Z = -8.94, p < .001, r = -.30$ ), young vs. older adults ( $Z = -9.13, p < .001, r = -.36$ ), and adults vs. older adults ( $Z = -3.93, p = .015, r = -.18$ ). All results are included in [Tables 7 & 8](#).

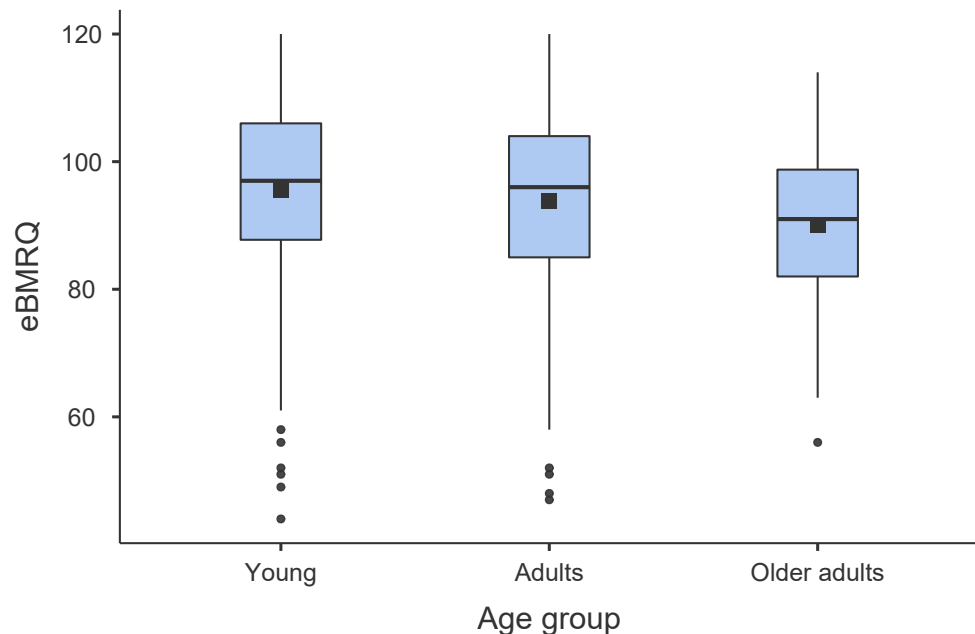
**Table 6** DSCF pairwise comparisons as a function of musicianship.

<i>eBMRQ and subscales scores</i>	<i>Musicianship</i>	<i>Wilcoxon Z</i>	<i>P value</i>
eBMRQ (overall sum)	Non-musicians vs. Amateurs	8.82	<.001
	Non-musicians vs. Musicians	5.87	<.001
	Amateurs vs. Musicians	1.19	0.677
Social reward	Non-musicians vs. Amateurs	14.50	<.001
	Non-musicians vs. Musicians	12.01	<.001
	Amateurs vs. Musicians	5.40	<.001
Musical seeking	Non-musicians vs. Amateurs	11.01	<.001
	Non-musicians vs. Musicians	7.59	<.001
	Amateurs vs. Musicians	1.68	0.459
Emotional evocation	Non-musicians vs. Amateurs	7.74	<.001
	Non-musicians vs. Musicians	5.33	<.001
	Amateurs vs. Musicians	1.67	0.464
Mood regulation	Non-musicians vs. Amateurs	2.874	0.105
	Non-musicians vs. Musicians	−0.694	0.876
	Amateurs vs. Musicians	−2.144	0.283
Sensory-motor	Non-musicians vs. Amateurs	−1.88	0.377
	Non-musicians vs. Musicians	−3.08	0.075
	Amateurs vs. Musicians	−1.73	0.437
Absorption in music	Non-musicians vs. Amateurs	8.38	<.001
	Non-musicians vs. Musicians	7.67	<.001
	Amateurs vs. Musicians	3.61	0.029

## DISCUSSION

The experience of pleasure in music has long been recognized as a crucial aspect of human engagement with this art form. The rewarding experience of music is, however, considerably subjective and diversified (e.g., [Garrido & Schubert, 2011](#); [Martínez-Molina et al., 2019](#); [Zatorre, 2015](#)). Validating a tool that can accurately and reliably measure such individual differences is thus crucial. The extended Barcelona Music Reward Questionnaire (eBMRQ) is a recent version developed by [Cardona et al. \(2022\)](#) which adds to the five scales of the original BMRQ by [Mas-Herrero et al. \(2013\)](#) (i.e., Sensory-Motor, Musical Seeking, Mood Regulation, Social Reward, and Emotional Evocation) a further scale assessing absorption in music, a crucial component indicating the profound emotional involvement and connection experienced when exposed to music ([Hall, Schubert & Wilson, 2016](#); [Kreutz et al., 2008](#)).

Whereas an Italian version of the BMRQ has recently been published ([Mannino et al., 2024](#)), an Italian validation of the eBMRQ was still lacking. With this study, we developed and validated an Italian version of the extended Barcelona Music Reward Questionnaire (eBMRQ) across a large sample of Italian participants ( $n = 1,012$ ). We also provided evidence on the effect of age, gender, and musicianship on individual music reward sensitivity, as indexed by eBMRQ and its relative subscales' scores. For the validation



**Figure 3** Box plot illustrating the distribution and means of eBMRQ scores in young, adults, and older adults.

Full-size  DOI: [10.7717/peerj.18403/fig-3](https://doi.org/10.7717/peerj.18403/fig-3)

process, we conducted an unrestricted confirmatory factor analysis based on Objectively Refined Target Matrix method (*Lorenzo-Seva & Ferrando, 2020*). The unrestricted approach is deemed to be more suited for evaluating factor models than the conventional restricted approach (*Nájera, Abad & Sorrel, 2023*). As with the original English version, the overall Italian version of the eBMRQ showed acceptable psychometric properties, indicating that the Italian version of the eBMRQ is a reliable tool to assess sensitivity to music reward. In addition, correlations between the various factors that emerged are strong, with values ranging from .245 to .769. Importantly, while the original version of the test proposes a factor model based on six facets (each facet defined by four items), the outcomes observed in the Italian version of the test suggest that not all the facets are equally defined as in the English version of the test. In particular, two items seem to load in different facets than expected. In addition, the assessment of the essential unidimensionality suggests that the unidimensional solution is a plausible factor model for the Italy population. We would suggest to Italian applied researchers to be careful when interpreting the factor scores of the six facets because the sub-dimensions in Italian might be less valid than in the original test. On the other hand, we would also advise researchers to base their assessments in the overall factor score (*i.e.*, the one obtained that considering the test as a unidimensional test). The two items which loaded into unexpected factors were 19 and 4. Item 19 (“*At a concert I feel connected to the performers and the audience*”) originally intended for the Social Reward factor, mainly loaded into the Sensory-Motor factor. One possible interpretation is that participants assessed their “connection” with performers and the audience mainly in terms of physical involvement and synchronization. The unexpected loading of item 4 (“*Music*

**Table 7** Kruskal–Wallis ANOVA as a function of age group.

	H <sup>2</sup>	df	P value
eBMRQ (overall sum)	16.71	2	<.001
Social reward	20.95	2	<.001
Musical seeking	2.72	2	0.257
Emotional evocation	6.04	2	0.049
Mood regulation	24.09	2	<.001
Sensory-motor	65.81	2	<.001
Absorption in music	8.60	2	0.014

keeps me company when I'm alone") into Musical Seeking rather than Mood Regulation could instead potentially be attributed to the characteristics of nearly half of our sample ( $n = 560$ ), who completed the questionnaire the day after participating to a conference-concert they had willingly attended. It is plausible that these participants associated the sense of being less alone through music, and more broadly, the ability to feel better with music, with the need to actively seek music in their daily lives (*i.e.*, musical seeking). On this line, a recent study conducted in the context of music and COVID suggested that engaging in activities such as listening to new music and attending virtual concerts (*i.e.*, musical seeking activities) was associated with the modulation of positive feelings and served as a way to socialize, respectively (*i.e.*, mood regulation and feeling less alone) (Ferreri et al., 2021). In general, the fact that these two items show the main loading value in a different factor than in previous factor analyses is not an issue for this work. Indeed, we observed that the test is essentially unidimensional, with highly correlated factors representing facets of the main factor. Thus, these items still contribute substantially to the main factor.

The results indicating that females' eBMRQ scores are significantly higher than males align with several BMRQ studies which pointed out a similar tendency (Fuentes-Sánchez et al., 2023; Hernández et al., 2019; Mas-Herrero et al., 2013). Consistent with the original eBMRQ study (Cardona et al., 2022), Musical Seeking scale scores did not show significant differences based on the gender. However, in contrast to the latter study, we found that scores in Absorption in Music scale were significantly higher among females than males. In general, as our sample consisted of significantly more females than males ( $n = 737$  and 262, respectively), the interpretation of gender results should be cautious as more gender-balanced research is needed.

An additional aim of our study was to explore the relationship between age and music reward sensitivity across the Italian population. Consistently with prior evidence (Belfi et al., 2022; Cardona et al., 2022), we observed a negative correlation between age and eBMRQ overall scores. Specifically, the effect of age is significantly negative in the overall, Sensory-Motor, Mood Regulation, and Absorption in Music scales, whereas it is significantly positive in the Social Reward scale. This latter result is not consistent with previous studies, although the relationship between age and the Social Reward scale has previously yielded conflicting results. For instance, Mas-Herrero et al. (2013) did not report significant associations between Social Reward scores and age, whereas Cardona et al. (2022) found a negative correlation. The reason for these inconsistencies may be linked to

**Table 8** DSCF pairwise comparisons as a function of age group.

<i>eBMRQ and subscales scores</i>	<i>Age group</i>	<i>Wilcoxon Z</i>	<i>P value</i>
eBMRQ (overall sum)	Young vs. Adults	−2.35	0.219
	Young vs. Older adults	−5.74	<.001
	Adults vs. Older adults	−4.06	0.012
Social reward	Young vs. Adults	6.075	<.001
	Young vs. Older adults	3.693	0.024
	Adults vs. Older adults	−0.267	0.981
Musical seeking	Young vs. Adults	−0.212	0.988
	Young vs. Older adults	−2.333	0.225
	Adults vs. Older adults	−2.052	0.315
Emotional evocation	Young vs. Adults	2.13	0.289
	Young vs. Older adults	−1.95	0.352
	Adults vs. Older adults	−3.46	0.038
Mood regulation	Young vs. Adults	−5.16	<.001
	Young vs. Older adults	−5.77	<.001
	Adults vs. Older adults	−2.65	0.147
Sensory-motor	Young vs. Adults	−8.94	<.001
	Young vs. Older adults	−9.13	<.001
	Adults vs. Older adults	−3.93	0.015
Absorption in music	Young vs. Adults	−1.23	0.661
	Young vs. Older adults	−4.17	0.009
	Adults vs. Older adults	−3.24	0.057

the highly activity-specific nature of the items comprising the scale, such as “*I like to sing or play an instrument with other people*” or “*At a concert I feel connected to the performers and the audience*”.

The non-significant effect of age on Emotion Evocation scale is in line with [Cardona et al. \(2022\)](#). However, contrary to the latter study, we found a negative correlation between age and Absorption in Music scale, although this significant effect is marginal ( $p = .049$ ). These discordant results might be due to the fact that those in our sample who scored lower on the Absorption in Music were older adults (*i.e.*, 61 years and older,  $n = 98$ ), and in Cardona’s study only 20 out of 920 individuals fell in this age category. A comprehensive interpretation of the results might be that the decrease in musical reward with advancing age may primarily arise from reduced physical engagement in music-based activities (*e.g.*, dancing), especially considering that older adults may experience mobility issues ([Lauretani et al., 2003](#)). Conversely, musical pleasure derived from the emotional and evocative aspects of music, as depicted in the Absorption in Music and Emotion Evocation scales, tends to be less sensitive to aging. Furthermore, in our study, we did not observe any age-related effect on Musical Seeking scale, which assesses the extent of individuals’ engagement in music-related activities. This is in contrast with [Cardona et al. \(2022\)](#) and [Mas-Herrero et al. \(2013\)](#) who both reported a negative association. Once again, this incongruent evidence could stem from the fact that many of our participants ( $n = 560$ ) were recruited during a

public event also involving music held in Milan. Therefore, a certain number of participants of this study might have been intrinsically motivated in the participation of music-based activities, supposedly affecting their Musical Seeking scores.

Given our extensive and diverse sample in terms of age ( $n = 1,012$ , age range 18–86), we conducted an additional analysis of eBMRQ scores across different age groups (young, adults, older adults). This further analysis pointed out that the decline in musical reward sensitivity is consistent across the lifespan, but it is significant only in young *vs.* older adults, and adults *vs.* older adults comparisons. In contrast, the Sensory-Motor is the only scale in which the score significantly decreases across all three age brackets. Lastly, we wanted to explore the relationship between musicianship and eBMRQ scores. Results indicate that musicians and amateurs scored significantly higher than non-musicians in the overall eBMRQ score. The positive association between musical expertise and musical reward has been previously observed in both behavioral (*Fuentes-Sánchez et al., 2023; Mas-Herrero et al., 2013*), and neuroimaging studies (*Alluri et al., 2015*). This effect appears significant in all eBMRQ scales except for Mood Regulation and Sensory Motor. Hence, also in light of the aforementioned results, the Sensory-Motor scale appears to be more sensitive to the effect of age rather than the level of musicianship.

## LIMITATIONS

This work includes some limitations which should be acknowledged. Firstly, although the age range of our sample was quite wide (18–86 years), the generalizability of our study may be limited by the fact that nearly half of the participants were university students (452 out of 1,012). Secondly, in our study musicianship was assessed based on participants' self-identification as musicians, amateurs, or non-musicians, with musicians being only 8% of the final sample. A more balanced and in-depth analysis, based on factors such as years of musical practice and/or type of instrument played, may certainly provide more precise insights into the relationship between musical expertise and music-related pleasure. Moreover, regarding the effect of age on eBMRQ scores, it should be noted that as our analysis is cross-sectional, we cannot establish a cause-and-effect relationship or analyze behavior over a period of time. In this regard, a longitudinal study on the trajectory of sensitivity to musical pleasure during the lifespan could provide further reliable evidence. Future research should delve deeper into the underlying mechanisms driving these age-related variations in music reward sensibility, with potential implications for promoting well-being and enhancing the musical experiences of individuals across the lifespan.

## CONCLUSIONS

The results we have reported suggest that the Italian version of the eBMRQ exhibits acceptable and reliable psychometric properties, making it a valid tool for assessing sensitivity to musical reward within the Italian population. Furthermore, the significant size of the sample ( $n = 1,012$ ) has enabled us to provide valuable insights into the effects of individual differences such as age, gender, and musicianship on the construct of music

reward sensitivity. The application of this tool in research can help delve further into the exploration of how individual differences, cultural influences, and various musical contexts shape the experience of musical pleasure. This expanded scope may potentially not only contribute to the advancement of music psychology but also provide valuable insights into the broader understanding of human enjoyment and well-being.

## ADDITIONAL INFORMATION AND DECLARATIONS

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### Competing Interests

The authors declare there are no competing interests.

### Author Contributions

- Giulio Carraturo conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the article, and approved the final draft.
- Laura Ferreri conceived and designed the experiments, performed the experiments, authored or reviewed drafts of the article, and approved the final draft.
- Gemma Cardona performed the experiments, authored or reviewed drafts of the article, and approved the final draft.
- Urbano Lorenzo-Seva analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the article, and approved the final draft.
- Antoni Rodriguez-Fornells conceived and designed the experiments, performed the experiments, authored or reviewed drafts of the article, and approved the final draft.
- Elvira Brattico conceived and designed the experiments, performed the experiments, authored or reviewed drafts of the article, and approved the final draft.

## Human Ethics

The following information was supplied relating to ethical approvals (i.e., approving body and any reference numbers):

For participants in Bari, the study was approved by the local Ethical Committee of the Department of Education, Psychology, Communication at the University of Bari “Aldo Moro” (Ethics reference code: ET-21-06). For participants in Milan, the study was approved by the Ethics Committee of the Department of Neurological and Behavioral Sciences at the University of Pavia (n° 111/22).

## Data Availability

The following information was supplied regarding data availability:

The raw data is available in the [Supplemental Files](#).

## Supplemental Information

Supplemental information for this article can be found online at <http://dx.doi.org/10.7717/peerj.18403#supplemental-information>.

## REFERENCES

- 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 DOI 10.1037/pmu0000124.
- Belfi AM, Moreno GL, Gugliano M, Neill C. 2022.** Musical reward across the lifespan. *Aging & Mental Health* 26(5):932–939 DOI 10.1080/13607863.2021.1871881.
- Blood AJ, Zatorre RJ. 2001.** Intensely pleasurable responses to music correlate with activity in brain regions implicated in reward and emotion. *Proceedings of the National Academy of Sciences of the United States of America* 98:11818–11823 DOI 10.1073/pnas.191355898.
- Bonetti L, Costa M. 2016.** Intelligence and musical mode preference. *Empirical Studies of the Arts* 34(2):160–176 DOI 10.1177/0276237416628907.
- 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(January):1–21 DOI 10.3389/fnhum.2015.00676.
- Brattico E, Pearce M. 2013.** The neuroaesthetics of music. *Psychology of Aesthetics, Creativity, and the Arts* 7(1):48–61 DOI 10.1037/a0031624.
- Brislin RW. 1970.** Back-translation for cross-cultural research. *Journal of Cross-Cultural Psychology* 1(3):185–216 DOI 10.1177/135910457000100301.
- Cardona G, Ferreri L, Lorenzo-Seva U, Russo FA, Rodriguez-Fornells A. 2022.** The forgotten role of absorption in music reward. *Annals of the New York Academy of Sciences* 1514(1):142–154 DOI 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 DOI 10.1177/03057356221081168.
- Curzel F, Carraturo G, Ripollés P, Ferreri L. 2023.** Better off alone? when sharing music reduces pleasure responses. *Advances in Cognitive Psychology* 19(4):29–45 DOI 10.5709/acp-0410-9.
- Curzel F, Osiurak F, Tràn E, Tillmann B, Ripollés P, Ferreri L. 2024.** Enhancing musical pleasure through shared musical experience. *Iscience* 27(6) DOI 10.1016/j.isci.2024.109964.
- Eerola T, Vuoskoski JK, Peltola HR, Putkinen V, Schäfer K. 2018.** An integrative review of the enjoyment of sadness associated with music. *Physics of Life Reviews* 25:100–121 DOI 10.1016/j.plrev.2017.11.016.
- Ferrando PJ, Lorenzo-Seva U. 2013.** Unrestricted item factor analysis and some relations with item response theory. Technical Report. Google Scholar.
- Ferrando PJ, Lorenzo-Seva U. 2016.** A note on improving EAP trait estimation in oblique factor-analytic and item response theory models. *Psicológica* 37(2):235–247.
- Ferrando PJ, Lorenzo-Seva U. 2018.** Assessing the quality and appropriateness of factor solutions and factor score estimates in exploratory item factor analysis. *Educational and Psychological Measurement* 78(5):762–780 DOI 10.1177/0013164417719308.
- Ferreri L, Mas-Herrero E, Zatorre RJ, Ripollés P, Gomez-Andres A, Alicart H, Olivé G, Marco-Pallarés J, Antonijoan RM, Valle M, Riba J, Rodriguez-Fornells A. 2019.** Dopamine modulates the reward experiences elicited by music. *Proceedings of the National Academy of Sciences of the United States of America* 116(9):3793–3798 DOI 10.1073/pnas.1811878116.
- Ferreri L, Rodriguez-Fornells A. 2022.** Memory modulations through musical pleasure. *Annals of the New York Academy of Sciences* 1516(1):5–10 DOI 10.1111/nyas.14867.
- Ferreri L, Singer N, McPhee M, Ripollés P, Zatorre RJ, 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* 12:1–11 DOI 10.3389/fpsyg.2021.673772.
- Fuentes-Sánchez N, Pastor MC, Eerola T, Pastor R. 2023.** Individual differences in music reward sensitivity influence the perception of emotions represented by music. *Musicae Scientiae* 27(2):313–331 DOI 10.1177/10298649211060028.
- Garrido S, Schubert E. 2011.** Individual differences in the enjoyment of negative emotion in music: a literature review and experiment. *Music Perception* 28(3):279–296 DOI 10.1525/mp.2011.28.3.279.
- Hall SE, Schubert E, Wilson SJ. 2016.** The role of trait and state absorption in the enjoyment of music. *PLOS ONE* 11(11):e0164029 DOI 10.1371/journal.pone.0164029.
- Harman HH. 1976.** *Modern factor analysis*. Chicago: University of Chicago Press.
- Hernández M, Palomar-García M-Á, Nohales-Nieto B, Olcina-Sempere G, Villar-Rodríguez E, Pastor R, Ávila C, Parcet M-A. 2019.** Separate contribution of striatum volume and pitch discrimination to individual differences in music reward. *Psychological Science* 30(9):1352–1361 DOI 10.1177/0956797619859339.

- Juslin PN, Västfjäll D. 2008.** Emotional responses to music: the need to consider underlying mechanisms. *Behavioral and Brain Sciences* **31**(5):559–575 DOI [10.1017/S0140525X08005293](https://doi.org/10.1017/S0140525X08005293).
- Kaiser HF, Rice J. 1974.** Little Jiffy, Mark Iv. *Educational and Psychological Measurement* **34**(1):111–117 DOI [10.1177/001316447403400115](https://doi.org/10.1177/001316447403400115).
- Keller PE, Novembre G, Hove MJ. 2014.** Rhythm in joint action: psychological and neurophysiological mechanisms for real-time interpersonal coordination. *Philosophical Transactions of the Royal Society B: Biological Sciences* **369**(1658):20130394 DOI [10.1098/rstb.2013.0394](https://doi.org/10.1098/rstb.2013.0394).
- Kreutz G, Ott U, Teichmann D, Osawa P, Vaitl D. 2008.** Using music to induce emotions: influences of musical preference and absorption. *Psychology of Music* **36**(1):101–126 DOI [10.1177/0305735607082623](https://doi.org/10.1177/0305735607082623).
- Lauretani F, Russo CR, Bandinelli S, Bartali B, Cavazzini C, Di Iorio A, Corsi AM, Rantanen T, Guralnik JM, Ferrucci L. 2003.** Age-associated changes in skeletal muscles and their effect on mobility: an operational diagnosis of sarcopenia. *Journal of Applied Physiology* **95**(5):1851–1860 DOI [10.1152/jappphysiol.00246.2003](https://doi.org/10.1152/jappphysiol.00246.2003).
- Lorenzo-Seva U, Ferrando PJ. 2006.** FACTOR: a computer program to fit the exploratory factor analysis model. *Behavior Research Methods* **38**(1):88–91 DOI [10.3758/BF03192753](https://doi.org/10.3758/BF03192753).
- Lorenzo-Seva U, Ferrando PJ. 2020.** Unrestricted factor analysis of multidimensional test items based on an objectively refined target matrix. *Behavior Research Methods* **52**(1):116–130 DOI [10.3758/s13428-019-01209-1](https://doi.org/10.3758/s13428-019-01209-1).
- Lorenzo-Seva U, Ferrando PJ. 2021.** MSA: the forgotten index for identifying inappropriate items before computing exploratory item factor analysis. *Methodology* **17**(4):296–306 DOI [10.5964/meth.7185](https://doi.org/10.5964/meth.7185).
- Lorenzo-Seva U, Ferrando PJ. 2023.** A simulation-based scaled test statistic for assessing model-data fit in least-squares unrestricted factor-analysis solutions. *Methodology* **19**(2):96–115 DOI [10.5964/meth.9839](https://doi.org/10.5964/meth.9839).
- Lorenzo-Seva U, Ferrando PJ. 2024.** Determining sample size requirements in EFA solutions: a simple empirical proposal. *Multivariate Behavioral Research* **59**:899–912 DOI [10.1080/00273171.2024.2342324](https://doi.org/10.1080/00273171.2024.2342324).
- Mannino A, Di Maso M, Viganò M, Corbo M, Sozzi M. 2024.** Italian validation of the barcelona music reward questionnaire. *Music Perception: An Interdisciplinary Journal* **41**(4):307–319 DOI [10.1525/mp.2024.41.4.307](https://doi.org/10.1525/mp.2024.41.4.307).
- Martínez-Molina N, Mas-Herrero E, Rodríguez-Fornells A, Zatorre RJ, Marco-Pallarés J. 2016.** Neural correlates of specific musical anhedonia. *Proceedings of the National Academy of Sciences of the United States of America* **113**(46):E7337–E7345 DOI [10.1073/pnas.1611211113](https://doi.org/10.1073/pnas.1611211113).
- Martínez-Molina N, Mas-Herrero E, Rodríguez-Fornells A, Zatorre RJ, Marco-Pallarés J. 2019.** White matter microstructure reflects individual differences in music reward sensitivity. *The Journal of Neuroscience* **39**(25):5018–5027 DOI [10.1523/JNEUROSCI.2020-18.2019](https://doi.org/10.1523/JNEUROSCI.2020-18.2019).

- Mas-Herrero E, Maini L, Sescousse G, Zatorre RJ. 2021.** Common and distinct neural correlates of music and food-induced pleasure: a coordinate-based meta-analysis of neuroimaging studies. *Neuroscience & Biobehavioral Reviews* **123**:61–71 DOI [10.1016/j.neubiorev.2020.12.008](https://doi.org/10.1016/j.neubiorev.2020.12.008).
- Mas-Herrero E, Marco-Pallares J, Lorenzo-Seva U, Zatorre RJ, Rodriguez-Fornells A. 2013.** Individual differences in music reward experiences. *Music Perception* **31**(2):118–138 DOI [10.1525/mp.2013.31.2.118](https://doi.org/10.1525/mp.2013.31.2.118).
- Nájera P, Abad FJ, Sorrel MA. 2023.** Is exploratory factor analysis always to be preferred? A systematic comparison of factor analytic techniques throughout the confirmatory–exploratory continuum. *Psychological Methods* DOI [10.1037/met0000579](https://doi.org/10.1037/met0000579).
- Nakamura J, Csikszentmihalyi M. 2002.** The concept of flow. In: Csikszentmihalyi M, Csikszentmihalyi IS, eds. *A life worth living: contributions to positive psychology*. Oxford: Oxford University Press, 89–105.
- North AC, Hargreaves DJ. 2000.** Musical preferences during and after relaxation and exercise. *The American Journal of Psychology* **113**(1):43–67 DOI [10.2307/1423460](https://doi.org/10.2307/1423460).
- Nummenmaa L, Putkinen V, Sams M. 2021.** Social pleasures of music. *Current Opinion in Behavioral Sciences* **39**:196–202 DOI [10.1016/j.cobeha.2021.03.026](https://doi.org/10.1016/j.cobeha.2021.03.026).
- Reybrouck M, Vuust P, Brattico E. 2021.** Neural correlates of music listening: does the music matter? *Brain Sciences* **11**(12):1553 DOI [10.3390/brainsci11121553](https://doi.org/10.3390/brainsci11121553).
- Saarikallio S, Erkkilä J. 2007.** The role of music in adolescents' mood regulation. *Psychology of Music* **35**(1):88–109 DOI [10.1177/0305735607068889](https://doi.org/10.1177/0305735607068889).
- Sachs ME, Damasio A, Habibi A. 2015.** The pleasures of sad music: a systematic review. *Frontiers in Human Neuroscience* **9**(July):1–12 DOI [10.3389/fnhum.2015.00404](https://doi.org/10.3389/fnhum.2015.00404).
- Salimpoor VN, Benovoy M, Larcher K, Dagher A, Zatorre RJ. 2011.** Anatomically distinct dopamine release during anticipation and experience of peak emotion to music. *Nature Neuroscience* **14**(2):257–262 DOI [10.1038/nn.2726](https://doi.org/10.1038/nn.2726).
- Sandstrom GM, Russo FA. 2013.** Absorption in music: development of a scale to identify individuals with strong emotional responses to music. *Psychology of Music* **41**(2):216–228 DOI [10.1177/0305735611422508](https://doi.org/10.1177/0305735611422508).
- Savage PE, Loui P, Tarr B, Schachner A, Glowacki L, Mithen S, Fitch WT. 2021.** Music as a coevolved system for social bonding. *Behavioral and Brain Sciences* **44**:e59 DOI [10.1017/S0140525X20000333](https://doi.org/10.1017/S0140525X20000333).
- Soley G, Hannon EE. 2010.** Infants prefer the musical meter of their own culture: a cross-cultural comparison. *Developmental Psychology* **46**(1):286–292 DOI [10.1037/a0017555](https://doi.org/10.1037/a0017555).
- Tarr B, Launay J, Dunbar RI. 2014.** Music and social bonding: self-other merging and neurohormonal mechanisms. *Frontiers in Psychology* **5**:1096 DOI [10.3389/fpsyg.2014.01096](https://doi.org/10.3389/fpsyg.2014.01096).
- Van den Tol AJ, Edwards J. 2015.** Listening to sad music in adverse situations: how music selection strategies relate to self-regulatory goals, listening effects, and mood enhancement. *Psychology of Music* **43**(4):473–494 DOI [10.1177/0305735613517410](https://doi.org/10.1177/0305735613517410).
- Van Goethem A, Sloboda J. 2011.** The functions of music for affect regulation. *Musicae Scientiae* **15**(2):208–228 DOI [10.1177/1029864911401174](https://doi.org/10.1177/1029864911401174).

- Vuilleumier P, Trost W. 2015.** Music and emotions: from enchantment to entrainment. *Annals of the New York Academy of Sciences* **1337(1)**:212–222 DOI [10.1111/nyas.12676](https://doi.org/10.1111/nyas.12676).
- Wallmark Z, Deblieck C, Iaconi M. 2018.** Neurophysiological effects of trait empathy in music listening. *Frontiers in Behavioral Neuroscience* **12(April)**:1–19 DOI [10.3389/fnbeh.2018.00066](https://doi.org/10.3389/fnbeh.2018.00066).
- Wild TC, Kuiken D, Schopflocher D. 1995.** The role of absorption in experiential involvement. *Journal of Personality and Social Psychology* **69(3)**:569–579 DOI [10.1037/0022-3514.69.3.569](https://doi.org/10.1037/0022-3514.69.3.569).
- Zatorre RJ. 2015.** Musical pleasure and reward: mechanisms and dysfunction: musical pleasure and reward. *Annals of the New York Academy of Sciences* **1337(1)**:202–211 DOI [10.1111/nyas.12677](https://doi.org/10.1111/nyas.12677).