DOI: 10.1111/nyas.14790

ORIGINAL ARTICLE

ANNALS OF THE NEW YORK ACADEMY OF SCIENCES

The forgotten role of absorption in music reward

Gemma Cardona[1,2] | **Laura Ferreri**[3,4] | **Urbano Lorenzo-Seva**[5] | **Frank A. Russo**[6] | **Antoni Rodriguez-Fornells**[1,2,7]

[1]Department of Cognition, Development and Educational Psychology, University of Barcelona, Barcelona, Spain

[2]Cognition and Brain Plasticity Unit, Bellvitge Biomedical Research Institute, L'Hospitalet de Llobregat, Barcelona, Spain

[3]Laboratoire d'Etude des Mécanismes Cognitifs, Université Lumière Lyon 2, Lyon, France

[4]Department of Brain and Behavioral Sciences, University of Pavia, Pavia, Italy

[5]Department of Psychology, Universitat Rovira i Virgili, Tarragona, Spain

[6]Department of Psychology, Ryerson University, Toronto, Ontario, Canada

[7]Institució Catalana de Recerca i Estudis Avançats, Barcelona, Spain

Correspondence
Gemma Cardona and Antoni Rodriguez-Fornells, Cognition and Brain Plasticity Unit, Bellvitge Biomedical Research Institute, L'Hospitalet de Llobregat, 08907 Barcelona, Spain.
Email: gcardona.cbpu@gmail.com; arfornells@gmail.com

Funding information
Ministerio de Ciencia, Innovación y Universidades (MCIU), Grant/Award Number: PGC2018-099859-B-I00

Abstract

Interindividual differences in music-related reward have been characterized as involving five main facets: musical seeking, emotion evocation, mood regulation, social reward, and sensory-motor. An interesting concept related to how humans decode music as a rewarding experience is music transcendence or absorption (i.e., music-driven states of complete immersion, including momentary loss of self-consciousness or even time-space disorientation). Here, we investigated the relation between previously characterized facets of music reward and individual differences in music absorption. A first sample of participants ($N = 370$) completed both the Barcelona Music Reward Questionnaire (BMRQ) and the Absorption in Music Scale (AIMS). Results showed that both constructs were highly interrelated ($r = 0.78$, $p < 0.001$), indicating that higher music reward sensitivity is associated with a greater tendency to music-related absorption states. In addition, four items from the AIMS were identified as suitable to be added to an extended version of the BMRQ (eBMRQ). A second sample ($N = 550$) completed the eBMRQ for a validation study. Exploratory and confirmatory factor analyses on the whole sample ($N = 920$) showed the reliable psychometric properties of the eBMRQ and suggested that taking into account an absorption facet could contribute to a better characterization of individual differences in the sensitivity to experience music-related reward and pleasure.

KEYWORDS
absorption, music, reward, transcendence

INTRODUCTION

Music has an inherent capacity to evoke a rich and meaningful landscape of emotions and feelings in humans. As such, it is efficiently used across cultures and ages as a powerful mood regulator.[1–9] In special or extraordinary circumstances, people might experience strong peak emotional experiences during music listening and some of them could be associated with transcendence or absorption states.[10] Absorption is usually described as "an effortless, non-volitional quality of deep involvement with the objects of consciousness,"[11] in which attention becomes deeply focused and narrowed, thus lessening awareness of internal states or external conditions.[12] In these states, a person might feel like being merged with something bigger (sometimes materialized as an attentional-capture process, harmony/diffusion with the environment or the universe, experiencing joy, peace, ecstasy, and more complex emotions) or that goes beyond what is considered an ordinary state of consciousness. These transient mental states and feelings associated with reduced self-consciousness processing (dissolution of body/self-boundaries) and increased feelings of connectedness (beyond the self, including others and one's environment) have been recently grouped under the umbrella of self-transcendent experiences.[13] Historically, diverse forms of music (e.g., Sufi, tarantella, or minimalism; see Ref. 14), accompanied or not by dance or stimulating drugs,[15–17] have been used as a catalyzer for eliciting altered states of consciousness (for a relation between religion, transcendence, and music, see Refs. 18–21). Maslow[22] initially proposed that music might be an easy way of experiencing peak emotional experiences, described as "moments of highest happiness and fulfilment"[23] and characterized by disorientation of time and space, a loss of fear, anxiety, and inhibition, and a total absorption by the phenomenon. This type of experience also relates to the concept of *flow* states,[24] shown to be promoted by musical activities.[25,26]

However, while one person could enter into these absorption states through listening to *Spiegel im Spiegel* by Arvo Pärt, others might be more easily absorbed by Springsteen's *Nebraska* album, Rosalía's *El Mal Querer* or Massive Attack's trip hop music. Music-driven transcendence and absorption experiences tend to be highly valued but are not experienced by everybody and might depend on certain individual characteristics.[27] For example, Kreutz and colleagues[28] showed that people high in absorption trait (evaluated using the Tellegen Absorption Scale, TAS)[29] tend to have more intense emotional reactions to music (see also Ref. 30). Also, these kinds of states of consciousness have been related to previous music exposures (i.e., background musical culture and identity) in special moments of a person's life.[31]

These transcendental experiences are emotionally extraordinary, and they might impact and depend on the activation of emotion and reward processing brain networks.[32] Strong emotional reactions to music are usually accompanied with behavioral (intense feelings of pleasure), psychophysiological (breathing, heart rate, and skin conductance changes associated with chills), and neural mesolimbic dopaminergic reward activations.[32–36] However, remarkable individual differences exist in music reward sensitivity.[37] The Barcelona Musical Reward Questionnaire (BMRQ)[37] is a self-report questionnaire distinguishing five factors or music-reward facets: musical seeking, emotion evocation, mood regulation, sensory-motor, and social reward. By employing the BMRQ, we found that while some listeners experienced normal to high-pleasure in response to music, others, termed musical anhedonics, reported experiencing musical pleasure to a very small degree or not at all, despite being capable of experiencing other kinds of pleasure.[37,38] Subsequent neuroimaging studies showed that musical anhedonia was associated with decreased connectivity between the auditory and reward networks.[39] Therefore, the nature of pleasure decoding abilities in the human brain varies largely across people, and this variability can deeply characterize individuals' relationship with music.

Because of the complex landscape of emotions that characterize music, an interesting question arises about the extent to which individual differences in the susceptibility to experience absorption in music might be associated with the different dimensions of musical reward.[37] Revising the initial large pool of items reflecting activities and situations associated with music-reward and pleasure experiences gathered across musicians and nonmusicians and that entered into the initial study for the development of the BMRQ, it is clear that this pool did not reflect the specific content associated with strong peak experiences, transcendence, and absorption in music. This might have limited the capacity of the BMRQ scale to incorporate this absorption construct.

Thus, the present research aims at understanding the relationship between transcendence or absorption states during music listening and individual differences in the susceptibility to experience reward from music. With this purpose, we used the Absorption in Music Scale (AIMS)[40] and the BMRQ.[37] The AIMS is a well-known measure of music absorption that possesses good psychometric properties in terms of internal consistency, test-retest reliability, and convergent validity. These scales present some conceptual overlap, but they can also be viewed as unique. For example, one AIMS item states that "It is sometimes possible for me to be completely immersed in music and to feel as if my whole state of consciousness has been temporarily altered." This item does not appear to fit squarely with any of the BMRQ factors: musical seeking (e.g., "I'm always looking for new music"), emotion evocation (e.g., "I like to listen to music that contains emotion"), mood regulation (e.g., "music comforts me"), social reward (e.g., "music makes me bond with other people"), or sensory motor (e.g., "music often makes me dance"). This lack of concordance is not surprising as the AIMS was derived from Tellegen and Atkinson's[29] concept of absorption as an attentional (cognitive) process, whereas the BMRQ was derived from an individual differences approach that focuses on music reward-related experiences and activities.[37]

Despite the unique derivations of these two scales, we predicted a strong relationship between sensitivity to music-driven absorption and sensitivity to music reward, as they might highjack common neural networks for decoding pleasure states from music. Although this relationship is probably related to the common use of cognitive and neural resources involved in music-reward processing, it is important to notice that absorption states are characterized by altered states of consciousness, attention-capture, and mind wandering and are accompanied by emerging mental contents that are clearly not present during standard music listening. Thus, we also predicted that individual differences on the susceptibility to experience absorption states might uniquely contribute to the experience of music-reward and might, therefore, be considered as a potential new facet of the music-related reward scale.

METHODS

Participants

Nine hundred and twenty participants (64% women, 29.8 ± 12 years old) took part in the study. Of those, 34% reported some musical training (mean number of years of training, 7.4 ± 4.9). Participants responded to the questionnaires online via Google Forms.

A set of 370 individuals answered the 20 items of the BMRQ and the 34 items of the AIMS. This sample was used to select the four items of AIMS with the optimal psychometrical properties to be added to the 20 items of the BMRQ, in order to obtain a 24 items questionnaire that we named Extended Barcelona Music Reward Questionnaire (eBMRQ). Then, 550 participants responded the new eBMRQ. Finally, participants' responses from both samples were mixed to conform the final sample of 920 participants.

The total sample was half-splat using Solomon procedure.[41] This procedure aims to find two subsamples in which all the sources of common variance are equally represented. The first subsample was analyzed with an exploratory factor analysis (EFA) using FACTOR software.[42] The second subsample was analyzed with a confirmatory factor analysis (CFA) using LISREL 8.5.[43] The aim of the overall analysis was: (1) to explore in the first subsample if the expected factor model can be fitted in the sample at hand; and (2) to assess using the second subsample whether the factor model explored in the first subsample can be accepted to be the factor model in the population. As both analyses led to the same conclusions, the total sample was used to obtain the factorial loadings, scale properties, and weights needed to compute scores.

Instruments

The BMRQ[37] evaluates individual differences in how people experience reward in music-related activities. It includes 20 items representing five different factors: musical seeking, emotion evocation, mood regulation, social reward, and sensory-motor (0.89, 0.88, 0.87, 0.78, and 0.93 reliability, respectively). The overall test shows a 0.92 reliability. All factors and the overall scale correlated with Feeling and Aesthetics facets and the overall measure Openness to experience (Spanish version of the NEO-PI-R),[44] as well as Fun Seeking, BAS Drive, and Reward Responsiveness from the BIS/BAS questionnaire.[45] On the other hand, they were negatively correlated with Physical Anhedonia Scale.[46] In addition, all facets except Musical Seeking positively correlated with the BIS scale.

The AIMS[40] comprises 34 items designed to measure individuals' ability and willingness to allow music to draw them into an emotional experience. It presents a good internal consistency (Cronbach's alpha ranging 0.92–0.94), and strong test-retest reliability (0.86, p = 0.001). Convergent validity is supported by its correlation with similar scales, such as the Tellegen Absorption Scale[29] (r = 0.76, p < 0.01) and the Musical Involvement Scale[47] (r = 0.74, p < 0.01). In addition, AIMS showed a positive correlation with the Fantasy subscale of the Interpersonal Reactivity Index[48] (r = 0.50, p < 0.01).

Items of both tests describe situations that participants could experience in their daily life. Participants were requested to indicate the level of agreement with each statement by using a five-point scale (from 1 "fully disagree" to 5 "fully agree"). Questionnaires were submitted once all the items were answered. There was no time limit imposed on completion of the questionnaire.

Data analysis

Relation between the BMRQ and the AIMS

Pearson's correlation coefficient was used to assess the relationship between the BMRQ (the five facets and the overall scale) and the AIMS. By using the interquartile range criterion, we found nine participants to be outliers. However, because we wanted to assess the relationship between the BMRQ and the AIMS across the population, only two participants who were outliers for just one of the variables were removed from the analyses reported here. Therefore, the sample size for these analyses was N = 368.

We additionally assessed the correlation between the different eBMRQ facets and the overall scale in the final sample (N = 918). To compare the set of correlations obtained in the initial sample (N = 368) to the one obtained in the total sample (N = 918), we computed root mean square of residuals (RMSR). Harman proposed a threshold value of 0.05 to conclude that differences between two sets of correlations are low.[49]

Selection of four items from AIMS

Different criteria were used to select a final set of four items out of the overall pool of 34 AIMS items. First, we performed a unidimensional EFA of the 34 AIMS items. 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 0.990 are considered *excellent*), and goodness of fit index (GFI; values larger than 0.990 have been recommended to represent good fit). Three different criteria were used to perform a preliminary selection of eligible items: (1) having a loading value higher than 0.60, (2) being related to the concept of absorption, and (3) not having a mean too similar to the other items' means. These selection criteria left us with four items. Then, we performed a second EFA with these four items to inspect if the loading values in the reduced set of items were still large. These four items were added to the 20 items from the BMRQ to compose the eBMRQ (see Supplementary Files: Appendices A and B for the Spanish and English versions of the eBMRQ). In this way, we constituted the new test (eBMRQ) that was composed of 24 items. The analyses described below were carried out with these 24 items.

EFA of the first Solomon subsample

Regarding the development of an extended version of the BMRQ (i.e., the eBMRQ), examination of the item scores showed that the distributions were generally skewed. Therefore, the item scores were treated as ordered-categorical variables, and the factor analysis based on the polychoric interitem correlations was the model chosen to fit the data. This model is an alternative parameterization of the multidimensional item response theory graded response model.[50] In order to assess the adequacy of the matrix correlation to be factor analyzed, Kaiser–Meyer–Olkin (KMO) Test for sampling adequacy was computed.[51] Items' normed-MSA (measure of sampling adequacy) indices were also inspected in order to decide if some item was not sharing enough communality with the whole set of items: values of normed-MSA below 0.50 suggest that the item does not measure the same domain as the remaining items in the pool, and so that it should be removed.[52] Next, the factor analysis solution was fitted by using robust factor analysis based on the diagonally weighted least squares criterion as implemented in the program FACTOR,[42] and six factors were extracted. The factor solution was rotated using Robust Promin.[53] Again, in order to assess the goodness-of-fit of the factor model, RMSEA, CFI, and GFI were inspected. In order to assess essential unidimensionality, unidimensional congruence (UNICO), explained common variance (ECV), and mean of item residual absolute loadings (MIREAL) were inspected.[54] Values of UNICO larger than 0.95, ECV larger than 0.85, and MIREAL lower than 0.30 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.

CFA of the second Solomon subsample

In order to study the replicability of the factor structure obtained in the first Solomon subsample, a CFA was carried out on the second Solomon subsample. Unweighted least square estimates were computed from the interitems polychoric correlation matrix. It was proposed that the model should retain six correlated factors, as suggested by the previous EFA. When personality questionnaires obtained by EFA are tested using CFA, the model proposed is usually rejected, although a series of different exploratory studies have previously replicated the same factorial structure, especially in multidimensional questionnaires.[55] In these cases, a semirestricted model is more appropriate for testing the model fit in CFA. Taking this into account, we applied this analysis by selecting six marker items. To select these items, we selected the simplest items from the previous EFA.

Factor analysis and psychometric properties of the total sample

Finally, as both previous analyses led to the same conclusions, the total sample was factor analyzed following the same specifications used in the first EFA. Both (the six dimensional and the unidimensional) factor models were computed. In order to estimate factor reliabilities of factor scores, we computed ORION reliability index of factor scores.[56] The quality of the factor solution was inspected using the construct replicability, and the quality of factor score estimates was assessed with indices H, sensitivity ratio (SR), and expected percentage of true differences (EPTD).[54] 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 (> 0.80) suggest a well-defined latent variable. The SR can be interpreted as the number of different factor levels that can be differentiated based on the factor score estimates. The EPTD is the estimated percentage of differences between the observed factor score estimates that are in the same direction as the corresponding true differences. If factor scores are to be used for individual assessment, marginal reliabilities above 0.80, SR above 2, and the EPTDs above 90% are recommended.

Age and group differences

As further exploratory analyses, we assessed whether the six factors of the eBMRQ varied according to age and years of musical training through Pearson's correlation. Independent samples *t*-tests were performed to check for gender-related differences. Nonbinary participants ($N = 7$) were excluded from the *t*-tests.

RESULTS

Relation between the BMRQ and the AIMS

All BMRQ factors positively correlated with the AIMS, $p < 0.001$ (see Table 1). In addition, the overall BMRQ score showed a high correlation with the AIMS ($r(366) = 0.78$, $p < 0.001$, see Figure 1). These results confirmed our first prediction suggesting that a large amount of variance would be shared between both constructs, music-reward and absorption, thus indicating that they are highly related.

Table 1 shows the set of correlations obtained for the total sample ($N = 918$). Interestingly, correlations between the absorption in music (AM) facet and the rest of the eBMRQ facets were higher in the total sample than in the initial one. This might be related to the order in which items were presented: whereas in the initial sample, the four AM items were embedded in the 34 AIMS items, in the second sample, those four AM items were mixed with the rest of the eBMRQ items, thus helping subjects to use the same criteria for all items.

eBMRQ

Selection of four items from the AIMS

From the overall pool of AIMS items, selection criteria led us to keep items 3, 13, 15, and 29 (see Table 2). A factor analysis of these four items extracting a single factor showed high loading values (i.e., values between 0.727 and 0.873), and the solution reached acceptable goodness-of-fit levels in terms of RMSEA = 0.087, CFI = 0.997, and GFI > 0.999. ORION reliability was 0.889. These values suggested that these four items could be a convenient set of items to be added to the BMRQ in order to conform the eBMRQ.

EFA of the first Solomon subsample

The interitem polychoric correlation matrix was considered suitable to be factor-analyzed (KMO = 0.904). Normed-MSA for items ranged between 0.719 and 0.946. The factor analysis solution reached

TABLE 1 Pearson correlation values, mean, and standard deviation for eBMRQ facets and the overall sum ($N = 918$)

	MS	EE	MR	SM	SR	AM	eBMRQ
Emotion evocation (EE)	0.44						
Mood regulation (MR)	0.57	0.60					
Sensory-motor (SM)	0.37	0.34	0.46				
Social reward (SR)	0.61	0.47	0.62	0.52			
Absorption in music (AM)	0.50	0.57	0.65	0.36	0.55		
eBMRQ (overall sum)	0.76	0.73	0.84	0.65	0.82	0.81	
$\bar{X}$	13.8	16.9	17.3	17.2	15.5	14.1	94.8
SD	3.6	3.0	2.9	3.1	3.2	4.0	15.2

Note: All $p < 0.001$. eBMRQ maximum score = 120. Facet scores were obtained from the raw addition of participants' responses to the items.
Abbreviations: AM, absorption in music; eBMRQ, extended BMRQ (overall sum); EE, emotion evocation; MR, mood regulation; MS, musical seeking; SM, sensory-motor; SR, social reward.

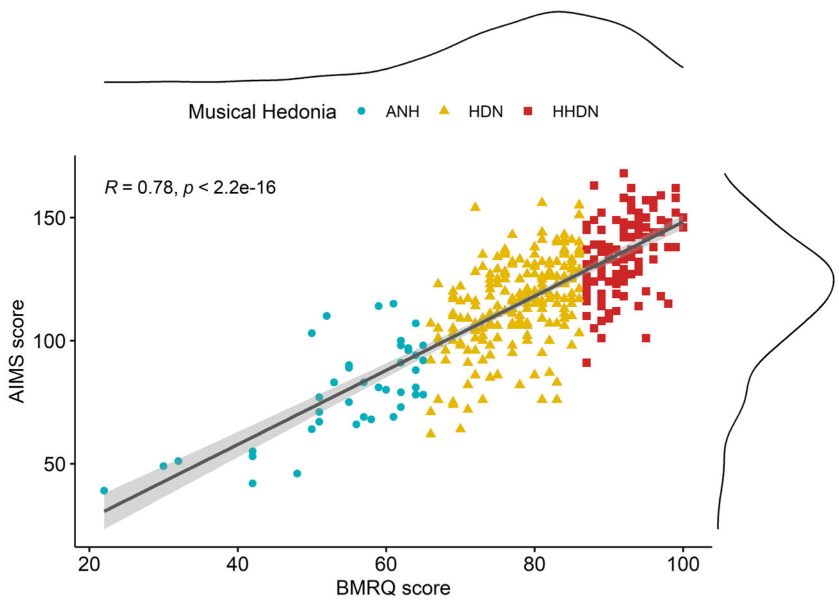

FIGURE 1 Correlation between the BMRQ and AIMS scores. For illustrative purposes, participants are represented in three different colors according to their level of musical hedonia:[39] anhedonics (ANH, BMRQ score ≤ 65), hedonics (HDN, 65 < BMRQ score < 87), and hyperhedonics (HHDN, BMRQ score ≥ 87). In the margins, density plots for BMRQ and AIMS scores are shown

TABLE 2 AIMS items selected to be part of the eBMRQ

Item		Response average	Loading value
3	I sometimes feel like I am "one" with the music.	3.633	0.779
13	While listening to music, I may become so involved that I may forget about myself and my surroundings.	3.683	0.823
15	It is sometimes possible for me to be completely immersed in music and to feel as if my whole state of consciousness has been temporarily altered.	3.520	0.873
29	When listening to great music I sometimes feel as if I am being lifted into the air.	3.308	0.727

acceptable goodness-of-fit levels: RMSEA = 0.027, CFI = 0.998, and GFI > 0.999. The rotated solution was inspected to assess whether the patterns of items corresponded to the expected solution. While the overall pattern of loadings was as expected, some items showed a complex pattern. Nonetheless, the dimensions were related to a reasonable number of salient loadings (i.e., loadings with absolute value larger than 0.25): between 4 (dimensions MS, SM, and AM) and 6 (dimensions MR and SR). These outcomes support the hypothesis of a six-dimensional solution.

The values of the interfactor correlation matrix ranged between 0.339 and 0.704. In addition, the values of the indices to assess essential unidimensionality were UNICO = 0.951, ECV = 0.839, and MIREAL = 0.223. These outcomes suggested that a single dimension could also be acceptable for the dataset. To assess it, a second factor analysis with a single factor was computed. The corresponding goodness-of-fit indices were RMSEA = 0.071, CFI = 0.975, and GFI = 0.970. While the fit worsened, it was still acceptable. The loading values in the single factor ranged from 0.423 to 0.819. Finally, the EAP reliability of the factor was 0.952.

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

CFA of the second Solomon subsample

To assess if the conclusion reached in the previous EFA could be replicated, the second Solomon subsample was analyzed using CFA. The values of goodness-of-fit indices related to the six-factor model were RMSEA = 0.070, CFI > 0.999, and GFI > 0.999. These values suggested an acceptable model fit, and the replication of the six-factor model observed in the EFA. The unidimensional model showed a goodness-of-fit indices of RMSEA = 0.140, CFI = 0.970, and GFI = 0.970. Again, and as expected, the fit worsened but was still acceptable.

Factor analysis and psychometric properties of the total sample

The polychoric correlation matrix related to the total sample had a KMO value of 0.921, and normed-MSA for the items ranged from 0.758 to 0.964. The goodness-of-fit indices related to the six-factor model were RMSEA = 0.039, CFI = 0.995, and GFI > 0.999. Interfactor correlation matrix showed values between 0.430 and 0.791. In addition, the values of the indices to assess essential unidimensionality were UNICO = 0.949, ECV = 0.846, and MIREAL = 0.206. Finally, the goodness-of-fit indices related to the one factor model were RMSEA = 0.096, CFI = 0.951, and GFI > 0.999. Table 3 shows the loading values in the six dimensions (MS, EE, MR, SM, SR, and AM) and the single factor (eBMRQ) solutions. ORION reliabilities of the six dimensions ranged from 0.836 to 0.932, whereas the ORION reliability of the overall dimension was 0.952. The values of the interfactor-correlation matrix ranged between 0.439 and 0.791.

As observed in Table 3, there are some complex items that show salient loadings not only for the factor they are supposed to represent but also for another factor (see items 13, 20, 2, 21, and 17). Interestingly, for most of these items, the other factor is social reward. Particularly complex is item 2 (i.e., *In my free time I hardly listen to music*), which even though it is informative of musical seeking (loading = 0.366), it also gives information about mood regulation and social reward (loadings of 0.647 and −0.387, respectively).

The indices to assess the quality of the factor solution are shown in Table 4. H-latent assesses how well the factor can be identified by the continuous latent response variables that underlie the observed item scores (i.e., the factor score estimates), whereas H-observed assesses how well it can be identified from the observed item scores (i.e., the score obtained from the raw addition of participants' responses to the items). As the values of H-latent are systematically larger than the corresponding values of H-observed, factor scores should be computed instead of the simple addition of responses to items. In the Supplementary Materials, we provide researchers an excel file that computes factor scores from the participants' responses to the items.

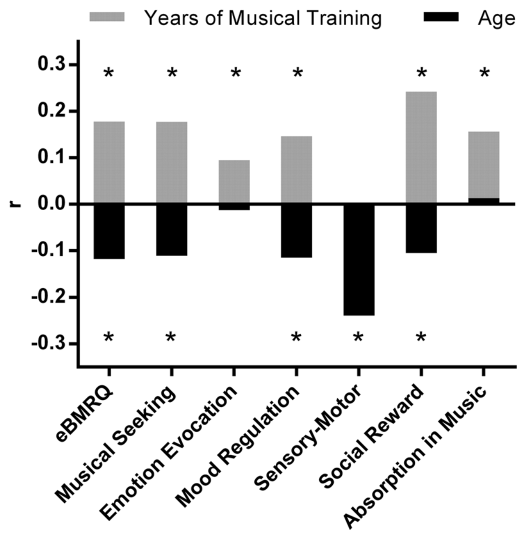

FIGURE 2 Graphical representation of Pearson's correlation coefficients showing the relationship between years of musical training (gray) or age (black) and the eBMRQ's overall sum and its different factors. $^{*}p < 0.005$

The value of the indices showed that the six dimensions and the overall dimension have an acceptable quality. The facet that showed a lower quality is MS. In general, the indices related to the unidimensional solution were higher than the ones obtained in the six dimensions. This indicated that the factor score in the overall questionnaire is more reliable and informative than the scores in the six facets that compose the test.

Age and group differences

We assessed how these music reward factors are modulated by age, gender, and musical experience.

Four out of six factors were negatively correlated with age: musical seeking, $r(916) = -0.111$, $p = 0.001$; mood regulation, $r(916) = -0.115$, $p < 0.001$; sensory-motor, $r(916) = -0.239$, $p < 0.001$; and social reward, $r(916) = -0.105$, $p = 0.001$ (see Figure 2 and Figure S1). Emotion evocation and absorption in music factors did not show a significant correlation with age ($r(916) = -0.013$, $p = 0.69$; and $r(916) = 0.013$, $p = 0.69$, respectively).

Women presented higher values in emotion evocation ($t(909) = 2.36$, $p = 0.019$), mood regulation ($t(909) = 3.86$, $p < 0.001$), sensory-motor ($t(909) = 9.68$, $p < 0.001$), and social reward ($t(909) = 4.29$, $p < 0.001$) factors (see Figure S2). However, no differences were reported in musical seeking ($t(909) = 0.72$, $p = 0.47$) or absorption in music ($t(909) = 1.57$, $p = 0.12$) factors.

Finally, we studied the correlation between years of musical training and the six factors of the eBMRQ. Musical training showed a significant positive correlation with musical seeking ($r(916) = 0.177$, $p < 0.001$), emotion evocation ($r(916) = 0.095$, $p = 0.004$), mood regulation ($r(916) = 0.146$, $p < 0.001$), social reward ($r(916) = 0.242$, $p < 0.001$), and absorption in music ($r(916) = 0.143$, $p < 0.001$) factors (see Figure 2 and Figure S3). In contrast, no significant correlation was found with the sensory–motor ($r(916) = 0.003$, $p = 0.92$) factor.

TABLE 3 Factor solutions of multidimensional and unidimensional factor analysis related to the total sample

Item		MS	EE	MR	SM	SR	AM	eBMRQ
13	*I'm always looking for new music.*	**0.553**	−0.015	**0.281**	0.059	−0.119	0.004	0.591
8	*I inform myself about music I like.*	**0.695**	0.202	0.045	−0.075	0.065	−0.152	0.592
20	*I spend quite a bit of money on music and related items.*	**0.744**	−0.038	−0.188	−0.107	**0.283**	0.057	0.566
2	*In my free time I hardly listen to music.*	**0.366**	−0.107	**0.647**	0.148	**−0.387**	0.001	0.537
21	*I sometimes feel chills when I hear a melody that I like.*	0.196	**0.762**	−0.033	0.018	**−0.293**	0.167	0.643
14	*I can become tearful or cry when I listen to a melody that I like very much.*	−0.045	**0.742**	−0.093	0.064	−0.009	0.089	0.609
9	*I get emotional listening to certain pieces of music.*	−0.063	**0.894**	0.092	−0.066	0.121	−0.116	0.733
3	*I like listen to music that contains emotion.*	0.005	**0.782**	0.076	0.023	−0.052	−0.066	0.632
16	*Music helps me chill out.*	−0.018	−0.078	**0.953**	−0.052	0.026	0.007	0.777
10	*Music calms and relaxes me.*	−0.009	0.127	**0.730**	−0.043	−0.007	−0.040	0.689
22	*Music comforts me.*	−0.023	0.162	**0.413**	0.039	0.169	0.161	0.805
4	*Music keeps me company when I'm alone.*	0.120	0.043	**0.672**	−0.050	−0.062	0.058	0.692
11	*Music often makes me dance.*	0.024	0.072	−0.014	**0.905**	0.026	−0.098	0.658
23	*When I hear a tune I like a lot I can't help tapping or moving to its beat.*	−0.186	0.060	−0.068	**0.775**	0.214	0.085	0.672
17	*I can't help humming or singing along to music that I like.*	−0.177	0.128	0.205	**0.354**	**0.267**	−0.121	0.547
5	*I don't like to dance, not even with the music I like.*	0.137	−0.136	−0.009	**1.005**	−0.239	0.029	0.522
15	*I like to sing or play an instrument with other people.*	0.174	−0.047	0.069	0.080	**0.386**	−0.050	0.505
1	*When I share music with someone I feel a special connection with that person.*	0.045	−0.146	0.030	−0.003	**0.694**	0.094	0.626
7	*Music makes me bond with other people.*	0.030	−0.153	0.056	0.022	**0.871**	0.030	0.752
19	*At a concert I feel connected to the performers and the audience.*	0.237	−0.031	−0.061	0.125	**0.411**	0.115	0.643
6	*I sometimes feel like I am "one" with the music.*	0.066	0.021	0.026	0.008	0.055	**0.678**	0.725
12	*While listening to music, I may become so involved that I forget about myself and my surroundings.*	−0.070	−0.037	0.226	−0.032	−0.058	**0.782**	0.719
18	*It is sometimes possible for me to be completely immersed in music and to feel as if my whole state of consciousness has been temporarily altered.*	−0.047	−0.112	0.068	−0.048	0.021	**0.957**	0.737
24	*When listening to great music I sometimes feel as if I am being lifted into the air.*	−0.015	0.223	−0.247	0.040	0.065	**0.711**	0.644

Note: Salient loadings in the multidimensional solution are printed in bold face. Items 2 and 5 were reversed. Items are ordered by facets, and within every facet, the order is the same as in Mas-Herrero *et al.*[37] to facilitate further comparisons.
Abbreviations: AM, absorption in music; EE, emotion evocation; MR, mood regulation; MS, musical seeking; SM, sensory motor; SR, social reward.

TABLE 4 Indices to assess the quality of the factor solution related to the total sample

Index	MS	EE	MR	SM	SR	AM	eBMRQ
H-latent	0.833	0.917	0.917	0.932	0.893	0.918	0.952
H-observed	0.802	0.801	0.828	0.786	0.830	0.887	0.935
SR	2.257	3.332	3.319	3.712	2.894	3.337	4.440
EPTD	89.9%	93.3%	93.3%	94.2%	92.2%	93.4%	95.4%

Abbreviations: AM, absorption in music; eBMRQ, Extended Barcelona Music Reward Questionnaire; EE, emotion evocation; MR, mood regulation; MS, musical seeking; SM, sensory motor; SR, social reward.

DISCUSSION

The aim of the present study was to investigate the relationship between individuals' susceptibility to experience music-induced transcendence or absorption states and their susceptibility to experience reward and pleasure from music. In order to do that, we evaluated the relationship between the AIMS[40] and the BMRQ.[37] Results showed that the two constructs were highly correlated, suggesting that the individual differences in the susceptibility to experience music-related absorption states and to experience reward from music are intimately related. Although this relation was strong, the amount of unshared variance between both constructs suggested that it might be possible to incorporate an absorption facet to the BMRQ. We believe that the extension of the BMRQ into the domain of absorption/transcendence could improve its capacity to characterize individual differences in the sensitivity to experience music-related reward and pleasure.

Our first result confirmed that a large amount of variance is shared between both constructs, music-reward and absorption. Importantly, the BMRQ facets that correlated the most with AIMS's overall sum were mood regulation, social reward, and emotion evocation ($r = 0.69$, $r = 0.68$, and $r = 0.62$, respectively). Accordingly, Kreutz and colleagues[28] showed that people high in trait absorption had more intense emotional reactions in response to music than those with low absorption trait. Similarly, Sandstrom and Russo[40] showed that people high in trait absorption were more likely than people low in trait absorption to recover from an acute stressor in the presence of peaceful music. Furthermore, absorption states have been suggested to be linked to an emotional involvement with the attentional object.[57] In line with the present results, Garrido and Schubert[58] showed a positive relationship between trait absorption and the enjoyment of evoked negative emotions in response to music (i.e., rating of the item *I like to listen to music which makes me feel sadness or grief*). This relationship was further demonstrated by Hall *et al.*,[59] who found that people high in trait absorption reported high enjoyment of self-selected music that was strongly evocative of negative emotions. To explain these intriguing results, Schubert[60] proposed that, because these negative emotions are experienced in an aesthetic context, they can become activated without their unpleasant effect and can be thoroughly enjoyed. This ability to disconnect from the negative aspects of the experience would be enhanced in individuals high in trait absorption, since absorption represents a disconnection from one's surroundings and immersion in internal thoughts. Overall, undergoing these exceptional experiences of absorption triggers a wealth of complex emotions,[22] explaining the high correlation observed between absorption in music and the emotion evocation facet.

At a neural level, this marked relationship between transcendence or absorption states and music reward might be explained by partial activation of similar brain networks. For example, one of the characteristics of absorption is that attention becomes deeply focused and narrowed.[12] Interestingly, Yacubian and Büchel showed that, when meaningful objects are in the focus of attention, there are phasic increases in dopamine release. Specifically, as the personal meaning and valence of the object in focus becomes higher, an indirect increase in dopamine release is observed.[61] Complementing this perspective, recent studies have associated self-transcendence experiences (i.e., experiencing *awe* emotions) with temporary disruption of activity in the default mode network associated with self-awareness.[62] This result converges with the attenuated connectivity in the default mode network (DMN) observed in participants after psychedelic drug administration and when experiencing mystic-transcendence experiences (e.g., ego dissolution, feelings of internal and external unity, and transcendence of time and space).[63] Previous research has consistently shown the implication of dopaminergic transmission and mesolimbic activation in experiencing music listening as a rewarding activity.[35,64] We could, therefore, expect that, during music-induced absorption states, and because of the meaningful relevance and high reward value of these experiences, increased activation in mesolimbic dopamine networks could be observed together with decreased activation in self-awareness networks (i.e., DMN).

Despite the high correlation between the two constructs, it is important to recognize that 41% of the variance in these constructs was unshared, meaning that the incorporation of an absorption facet to the BMRQ could contribute to better characterizing individual differences in the ability to extract reward from music. Therefore, we selected four AIMS items representing this new facet. To do that, we performed a unidimensional EFA, and we discarded those items with loading values lower than 0.60. Then, the content and adequacy of the remaining items was subjectively assessed, and four final items were selected. While the first two items (i.e., *I sometimes feel like I am "one" with the music*, and *While listening to music, I may become so involved that I may forget about myself and my surroundings*) exclusively represent the concept of absorption, the third and fourth items (i.e., *It is sometimes possible for me to be completely immersed in music and to feel as if my whole state of consciousness has been temporarily altered*, and *When listening to great music I sometimes feel as if I am being lifted into the air*) could be interpreted as absorption or transcendence. Importantly, these items represent certain aspects that were not contemplated in the previously existing version of the BMRQ. A careful examination of the items that were initially considered to be included in the BMRQ revealed that none of them approached the concept of absorption or transcendence. The only items that could be somehow, though remotely, linked to this concept were related to the usage of music as a means of escaping reality (i.e., *Music makes me feel free*, *Time flies when I listen to music*, *Music inspires me*, and *Listening to music helps me to dream and imagine things*). The lack of transcendence or absorption-related items could be explained by the fact that these are not very common experiences, so they are not easily accessible in our minds (lack of availability) and the probability of retrieving them in a free recall might be lower than other music activities, which are commonly very pleasant.[65] Thus, when people are asked to recall about music-related pleasure experiences, they might report everyday memories and might not access these more complex and unusual events. One might, however, counterargue that because they are novel and highly meaningful, absorption experiences with music might be more salient and might be more accessible to free recall. In this regard, it is interesting to consider that because of the uniqueness of the absorption experiences, they could be associated with clear autobiographical and self-relevant information. The interaction between long-term autobiographical information and reward-pleasure might be especially relevant for the value we ascribe to these experiences (for a similar theoretical framework in neuroaesthetics, see Ref. 66).

Following this line of reasoning, one could even consider the recall of music absorption or transcendence states as a type of flashbulb memory (FBM), created after exceptional events, and that endure for long periods of time, retaining many details that would be easily forgotten in ordinary everyday memories.[67] FBMs depend on the degree of emotional arousal, surprise, importance, consequentiality (e.g., having personal consequences), and rehearsal.[68,69] Given their emotional impact (in most cases negative), FBMs have been linked to emotional encoding brain regions with participation of the amygdala (see Refs. 70–74, but see also Ref. 75) and its interaction with the autobiographical memory encoding system, comprising medial temporal lobe, retrosplenial cortex, medial and prefrontal cortices, as well as the temporoparietal junction.[76–80] Accordingly, there could be a difference between the memories of the actual piece of music (i.e., origin of the event) and the memories of one's own situation at the time of experiencing these states (i.e., reception event).[68,81] In the future, it might be interesting to observe the impact of music absorption states in both dimensions, memory for music (i.e., factual information) and memory for the personal situation experienced at that moment (i.e., autobiographical information), as well as the implication of reward-processing networks during the recall of these events and personal narratives.[82] Finally, note that the potential impact of FBM depends on its consequences, especially on one's own life.[67] Similarly, absorption and self-transcendence states seem to have clear impact on people's narratives, being sometimes reported as some of the most important experiences in life.[83,84]

Interestingly, the four items selected to constitute the eBMRQ's absorption in music facet do not evaluate specific emotional correlates. Indeed, the selected items describe some aspects previously associated with peak emotional experiences[27,85] (i.e., being merged/fused with the music [item 3], being captured and fully involved [item 15], loss of self [item 13], and experiencing altered states of consciousness [item 15] and physical changes [e.g., being lifted, item 29]) but they are not especially associated with the emotions and feelings induced by music listening.[36] This apparent dissociation between absorption states and the affective dimension is interesting and needs further exploration. However, it is important to remind that the original concept of peak experience, as proposed by Maslow,[85] comprises a complex phenomenon characterized by absorption states, including emotional aspects (see, e.g., how the concept of *peak experience* was presented to Maslow's participants: "(…) the most wonderful experience of your life, happiest moments, ecstatic moments, moments of rapture, perhaps from being in love, or from listening to music, or suddenly 'being hit' by a book or painting, or from some great creative moment").[23,27] Interestingly, Maslow also pointed to the different time-course development of some phenomenological experiences both during and after the event. Subsequent work on peak emotional experiences[4,5,27,86–88] revealed different components associated with these experiences and, in most of the cases, both (1) absorption/transcendental (ecstatic) states (associated with cognitive aspects, such as perceptual narrowing, becoming merged, object capture, and fusion with the medium), and (2) emotional changes (associated with physical aspects, such as tears, heart beat changes, floating sensation, and feelings of joy, happiness, tenderness, calm, peace, etc.) were present. Similarly, Panzarella[86] commented on the three possible temporal stages of the peak experience: (1) cognitive responses to the feeling of loss of self, (2) climax phase with loss of self and motor-physical reactions, and (3) ending with emotional responses and self-transformations. Thus, overall, music-induced peak experiences contain perceptual, cognitive, physical, and emotional components, which could have different time courses during the full experience.[27] It would be interesting to further study the time course of these complex experiences. Importantly, individual differences might play a role in the intensity and valence of emotions during absorption-transcendental experiences. In this regard, Vroegh[89] found that highly susceptible individuals are clustered in two different types of absorption (labeled as zoning in and tuning in), showing unique bonding of imagery and emotions with other dimensions of consciousness. Specifically, whereas subjects who were tuned-in clearly experienced positive affect and were consciously aware of their altered consciousness, individuals zoning in had mixed emotions and were more self-forgetful. Interestingly, these findings were in line with the idea that connections between affect and cognition are common in ordinary states consciousness, but they tend to decouple in trance-related experiences.[89]

It is worth noting that not all individuals are equally prone to these types of exceptional experiences. Some elements of personality, especially flexibility and openness to experience, seem to encourage them.[27] Interestingly, absorption (measured through the TAS[29]) has been shown to be highly correlated with specific aspects of openness to experience (measured through the Coan's Experience Inventory, CEI,[90] and the openness to experience subscale of the NEO Personality Inventory, NEO-OE[91]) related to aesthetic sensitivity, unusual perceptions and associations, fantasy and dreams, unconventional views of reality, and awareness of inner feelings.[92] Similarly, it has been shown that people higher in openness to experience trait get chills from music more often.[93,94] Therefore, it may be possible that people who are high in trait absorption tend to experience greater levels of music-related reward. Consistent with this view, Loxton and colleagues[95] found that AIMS correlated positively with reward sensitivity as well as involvement in music as assessed by a series of questions concerning musical activities. Moreover, AIMS was found to mediate the association between reward sensitivity and involvement in music.

Regarding the relationship between age and the different eBMRQ factors, we found that musical seeking, social reward, sensory-motor, and mood regulation factors were negatively correlated with age. These results seem reasonable given that, while music plays an essential role during adolescence (e.g., it helps developing an individual and cultural identity, it contributes to socialization and integration with peers, it constitutes a coping strategy, etc.),[96] as we get older our relationship with music changes (e.g., our musical preferences have already been established and we are usually reticent to look for new music, as well as we cannot go clubbing every Saturday night and dance to the music with our friends, etc.). Note that, in line with the results reported by Sandstrom and Russo,[40] the absorption in music factor was not significantly correlated with age. Interestingly, and contrary to the results reported in Mas-Herrero *et al.*,[37] the correlation between age and emotion evocation was not significant, suggesting that music's ability to elicit emotions persists over time. Accordingly, a recent study[97] found no significant relationship between age and the Aesthetic Experience Scale in Music (AES-M).[98] These findings may be related to the fact that music often evokes autobiographical memories that are strongly emotional[99] and that persist even in persons with significant memory impairments.[100] Therefore, when we get old, music might help to remember episodes of our life that trigger intense emotions.

It is worth noting that the present study is a cross-sectional study and, consequently, the significant correlations between age and the different eBMRQ factors could be possibly due to a cohort effect rather than a true effect of age. In addition, in the collected sample of participants, ages were not equally represented and, therefore, the correlations here reported cannot be definitively explained by maturation effects. Similarly, results showing that women presented higher scores than men in all factors except in musical seeking (in line with Ref. 37) need to be interpreted with caution since the sample was not gender-balanced (i.e., 64% female).

Regarding musical training, we observed a positive correlation between years of training and musical seeking, emotion evocation, mood regulation, social reward, and absorption in music. In the original paper on the BMRQ, Mas-Herrero *et al.*[37] reported higher scores in professional musicians and musically trained participants than in untrained participants only for musical seeking and emotion evocation subscales. For the absorption in music facet, and contrary to Sandstrom and Russo,[40] we found a significant correlation between absorption and musical training. Such discrepancies could be related to differences in the distribution of music training across the studies. In the present study, only 34% of participants reported to have musical training and we did not fully assess it (e.g., we did not ask if they received group or private instruction, or if they were autodidacts, etc.). Thus, further studies are needed to disentangle the relationship between musical training and individual differences in the experience of music-related reward and absorption.

It is also interesting to specifically focus on participants who could have been considered musical anhedonics ($N = 43$) (following previous criteria[39]). The scatterplot (Figure 1) highlighted the presence of seven unquestionably anhedonic participants with very low BMRQ scores, who also showed very low scores in music absorption. On the other hand, it was also possible to observe five participants with less extreme musical anhedonia reporting AIMS scores close to the mean score of the whole sample. In line with what we previously discussed, this would suggest that, although musical absorption is strictly related to musical reward, some aspects of music-driven absorption states exist independently from the pleasure derived while listening to music. This dissociation might appear, for example, in scenarios in which music drives specific emotional states via its strong ritual efficacy[101] (e.g., meditation sessions evoking mental imageries[102] or religious rituals promoting associative conditioning[1]). Further research specifically addressing musical anhedonia and absorption states is needed to clarify these interesting findings.

The present study presents some limitations. First, we employed the BMRQ and the AIMS questionnaires, but we did not request participants to complete other questionnaires related to hedonia or absorption, such as the BIS/BAS,[45] the Physical Anhedonia Scale,[46] or Tellegen's Absorption Scale.[29] Therefore, external validity of the eBMRQ remains to be assessed. Second, and as previously mentioned, we did not specifically control our sample for age, gender, or musical training. Thus, further studies would be needed to investigate how these variables influence the different ways of deriving pleasure from music.

It is worth mentioning that this study was never aimed at extracting the most representative items from the AIMS to obtain a reduced scale. Rather, our aim was to enrich the BMRQ by adding a new facet accounting for the absorption construct. Thus, researchers looking for a measure of absorption in music should use the AIMS.[40]

Importantly, the identification of this new absorption in music facet could contribute to a better characterization of individual differences in the ability to experience reward from music. Several studies have provided evidences of the beneficial effects of music in both patients and healthy participants.[103,104] Of particular interest is the use of music for rehabilitation. It has been shown that music-supported rehabilitation programs for stroke patients lead to significant improvements at both cognitive and emotional levels.[105–107] Other studies have also reported improvements in cognitive function, as well as quality of life and depressive symptoms in patients with dementia and Alzheimer's disease.[108,109] Crucially, several studies have shown that musical reward and its different facets can predict music-related benefits on cognition and well-being.[110–114] A better characterization of subjects' relationship with music by means of the eBMRQ might help, therefore, to predict the effectiveness of music-based treatments at an individual level.

Overall, in the present study, we showed that there is a close relationship between individual differences in the susceptibility to experience music-related absorption states and in the ability to experience reward from music. Accordingly, we constructed and validated an extended version of the BMRQ, including an absorption/transcendence facet. Using the eBMRQ could contribute to a better characterization of individual differences in the sensitivity to experience music-related reward and pleasure.

ACKNOWLEDGMENTS

This work was supported and cofunded by Ministerio de Ciencia, Innovación y Universidades (MCIU), which is part of Agencia Estatal de Investigación (AEI), through the grant "Generación del Conocimiento," number PGC2018-099859-B-I00 (cofunded by ERDF and awarded to A.R.F.). G.C. was supported by the grant PRE2019-088409 (cofunded by European Social Fund. ESF investing in your future). We thank CERCA Programme/Generalitat de Catalunya for institutional support. L.F. was supported by IMPULSION Grant (IDEX Lyon).

AUTHOR CONTRIBUTIONS

L.F. and A.R.F. conceived the research. G.C. collected the data. G.C. and U.L.S. analyzed the data. G.C., L.F., U.L.S., F.A.R., and A.R.F. wrote the paper.

DATA AVAILABILITY STATEMENT

The datasets generated during the current study, the factor analyses outputs, an Excel file to calculate factor scores, as well as two Word files with ready-to-administer the eBMRQ questionnaires in both languages, English and Spanish, are available in the OSF repository (link: https://osf.io/tyav2/?view_only=d2f6c6703af04b848eaafe776db77141).

COMPETING INTERESTS

The authors declare no competing interests.

ORCID

Gemma Cardona https://orcid.org/0000-0003-4357-834X
Laura Ferreri https://orcid.org/0000-0002-6143-1467
Urbano Lorenzo-Seva https://orcid.org/0000-0001-5369-3099
Frank A. Russo https://orcid.org/0000-0002-2939-6358
Antoni Rodriguez-Fornells https://orcid.org/0000-0002-3249-6931

REFERENCES

1. Juslin, P. N., & Västfjäll, D. (2008). Emotional responses to music: The need to consider underlying mechanisms. *Behavioral and Brain Sciences*, *31*, 559–575.
2. Saarikallio, S., & Erkkilä, J. (2007). The role of music in adolescents' mood regulation. *Psychology of Music*, *35*, 88–109.
3. Saarikallio, S. (2011). Music as emotional self-regulation throughout adulthood. *Psychology of Music*, *39*, 307–327.
4. Gabrielsson, A. (2001). Emotions in strong experiences with music. In P.N. Juslin & J.A. Sloboda, (Eds.) *Series in affective science. Music and emotion: Theory and research*. pp. 431–449. Oxford University Press.
5. Gabrielsson, A. (2010). Strong experiences with music. In *Series in affective science. Handbook of music and emotion: Theory, research, applications*. P.N. Juslin & J.A. Sloboda, Eds. pp. 547–574. Oxford University Press.
6. Denora, T. (1999). Music as a technology of the self. *Poetics*, *27*, 31–56.
7. North, A. C., Hargreaves, D. J., & O'neill, S. A. (2000). The importance of music to adolescents. *British Journal of Educational Psychology*, *70*, 255–272.
8. Sloboda, J. A., & O'Neill, S. A. (2001). Emotions in everyday listening to music. In *Series in affective science. Music and emotion: Theory and research*. P.N. Juslin & J.A. Sloboda, Eds. pp. 71–104. Oxford University Press.
9. Sloboda, J. A. (2010). Music in everyday life: The role of emotions. In *Series in affective science. Handbook of music and emotion: Theory, research, applications*. P.N. Juslin & J.A. Sloboda, Eds. pp. 493–514. Oxford University Press.
10. Gabrielsson, A. (2011). *Strong experiences with music: Music is much more than just music*. Oxford University Press.
11. Jamieson, G. A. (2005). The modified Tellegen absorption scale: A clearer window on the structure and meaning of absorption. *Australian Journal of Clinical and Experimental Hypnosis*, *33*, 119–139.
12. Eisen, M. L., & Lynn, S. J. (2001). Dissociation, memory and suggestibility in adults and children. *Applied Cognitive Psychology*, *15*, S49–S73.
13. Yaden, D. B., Haidt, J., Hood, R. W., Vago, D. R., & Newberg, A. B. (2017). The varieties of self-transcendent experience. *Review of General Psychology*, *21*, 143–160.
14. Kirkegaard, A. (2012). Music and transcendence: Sufi popular performances in East Africa. *Temenos*, *48*, 29–48.
15. Bachner-Melman, R., Dina, C., Zohar, A. H., Constantini, N., Lerer, E., Hoch, S., Sella, S., Nemanov, L., Gritsenko, I., Lichtenberg, P., Granot, R., & Ebstein, R. P. (2005). AVPR1a and SLC6A4 gene polymorphisms are associated with creative dance performance. *PLoS Genetics*, *1*, 394–403.
16. Forstmann, M., Yudkin, D. A., Prosser, A. M. B., & Crockett, M J. (2020). Transformative experience and social connectedness mediate the mood-enhancing effects of psychedelic use in naturalistic settings. *Proceedings of the National Academy of Sciences of the United States of America*, *117*, 2338–2346.
17. Katz, F., & De Rios, M. D. (1971). Hallucinogenic music: An analysis of the role of whistling in Peruvian ayahuasca healing sessions. *Journal of American Folklore*, *84*, 320.
18. Hills, P., & Argyle, M. (1998). Musical and religious experiences and their relationship to happiness. *Personality and Individual Differences*, *25*, 91–102.
19. Miller, M. M., & Strongman, K. T. (2002). The emotional effects of music on religious experience: A study of the Pentecostal-Charismatic style of music and worship. *Psychology of Music*, *30*, 8–27.
20. Penman, J., & Becker, J. (2009). Religious ecstatics, "deep listeners," and musical emotion. *Empirical Musicology Review*, *4*, 49–70.
21. Becker, J. (2004). *Deep listeners: Music, emotion, and trancing*. Bloomington, IN: Indiana University Press.
22. Maslow, A. (1971). *The farther reaches of human nature*. New York: Viking Press.
23. Maslow, A. (1968). *Toward a psychology of being*. Van Nostrand.
24. Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. New York: Harper and Row.
25. Chirico, A., Serino, S., Cipresso, P., Gaggioli, A., & Riva, G. (2015). When music "flows". State and trait in musical performance, composition and listening: A systematic review. *Frontiers in Psychology*, *6*, 690.
26. Vroegh, T., Wiesmann, S. L., Henschke, S., & Lange, E. B. (2021). Manual motor reaction while being absorbed into popular music. *Consciousness and Cognition*, *89*, 103088.
27. Whaley, J., Sloboda, J. A., & Gabrielsson, A. (2009). Peak experiences in music. In *Oxford handbook of music psychology*. Oxford University Press.
28. 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*, 101–126.
29. Tellegen, A., & Atkinson, G. (1974). Openness to absorbing and self-altering experiences ('absorption'), a trait related to hypnotic susceltibility. *Journal of Abnormal Psychology*, *83*, 268–277.
30. Rhodes, L. A., David, D. C., & Combs, A. L. (1988). Absorption and enjoyment of music. *Perceptual and Motor Skills*, *66*, 737–738.
31. Herbert, R. (2011). Musical and non-musical involvement in daily life: The case of absorption. *Music & Science*, *16*, 41–66.
32. Koelsch, S. (2014). Brain correlates of music-evoked emotions. *Nature Reviews Neuroscience*, *15*, 170–180.
33. Huron, D., & Margulis, E. H. (2010). Musical expectancy and thrills. In *Series in affective science. Handbook of music and emotion: Theory, research, applications*. P.N. Juslin & J.A. Sloboda, Eds. pp. 575–604. Oxford University Press.
34. Zald, D. H., & Zatorre, R. J. (2011). Music. In *Neurobiology of sensation and reward*. J.A. Gottfried, Ed. pp. 405–428. Boca Raton, FL: CRC Press.
35. Salimpoor, V. N., Benovoy, M., Larcher, K., Dagher, A., & Zatorre, R. J. (2011). Anatomically distinct dopamine release during anticipation and experience of peak emotion to music. *Nature Neuroscience*, *14*, 257–262.
36. Grewe, O., Nagel, F., Kopiez, R., & Altenmüüller, E. (2007). Listening to music as a re-creative process: Physiological, psychological, and psychoacoustical correlates of chills and strong emotions. *Music Perception*, *24*, 297–314.
37. Mas-Herrero, E., Marco-Pallares, J., Lorenzo-Seva, U., Zatorre, R. J., & Rodriguez-Fornells, A. (2013). Individual differences in music reward experiences. *Music Perception*, *31*, 118–138.
38. 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*, 699–704.
39. 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 of the United States of America*, *113*, 7337–7345.

40. Sandstrom, G. M., & Russo, F. A. (2013). Absorption in music: Development of a scale to identify individuals with strong emotional responses to music. *Psychology of Music*, *41*, 216–228.
41. Lorenzo-Seva, U. (2021). SOLOMON: A method for splitting a sample into equivalent subsamples in factor analysis. *Behavior Research Methods*. https://doi.org/10.3758/s13428-021-01750-y
42. Ferrando, P. J., & Lorenzo-Seva, U. (2017). Program FACTOR at 10: Origins, development and future directions. *Psicothema*, *29*, 236–240.
43. Jöreskog, K. G., & Sörbom, D. (2001). *LISREL 8.5: User's reference guide*. Chicago, IL: Scientific Software International, Inc.
44. Costa, P. T., & Mccrae, R. R. (1992). The five-factor model of personality and its relevance to personality disorders. *Journal of Personality Disorders*, *6*, 343–359.
45. Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS Scales. *Journal of Personality and Social Psychology*, *67*, 319–333.
46. Chapman, L. J., Chapman, J. P., & Raulin, M. L. (1976). Scales for physical and social anhedonia. *Journal of Abnormal Psychology*, *85*, 374–382.
47. Nagy, K., & Szabó, C. (2004). Differences in phenomenological experiences of music-listening: The influence of intensity of musical involvement and type of music on musical experiences. In *ICMPC8. Proceedings of the 8th International Conference on Music Perception & Cognition*, pp. 470–473. Evanston, IL.
48. Davis, M. H. (1980). A multidimensional approach to individual differences in empathy. *JSAS Catalog of Selected Documents in Psychology*, *10*, 85.
49. Harman, H. H. (1976). *Modern factor analysis*. Chicago, IL: University of Chicago Press.
50. Ferrando, P. J., & Lorenzo-Seva, U. (2013). Unrestricted item factor analysis and some relations with item response theory. Technical Report.
51. Kaiser, H. F., & Rice, J. (1974). Little Jiffy, Mark IV. *Educational and Psychological Measurement*, *34*, 111–117.
52. Lorenzo-Seva, U., & Ferrando, P. J. (2021). MSA: The forgotten index for identifying inappropriate items before computing exploratory item factor analysis. *Methodology*, *17*, 296–306.
53. Lorenzo-Seva, U., & Ferrando, P. J. (2019). Robust Promin: A method for diagonally weighted factor rotation. *Liberabit Revista Peruana de Psicología*, *25*, 99–106.
54. Ferrando, P. J., & 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*, 762–780.
55. Ferrando, P. J., & Lorenzo-Seva, U. (2000). Unrestricted versus restricted factor analysis of multidimensional test items: Some aspects of the problem and some suggestions. *Psicologica*, *21*, 301–323.
56. Ferrando, P. J., & Lorenzo-Seva, U. (2016). A note on improving EAP trait estimation in oblique factor-analytic and item response theory models. *Psicologica*, *37*, 235–247.
57. Roche, S. M., & Mcconkey, K. M. (1990). Absorption: Nature, assessment, and correlates. *Journal of Personality and Social Psychology*, *59*, 91–101.
58. Garrido, S., & Schubert, E. (2011). Individual differences in the enjoyment of negative emotion in music: A literature review and experiment. *Music Perception*, *28*, 279–296.
59. Hall, S. E., Schubert, E., & Wilson, S. J. (2016). The role of trait and state absorption in the enjoyment of music. *PLoS One*, *11*, e0164029.
60. Schubert, E. (2013). Loved music can make a listener feel negative emotions. *Music & Science*, *17*, 11–26.
61. Yacubian, J., & Büchel, C. (2009). The genetic basis of individual differences in reward processing and the link to addictive behavior. In J.-C. Dreher & L. Tremblay (Eds.), *Handbook of reward and decision making* (pp. 345–360). Elsevier Inc.
62. van, Elk, M., Gomez, A., M., A., van der, Zwaag, W., van Schie, H. T., & Sauter, D. (2019). The neural correlates of the awe experience: Reduced default mode network activity during feelings of awe. *Human Brain Mapping*, *40*, 3561–3574.
63. Tagliazucchi, E., Roseman, L., Kaelen, M., Orban, C., Muthukumaraswamy, S. D., Murphy, K., Laufs, H., Leech, R., McGonigle, J., Crossley, N., Bullmore, E., Williams, T., Bolstridge, M., Feilding, A., Nutt, D. J., & Carhart-Harris, R. (2016). Increased global functional connectivity correlates with LSD-induced ego dissolution. *Current Biology*, *26*, 1043–1050.
64. Ferreri, L., Mas-Herrero, E., Zatorre, R. J., Ripollés, P., Gomez-Andres, A., Alicart, H., Olivé, G., Marco-Pallarés, J., Antonijoan, R. M., 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*, 3793–3798.
65. Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive Psychology*, *5*, 207–232.
66. Bara, I., Binney, R. J., Ward, R., & Ramsey, R. (2020). A generalised semantic cognition account of aesthetic experience. *PsyArXiv*. https://psyarxiv.com/wbeqx/download
67. Brown, R., & Kulik, J. (1977). Flashbulb memories. *Cognition*, *5*, 73–99.
68. Conway, M. A., Anderson, S. J., Larsen, S. F., Donnelly, C. M., McDaniel, M. A., McClelland, A. G., Rawles, R. E., & Logie, R. H. (1994). The formation of flashbulb memories. *Memory & Cognition*, *22*, 326–343.
69. Conway, M. A. (1995). *Flashbulb memories. Essays in cognitive psychology*. Lawrence Erlbaum Associates.
70. Spanhel, K., Wagner, K., Geiger, M. J., Ofer, I., Schulze-Bonhage, A., & Metternich, B. (2018). Flashbulb memories: Is the amygdala central? An investigation of patients with amygdalar damage. *Neuropsychologia*, *111*, 163–171.
71. Sharot, T., Martorella, E. A., Delgado, M. R., & Phelps, E. A. (2007). How personal experience modulates the neural circuitry of memories of September 11. *Proceedings of the National Academy of Sciences of the United States of America*, *104*, 389–394.
72. Addis, D. R., Mcintosh, A. R., Moscovitch, M., Crawley, A. P., & McAndrews, M. P. (2004). Characterizing spatial and temporal features of autobiographical memory retrieval networks: A partial least squares approach. *Neuroimage*, *23*, 1460–1471.
73. Fink, G. R., Markowitsch, H. J., Reinkemeier, M., Bruckbauer, T., Kessler, J., & Heiss, W. D. (1996). Cerebral representation of one's own past: Neural networks involved in autobiographical memory. *Journal of Neuroscience*, *16*, 4275–4282.
74. Markowitsch, H. J., Thiel, A., Reinkemeier, M., Kessler, J., Koyuncu, A., & Heiss, W.-D. (2000). Right amygdalar and temporofrontal activation during autobiographic, but not during fictitious memory retrieval. *Behavioural Neurology*, *12*, 181–190.
75. Metternich, B., Spanhel, K., Schoendube, A., Ofer, I., Geiger, M. J., Schulze-Bonhage, A., Mast, H., & Wagner, K. (2020). Flashbulb memory recall in healthy adults–A functional magnetic resonance imaging study. *Memory (Hove, England)*, *28*, 461–472.
76. Addis, D. R., Knapp, K., Roberts, R. P., & Schacter, D. L. (2012). Routes to the past: Neural substrates of direct and generative autobiographical memory retrieval. *Neuroimage*, *59*, 2908–2922.
77. Martinelli, P., Sperduti, M., Devauchelle, A.-D., Kalenzaga, S., Gallarda, T., Lion, S., Delhommeau, M., Anssens, A., Amado, I., Meder, J. F., Krebs, M.-O., Oppenheim, C., & Piolino, P. (2013). Age-related changes in the functional network underlying specific and general autobiographical memory retrieval: A pivotal role for the anterior cingulate cortex. *PLoS One*, *8*, e82385.
78. Miró, J., Ripollés, P., Sierpowska, J., Santurino, M., Juncadella, M., Falip, M., & Rodríguez-Fornells, A. (2020). Autobiographical memory in epileptic patients after temporal lobe resection or bitemporal hippocampal sclerosis. *Brain Imaging and Behavior*, *14*, 1074–1088.

79. Maguire, E. A. (2001). Neuroimaging studies of autobiographical event memory. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *356*, 1441–1451.
80. Mccormick, C., Moscovitch, M., Valiante, T. A., Cohn, M., & McAndrews, M. P. (2018). Different neural routes to autobiographical memory recall in healthy people and individuals with left medial temporal lobe epilepsy. *Neuropsychologia*, *110*, 26–36.
81. Brewer, W. F. (1992). Affect and accuracy in recall: Studies of flashbulb memories. In *The theoretical and empirical status of the flashbulb memory hypothesis*. E. Winograd & U. Neisser, Eds. pp. 274–305. Cambridge University Press.
82. Janata, P. (2009). The neural architecture of music-evoked autobiographical memories. *Cerebral Cortex*, *19*, 2579–2594.
83. Griffiths, R., Richards, W., Johnson, M., McCann, Ud, & Jesse, R. (2008). Mystical-type experiences occasioned by psilocybin mediate the attribution of personal meaning and spiritual significance 14 months later. *Journal of Psychopharmacology*, *22*, 621–632.
84. Hood, R. W., Hill, P. C., & Spilka, B. (2009). *The psychology of religion: An empirical approach* (4th ed.). New York: Guilford Publications.
85. Maslow, A. H. (1962). Lessons from the peak-experiences. *Journal of Humanistic Psychology*, *2*, 9–18.
86. Panzarella, R. (1980). The phenomenology of aesthetic peak experiences. *Journal of Humanistic Psychology*, *20*, 69–85.
87. Laski, M. (1961). *Ecstasy in secular and religious experiences*. Tarcher, Inc.
88. Lamont, A. (2011). University students' strong experiences of music: Pleasure, engagement, and meaning. *Music & Science*, *15*, 229–249.
89. Vroegh, T. (2019). Zoning-in or tuning-in? Identifying distinct absorption states in response to music. *Psychomusicology: Music, Mind, Brain*, *29*, 156–170.
90. Coan, R. W. (1972). Measurable components of openness to experience. *Journal of Consulting and Clinical Psychology*, *39*, 346.
91. Costa, P. T., & McCrae, R. R. (1985). *The NEO Personality Inventory: Manual*. Odessa, FL: Psychological Assessment Resources.
92. Glisky, M. L., Tataryn, D. J., Tobias, B. A., Kihlstrom, J. F., & McConkey, K. M. (1991). Absorption, openness to experience, and hypnotizability. *Journal of Personality and Social Psychology*, *60*, 263–272.
93. Colver, M. C., & El-Alayli, A. (2016). Getting aesthetic chills from music: The connection between openness to experience and frisson. *Psychology of Music*, *44*, 413–427.
94. Nusbaum, E. C., & Silvia, P. J. (2011). Shivers and timbres: Personality and the experience of chills from music. *Social Psychological and Personality Science*, *2*, 199–204.
95. Loxton, N. J., Mitchell, R., Dingle, G. A., & Sharman, L. S. (2016). How to tame your BAS: Reward sensitivity and music involvement. *Personality and Individual Differences*, *97*, 35–39.
96. Miranda, D. (2013). The role of music in adolescent development: Much more than the same old song. *International Journal of Adolescence and Youth*, *18*, 5–22.
97. Belfi, A. M., Moreno, G. L., Gugliano, M., & Neill, C. (1991). Music structure and emotional response: Some empirical findings. *Psychology of Music*, *19*, 110–120.
98. Sloboda, J. A. (1991). Music structure and emotional response: Some empirical findings. *Psychology of Music*, *19*, 110–120.
99. Janata, P., Tomic, S. T., & Rakowski, S. K. (2007). Characterisation of music-evoked autobiographical memories. *Memory (Hove, England)*, *15*, 845–860.
100. El Haj, M., Postal, V., & Allain, P. (2012). Music enhances autobiographical memory in mild Alzheimer's disease. *Educational Gerontology*, *38*, 30–41.
101. Patel, A. D. (2010). Music, biological evolution, and the brain. In *Emerging disciplines: Shaping new fields of scholarly inquiry in and beyond the humanities*. M. Bailar, C.F. Levander & C. Henry, Eds. pp. 91–144. Houston, TX: Rice University Press.
102. Taruffi, L., & Küssner, M. B. (2019). A review of music-evoked visual mental imagery: Conceptual issues, relation to emotion, and functional outcome. *Psychomusicology: Music, Mind, Brain*, *29*, 62–74.
103. Stegemann, T., Geretsegger, M., Phan Quoc, E., Riedl, H., & Smetana, M. (2019). Music therapy and other music-based interventions in pediatric health care: An overview. *Medicines*, *6*, 25.
104. Altenmüller, E., & Schlaug, G. (2013). Neurologic music therapy: The beneficial effects of music making on neurorehabilitation. *Acoustical Science and Technology*, *34*, 5–12.
105. Sarkamo, T., Tervaniemi, M., Laitinen, S., Forsblom, A., Soinila, S., Mikkonen, M., Autti, T., Silvennoinen, H. M., Erkkilä, J., Laine, M., Peretz, I., & Hietanen, M. (2008). Music listening enhances cognitive recovery and mood after middle cerebral artery stroke. *Brain*, *131*, 866–876.
106. Rojo, N., Amengual, J., Juncadella, M., Rubio, F., Camara, E., Marco-Pallares, J., Schneider, S., Veciana, M., Montero, J., Mohammadi, B., Altenmüller, E., Grau, C., Münte, T. F., & Rodriguez-Fornells, A. (2011). Music-supported therapy induces plasticity in the sensorimotor cortex in chronic stroke: A single-case study using multimodal imaging (fMRI-TMS). *Brain Injury*, *25*, 787–793.
107. Rodriguez-Fornells, A., Rojo, N., Amengual, J. L., Ripollés, P., Altenmüller, E., & Münte, T. F. (2012). The involvement of audio-motor coupling in the music-supported therapy applied to stroke patients. *Annals of the New York Academy of Sciences*, *1252*, 282–293.
108. Fang, R., Ye, S., Huangfu, J., & Calimag, D. P. (2017). Music therapy is a potential intervention for cognition of Alzheimer's disease: A mini-review. *Translational Neurodegeneration*, *6*, 1–8.
109. Moreno-Morales, C., Calero, R., Moreno-Morales, P., & Pintado, C. (2020). Music therapy in the treatment of dementia: A systematic review and meta-analysis. *Frontiers in Medicine*, *7*, 1–11.
110. Ferreri, L., & Rodriguez-Fornells, A. (2017). Music-related reward responses predict episodic memory performance. *Experimental Brain Research*, *235*, 3721–3731.
111. Grau-Sánchez, J., Duarte, E., Ramos-Escobar, N., Sierpowska, J., Rueda, N., Redón, S., Heras, M. V. L., Pedro, J., Särkämö, T., & Rodríguez-Fornells, A. (2018). Music-supported therapy in the rehabilitation of subacute stroke patients: A randomized controlled trial. *Annals of the New York Academy of Sciences*, *1423*, 318–328.
112. Cardona, G., Rodriguez-Fornells, A., Nye, H., Rifà-Ros, X., & Ferreri, L. (2020). The impact of musical pleasure and musical hedonia on verbal episodic memory. *Science Reports*, *10*, 16113.
113. Ferreri, L., Mas-Herrero, E., Cardona, G., Zatorre, R. J., Antonijoan, R. M., Valle, M., Riba, J., Ripollés, P., & Rodriguez-Fornells, A. (2021). Dopamine modulations of reward-driven music memory consolidation. *Annals of the New York Academy of Sciences*, *1502*, 85–98.
114. 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*, *12*, 1–11.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Cardona, G., Ferreri, L., Lorenzo-Seva, U., Russo, F. A., & Rodriguez-Fornells, A. (2022). The forgotten role of absorption in music reward. *Ann NY Acad Sci*, 1–13. https://doi.org/10.1111/nyas.14790