Tell me what you see

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Dahl, Sofia; Stella, Antonio; Bjørner, Thomas

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Sofia Dahl, Antonio Stella, Thomas Bjørner

Abstract

The link between musical structure and evoked visual mental imagery (VMI), that is, seeing in the absence of a corresponding sensory stimulus, has yet to be thoroughly investigated. We explored this link by manipulating the characteristics of four pieces of music for synthesizer, guitars, and percussion (songs). Two original songs were selected on the basis of a pilot study, and two were new, specially composed to combine the musical and acoustical characteristics of the originals. A total of 135 participants were randomly assigned to one of four groups who listened to one song each; 73% of participants reported experiencing VMI. There were similarities between participants' descriptions of the mental imagery evoked by each song and clear differences between them. A combination of coding and content analysis produced ten categories: *Nature*; *Places and settings*; *Objects*; *Time*; *Movements and events*; *Color(s)*; *Humans*; *Affects*; *Literal sound*; and *Film*. Regardless of whether or not they had reported experiencing VMI, participants then carried out a card-sorting task in which they selected the terms they thought best described a scene or setting appropriate to the music they had heard and rated emotional dimensions. The results confirmed those of the content analysis. Taken together, participants' ratings, descriptions of VMI and selection of terms in the card-sorting task confirmed that new songs combining the characteristics of original songs evoke elements of visual mental imagery associated with the latter. The findings are important for the understanding of the musical and acoustical characteristics that may influence our experiences of music, including VMI.

Keywords
mental imagery, music structure, content analysis, emotional state, empathy, online survey, music listening test

> *For me music is such a visual thing . . . when I connect to a piece of music, it's almost like there's a location for it.* Ed O'Brien, Radiohead (That Pedal Show, 2019, 5:28)

There are numerous accounts of visual imagery in music, both with respect to imagery experienced when listening to music (Taruffi & Küssner, 2019), and the imagery encoded by a composer when writing music (Godøy & Jørgensen, 2001). As illustrated in the quotation from Ed O'Brien that serves as an epigraph, above, composers often use visual images or metaphors in their work. A widespread example of this is program music, typical in 19th century Western classical music (Grout & Palisca, 2001), in which the music is underpinned by a program that sometimes involves a narrative (e.g., Berlioz's *Symphonie Fantastique*). Films often utilize music, precisely because of the way it adds interpretations and emotions to visual scenes (Bullerjahn & Guldenring, 1994; Cohen, 2001).

However, music does not have to be accompanied by verbal descriptions or visual stimuli for it to evoke imagery spontaneously in listeners (Küssner & Eerola, 2019; Osborne, 1981; Taruffi & Küssner, 2019). In the present study, we aimed to investigate spontaneous visual mental imagery evoked by music in which specific musical and acoustical characteristics had been varied.

Mental imagery is the representation and perception-like experience of sensory information although the external stimuli that usually cause this experience are not present (Pearson et al., 2015). Visual mental imagery (VMI) is "seeing with the mind's eye" (Kosslyn et al., 2001, p. 635), or accessing perceptual information from memory rather than a visual stimulus that is present. More importantly, VMI is not the simple recall of previously perceived objects or events, nor always under voluntary control (Pearson, 2019), but can arise spontaneously from novel combinations and modifications of previously stored perceptual information (Kosslyn et al., 2001; 2010).

Generally, research on VMI for music has been sparse, but lately the field has been receiving more attention (Taruffi & Küssner, 2019). Research shows that listeners frequently report visual mental imagery in response to music (Juslin et al., 2008; Küssner & Eerola, 2019; Osborne, 1981), that visual imagery appears to be the most frequent form of mental imagery when listening to music (Osborne, 1981; Taruffi et al., 2017), and that music may facilitate VMI (Quittner, 1983). Overall, the reported prevalence of VMI appears to be high. In Osborne's study, participants heard electronic music after having carried out a brief relaxation exercise, and 48% of the described reactions were VMI (Osborne, 1983). In a survey by Küssner and Eerola (2019), 77% of a representative sample indicated experience of music-related VMI. Vuoskoski and Eerola (2015) provided listeners either a neutral or a sad written narrative, after which 80% of participants reported VMI related to the narrative they had read, indicating that the narrative promoted VMI in the listening context. Conversely, participants' eye-movements suppress VMI (Hashim et al., 2020).

VMI and emotions

Much recent research on VMI evoked by music has focused on its relationship to emotion, because VMI has been proposed as a mechanism by which music can elicit emotional responses in listeners (Juslin et al., 2008; Juslin & Västfjäll, 2008). The mechanism works by conjuring images (e.g., of landscapes) during listening, which in turn induce emotions. Other mechanisms proposed by Juslin and Västfjäll (2008) are emotional contagion, brainstem response, episodic memory, evaluative conditioning, musical expectancy, and cognitive appraisal, and their BRECVEMA framework was later expanded also to include rhythmic entrainment and aesthetic judgement (Juslin, 2013). An experience-sampling study by Juslin et al. (2008) showed that, after emotional contagion, brain stem response and episodic memory, VMI was the fourth most frequently reported cause of emotion when listening to music. However, the authors of recent studies (Day & Thompson, 2019; Presicce & Bailes, 2019) question the direction of the proposed causality. In three reaction-time experiments, Day & Thompson (2019) found that a majority of participants reported experiencing an emotion before experiencing VMI. One possible interpretation of this finding is that there are other mechanisms that induce an emotional reaction first, which then helps to produce VMI (Day & Thompson, 2019). Presicce and Bailes (2019) collected participants' continuous slider ratings of engagement and VMI, in alternation, in response to four solo piano pieces. Time-series analysis of the ratings showed individual differences with respect to engagement and VMI responses but, overall, VMI was predicted by engagement. Presicce and Bailes (2019) propose that listeners need to engage with the music at least to a certain degree before VMI is possible.

Factors proposed to influence VMI include empathy (Vuoskoski & Eerola, 2012), overall mood (Martarelli et al., 2016), and listeners' levels of musical experience (Küssner & Eerola, 2019; Presicce & Bailes, 2019), as well as the music itself. Several studies have used music with contrasting valence (e.g., happy and sad), finding that the music influences both the valence and vividness of daydreams. That is, the VMI induced by music validated as happy is more positive and vivid than VMI induced by music validated as sad (Martarelli et al., 2016; Taruffi et al., 2017). Vuoskoski and Eerola (2012) suggest that individuals with high trait empathy are able to enter a song's mood to a greater degree, and therefore experience stronger VMI. The musical valence and vividness of VMI predict the aesthetic appeal of music (Belfi, 2019). Also, indirect effects of sad and happy music (through valence) have been found on liking, although the vividness of daydreams does not appear significantly to mediate liking or relaxation (Martarelli et al., 2016).

Although details of the role of VMI in emotional reactions to music are still unclear, research findings support a link between them and indicate that the content of VMI is likely to correspond to the emotion being communicated or induced by the music (Martarelli et al., 2016; Taruffi et al., 2017; Taruffi, 2021). But while it is known how music can communicate emotion to a listener using cues such as sound level, tempo, timbre, and mode (e.g., Juslin, 2013; Juslin & Västfjäll, 2008;

Juslin & Sloboda, 2001; Scherer & Zentner, 2001), the musical and acoustical characteristics responsible for VMI call for more investigation (Taruffi & Küssner, 2019).

VMI and musical structure

Not many studies of VMI report the characteristics or the structure of music. Herff and colleagues (2021) presented listeners with two different renditions of three pieces of music and found that average tempo mediated the VMI reported, such that higher BPM predicted more positive responses while not affecting the vividness of VMI. The narratives provided by Presicce & Bailes' (2019) participants referred to the musical characteristics of the music to which they had listened. Bonde (2007) observes that listeners seemed to conceptualize the musical structure through a metaphorical nonverbal mapping between the music and so-called image schemata grounded in bodily experience, such as hearing the movement of a melody as upward (Bonde, 2007). The core concept of embodied music cognition is the idea that the body is at the center of the musical meaning-making (Godøy, 2003; Godøy & Leman, 2010; Leman, 2008; Leman et al., 2018). For instance, it has been proposed that any sound "can be understood as included in an action-trajectory" (Godøy, 2003, p.318) and that when people listen to music they imagine the actions movements that generate the sounds. By extension, listening to music can be seen as "reconstructing" and making models of "a condition (or state) that could have generated these sonic patterns" (Leman et al., 2018, p. 749). That is, when listening to music we also infer something about the intention or state of the composer and/or performer (Scherer & Zentner, 2001). VMI can also add not only an intention or state but also a place. In the epigraph to this article, Ed O'Brien states "it is almost like there's a location for it" (That Pedal Show, 2019, 5:28). In the same interview, he continues to emphasize the sound "it's all been about the sound *per se* . . . It's the sound that connects me with being in a place, in the energy"(That Pedal Show, 2019, 6:38). The Geneva Musical Metaphors Scale proposed by Schaerlaeken et al. (2019) is based on a factor analysis of metaphors used for classical music and include Flow, Movement, Force, Interior, and Wandering. Although the energy O'Brien refers to can be assumed to be related to the first three factors, the model does not include the category of place or nature frequently reported in descriptions of VMI, such as landscapes, sun, water, sky, and trees (Küssner & Eerola, 2019; Osborne, 1981; Presicce & Bailes, 2019; Taruffi et al., 2017). Reported VMI has included both realistic and abstract mental images (Day & Thompson, 2019; Küssner & Eerola, 2019; Martarelli et al., 2016; Osborne, 1981; Presicce & Bailes, 2019; Taruffi et al., 2017), including abstract shapes (Küssner & Eerola, 2019), images related to out-of-body experiences and religious images (Osborne, 1981), as well as references to movies (Day & Thompson, 2019; Hashim et al., 2021). Notably, mentions of contexts, films, and situations in some descriptions of VMI can be very specific, compared to the terms and metaphors used in descriptions of music and musical experiences more generally (Schaerlaeken et al., 2019).

Spontaneous VMI

Whereas Mental imagery is related to a number of cognitive processes (Fig. 5 Pearson, 2019), we here focus on VMI as a kind of spontaneous thought (Christoff et al. 2016). For spontaneous VMI evoked by music, the terms mind-wandering or daydreaming have also been used (Martarelli et al., 2016; Taruffi et al., 2017; Vroegh, 2019; Taruffi, 2021). Building on the framework by Christoff et al. (2016), Taruffi & Küssner (2019) outline the automatic and deliberate constraints that are likely to affect music-evoked VMI, with both automatic and deliberate constraints being weaker for spontaneous VMI (or mind-wandering) than for guided imagery with music (Taruffi & Küssner, 2019). Taruffi et al. (2017) found that sad music produced stronger and more self-referential mind-wandering than happy music. In an experience-sampling study (Taruffi, 2021) participants reported mind-wandering in 57% of sampled music episodes, with 19% being visual images that were largely associated with the music. By comparison, mind-wandering occurred in 36% of the randomly sampled non-music episodes.

From a study in which participants listened to self-chosen music before completing questionnaires on absorption and the phenomenology of consciousness, Vroegh (2019) identified four profiles representing different levels of attentional focus, altered awareness, and meta-awareness. Tuning-in and zoning-in shared high levels of attentional focus combined with altered awareness, but tuning-in also involved high meta-awareness, while zoning-in was lower in this respect but involved a relatively high degree of experiential intensity. They also differed with respect to VMI, which was linked to positive affect and altered experience for tuning-in, and to memory and, to a lesser degree, attentional focus, for zoning-in (Vroegh, 2019).

Guided imagery has a long-established function in music therapy and involves a more goal-directed type of cognition (Bonde, 2007; Grocke & Moe, 2015a). The choice of one or more images as the focus for listening and achieving a state of relaxation is common to several approaches (Grocke & Moe, 2015b). In the Bonny Method of Guided Imagery and Music (GIM) (Bonny & Savary, 1973), a therapist chooses a program of (typically) Western classical music. The aim is often to stimulate spontaneous imagery and the therapist can suggest a focus image for the patient who describes VMI and emotions to the therapist (Grocke & Moe, 2015b). A music-induced imagery session can produce relaxation and an altered state of consciousness, and reduce cortisol levels (McKinney et al., 1997). Spontaneous VMI, without the assistance of a therapist, has also been linked to listeners' relaxation (Küssner & Eerola, 2019) and altered experiences with positive affect (Vroegh, 2019). Koelsch and colleagues (2019) found heroic music to evoke more empowering and motivating thoughts in participants, in contrast to the more relaxing or depressing thoughts reported for sad music. Similarly, the experience-sampling study by Taruffi (2021) found that valence of thoughts could be predicted by music-evoked emotions. In a recent study using Indian Carnatic music, Sharma et al. (2021) found reduced anxiety scores for participants listening to clips manipulated to vary incrementally in tempo and octave, compared to those listening to clips that had not been manipulated (*stable* music). VMI was not investigated, but the authors interpreted the EEG results as showing that listeners experienced less mind-wandering when hearing manipulated music than stable music (Sharma et al., 2021).

The present study

Despite the advances of recent years, many questions as to the specifics and nature of musically evoked VMI must be answered if the link between VMI and emotion is to be clarified (Küssner & Eerola, 2019).

These questions include the kinds of images that are experienced and whether they are linked to the structure and other musical or acoustical characteristics of the music heard (Taruffi & Küssner, 2019). To answer these questions more focused descriptions of musical stimuli would be required than are typically provided. Furthermore, experimental studies of VMI have often used short excerpts in repeated-measures designs (e.g., Belfi, 2019; Day & Thompson, 2019) or primarily Western classical music tracks chosen for their clear valence (e.g., happy vs. sad) (Martarelli et al., 2016, Taruffi et al., 2017). While the study by Presicce & Bailes (2019) is a notable exception in supplying detailed descriptions of the music, participants heard several pieces in a repeated-measures design and rated imagery continuously. Although repeated-measures designs reduce the effects of individual variability, it seems reasonable to assume that there is a risk of fatiguing participants or adding constraints that might affect spontaneous thoughts. To avoid this, investigators can study spontaneously evoked VMI by using between-group designs and instructions not mentioning visual mental imagery (cf. Osborne, 1981).

Schneider and Godøy posed the question as to whether "musical experience ruled by individual intentionalities is similar for a number of subjects" (Schneider and Godøy, 2001, p. 14). We therefore asked if listeners infer similar states, places, atmospheres, and energy from the same music, as evidenced by reports of similar VMI. Specifically, we carried out an exploratory study in which we investigated the VMI of listeners to the same four excerpts from pieces of music for synthesizers, guitars, and percussion (*songs*) to find out if the same type of music evokes similar mental imagery. The research questions of the study can be summarized as: (RQ1) Would the proportion of participants reporting spontaneously occurring VMI when listening to the songs be similar to the proportions reported previously? (RQ2) What are the effects of the sound and musical structure on participants' VMI and thoughts about the music? (RQ3) Do the same musical characteristics evoke similar VMI? The study used a between-groups design, presenting participants with 2-min songs, collecting their VMI reports, and subsequently administering a card-sorting task and ratings of emotional state. Two original songs were selected on the basis of a pilot study, and two were new songs, specially composed to combine the characteristics of the originals. In this way we were able to test the effects of the sound and structure of the music on participants' VMI and thoughts about the music. We hypothesized that songs with similar musical characteristics would result in similar VMI and that combining them would result in VMI containing mixed elements. Regardless of VMI experiences or not, we hypothesized that songs with similar musical and acoustical characteristics would result in similar card selections and emotional ratings. To the best of our knowledge, this is the first VMI study both to manipulate musical structure and analyse participants' self-reports in detail.

Method

Design

The study consisted of an online survey involving a listening test and the completion of a questionnaire followed by a card-sorting task. Participants were randomly assigned to listen to one of four songs, asked to report any VMI, and select appropriate descriptions of the music from a set of predefined terms. The protocol for the study was reviewed and approved by the Technical Faculty of IT and Design, Aalborg University.

Participants

A convenience sample of 135 participants aged 14-73 years (*M*=36.9, *SD*=12.2) who had not participated in our earlier pilot study undertook the survey.

The survey was in English. It was described as being about music listening and emotions, and was distributed through social media (Facebook, LinkedIn) and selected email lists (e.g., Auditory list). We anticipated that participants with an active interest in music would be more likely than others to participate in the study. To increase the likelihood of participation of participants with cultural backgrounds outside Europe and North America we used a snowball-sampling approach by sending the survey to individuals from other regions or with networks in other regions, and asking them to distribute the survey to their networks.

More than 79% of participants reported growing up in Western countries, so the sample was unbalanced with respect to cultural background. Most participants had grown up in Italy and India (both *n*=19), the US (*n*=14), the UK (*n*=11), and Germany (*n*=11). The remaining participants had grown up in other countries in Europe (*n*=35), Latin America (*n*=12), North America (*n*=2), Asia and Australia (both *n*=1), and Africa (*n*=1).

Stimuli

Four 2-min songs were used as stimuli in the online listening test. This duration was chosen as a compromise between making the stimuli long enough to induce emotional responses and VMI, and keeping the test short enough for participants not to be fatigued. A pilot study had shown that two of the songs, Deep Blue Day (DBD, Eno 1983) and Tanca (TNC, Iosonouncane, 2015), were capable of evoking different types of VMI. The criteria for selecting the four songs used in the pilot study were that they 1) did not have words, 2) had different musical and acoustical characteristics in terms of tempo, instruments played, sound textures, and sound effects, and 3) while belonging to the genre of popular music, were likely to be unfamiliar to most listeners. In the pilot study (reported in Stella, 2019) which used a design similar to that of the present study, 52 of 77 participants reported VMI and provided distinctly different descriptions of DBD and TNC respectively. So as to manipulate evoked VMI, the second author composed and used Logic Pro X to produce two new songs, Test Song (TST) and Modified Song (MOD), which shared some of the musical and acoustical characteristics of DBD and TNC. Detailed descriptions and analyses of the stimuli are provided in Supplementary Material A; here we briefly describe their tempo, key, instrumentation, and harmony.

DBD has a tempo of 70 bpm and is in E major. The chord progression starts on B in the initial fade-in and then moves through E, A, E, B, and back to E. The song has a repetitive rhythmic pattern of drums and is characterized by a hall reverb. In the pilot study, DBD was perceived as having a dreamy, calm, and peaceful atmosphere, and many participants described peaceful and bright images.

TNC has a tempo of 95 bpm and is in F minor, although the central chord of the excerpt is C7. In the pilot study, TNC was perceived as having a dark and anxious atmosphere, and many participants referred in their descriptions to some sort of ritual.

TST was composed and produced with the intention of eliciting VMI that would resemble those evoked by DBD. The tempo is the same as that of DBD, although it is in C major with a chord progression that moves through C, F, C, G, and back to C. The structure of the song is almost identical, and it uses instruments with similar timbres.

To check that TST was sufficiently similar to DBD, we played TST to a focus group consisting of four listeners chosen because we knew they were familiar with the work of Brian Eno, and DBD in particular. We asked the participants in the focus group to identify the primary artistic influence on TST. None of them did so directly, but one participant associated TST with three songs, one of which was Running to Stand Still (U2, 1987) produced by Eno and Lanois. Another participant commented that it had the atmosphere of dream pop or bubblegum pop such as Pale Saints and Mogwai. Informed that TST was modelled on DBD, one participant agreed that there was a resemblance between them, primarily in the bass line. Based on the responses of the focus group, we concluded that TST was perceived as having the same characteristics as DBD, but it was not recognised as being a copy.

The first 27 s of MOD are identical to those of TST but from then on begin to incorporate the musical characteristics of TNC. While the melodic line is maintained throughout the song, drone voices, bass, and drums (identified from the pilot study) were added gradually, so as not to shift the structure of the song abruptly. We therefore expected participants' VMI reports for the first 27 s to resemble those associated with DBD and TST. For the remainder of the song, we expected VMI reports increasingly to resemble those associated with TNC, too. We hypothesized that descriptions would start with positive images (e.g., natural elements, bright, pleasant) that would subsequently be disturbed by unsettling elements (e.g., threats, something dangerous approaching), resulting in a combination of VMI evoked by DBD and TNC, for the whole song, representing a somewhat anxious environment.

Measures

Survey. The listening test and questionnaire were created in SoScisurvey (Leiner, 2019) targeting a maximum duration of 15 minutes and prioritizing items and tasks in order of importance (Reips, 2002), based on our research questions. We wanted to know whether participants experienced VMI (*yes/no*) and if so, how they described it. The tasks and questions are detailed in Supplementary Material B.

Responses to rating items from existing instruments were made using visual analogue scales (VAS) provided by the software. For emotional state we adopted the 9-item scale used by Lahdelma and Eerola (2016) including dimensions of Valence, Tension, Energy, Nostalgia/longing, Melancholy/sadness, Interest/expectancy, Tenderness, and Liking of the song. Since it has been suggested that trait empathy may influence experiences of VMI (Vuoskoski & Eerola, 2012), this was assessed briefly using two items from each of the four sub-scales of the Interpersonal Reactivity Index (IRI) (Davis, 1983), each targeting separate components of empathy. We selected 10 items from the Goldsmiths Musical Sophistication Index (Müllensiefen et al., 2014) to assess participants' musical training, for example whether they could identify songs they had heard or sing along with a melody that was played to them. We also included items gauging participants' listening behavior (Kamalzadeh et al., 2012) with respect to active and passive listening (i.e., listening to music for its own sake or during other activities, respectively).

***Card-sorting task**.* All participants were asked to choose and sort cards with a selection of terms. This task was inspired by the product reaction cards found in the desirability toolkit (Benedek & Miner, 2002), which originates from usability testing. Card sorting is aligned with the constructivist approach and particularly to personal construct theory (Kelly, 1955). The theory is based on the premise that people make sense of the world by categorizing it, and that people can describe their own categorization of the world with reasonable reliability and validity (Rugg & McGeorge, 1997).

Participants could choose from the 47 descriptive elements shown in Table 1. Note that these terms did not include verbs, as terms alluding to movement could be associated both with VMI and musical elements such as tempo, rhythm, and melodic contour. Due to the well-established link between motion and music (Godøy, 2003; Leman, 2008) participants could associate terms with either or both, and it would be impossible for us to know from the choice of a card which was intended. We therefore restricted the terms to describe different contexts, qualities, settings, atmospheres, weather conditions and colors/luminance. According to the principle of inclusion, terms such as “In heaven,” “Planet Earth,” and “In the sky” were included because they appeared in the pilot study as reports of VMI for DBD, and “During a ritual,” “Before a war,” and “Around a fire” in reports of VMI for TNC.

Table 1. Descriptive terms used in card-sorting task. On the basis of the pilot study, we assumed that participants who listened to DBD and TST would select more terms marked with * than participants who listened to TNC and MOD.

Category	*Terms for selection*
Nature	On open water,* On the beach,* On a mountain, In the desert, In the forest, In the sky,* In a valley, In heaven,* Planet Earth
Setting (places)	In a car, On a train, In the city, On a ship In outer space,* Inside a confined space, In a tunnel Around a fire, During a ritual, Before a war
Weather	Rainy, Cloudy, Sunny,* Stormy, Warm, Snowy, Foggy, Frozen, Cold, Hot
Color and luminance	Blue,* Green, Red, Yellow, Shiny, Light,* Dark, Contrast
Time of day	Morning, Evening, Afternoon, Night
Quality	Floating,* Peaceful,* Dense, Empty, Opaque, Tribal

Procedure

Participants were asked to take the test in a quiet listening environment. VMI was not mentioned in recruitment material or instructions before the stimuli had been heard. Participants were prompted to use headphones rather than internal laptop speakers, but no further assessment of listening quality or assessment of hearing thresholds was made. To monitor the listening environment, we also asked participants to describe where they were while responding to the survey.

After this setup phase, participants were randomly assigned to listen to one of four songs with the instruction “Please carefully listen to this two-minute song. Feel free to close your eyes if it helps you concentrate.” Participants could play the song again although this was not mentioned in the instruction. At the outset, all four stimuli were equiprobable. After a few weeks this was slightly adjusted to reduce the future probability of hearing the songs that had been played most often, DBD and TNC, to ensure that comparable numbers of participants would listen to each of the four songs. After they had listened to the song, participants were asked first if it was familiar to them and then “Did it make you visualize anything in your mind?” Participants who answered *yes* to the second question were directed to an open-ended form where they were asked to describe the VMI as thoroughly and accurately as they could. Those answering *no* were not asked for any description but redirected to the card-sorting task. After they had sorted the cards and responded to a probe question for familiarity, they were asked an open question about any particular sounds or instruments that may have influenced their choices in the card-sorting task and given the opportunity to listen to the song again, if needed. They then completed the items targeting emotional state, empathy, listening behaviors, and overall musical sophistication. We thanked and debriefed participants on the last page of the survey, telling them that its real focus was on VMI. We asked participants not to retake the test but encouraged them to spread information about the research to their networks without revealing its true objective. Finally, we invited participants to provide comments on the survey and their experience of taking part in the study.

Data analysis

Quantitative analysis. Statistical analyses were performed using R (R Core Team, 2020) and the Psych package (version 2.0.12) (Revelle, 2018). Items measured on VAS were re-scaled so their ranges corresponded to the original Empathy and Musical Sophistication scales. To assess internal consistency and reliability we used coefficient omega, which is considered superior to Cronbach’s alpha in realistic conditions (Dunn et al., 2014; Trizano-Hermosilla & Alvarado, 2016). We obtained ω= 0.88 for scale items related to Musical Sophistication, ω= 0.85 for IRI items for Empathy, and ω= 0.91 for the ratings for Emotion. Negative items were polarity-inverted and when the items measuring Empathy and Musical Sophistication had been combined, the Psych package was used to calculate correlations and estimate confidence intervals. We also used R for omnibus tests such as analysis of variance, or Kruskal-Wallis rank sum tests (when parametric assumptions were not met) and post-hoc tests (corrected for multiple comparisons).

Qualitative analysis. We applied a combined traditional coding (Bjørner, 2015), and content analysis (Küssner & Eerola, 2019, Osborne, 1981) to analyze the participants' reported VMI. The coding included three steps: organizing, content analysis, and interpretation. The first step was to collect and prepare the VMI data for analysis. The data consisted of responses to the question "Did it make you visualize anything in your mind" in the form of statements totaling 552 words. The statements were recorded separately for each song on a spreadsheet and all the nouns, adjectives, and place names were extracted from the statements. The second step was to carry out the content analysis. We did this by assigning the nouns, adjectives, and place names to categories, and counting the frequency with which each word occurred in each category. The third step was interpretation, which involved analyzing the categories and visualizing the findings.

The card-sorting task required both participants who reported and who did not report VMI to select and order the 47 terms shown in Table 1. Because some participants using hand-held devices experienced technical difficulties with ordering, we analyzed only the frequency of the selected terms.

Results

Participant information

Participants generally scored high for musical sophistication, and most reported some active engagement in music-making. While 24 participants reported not playing any instrument, the median was 2 instruments and three participants reported being able to play more than 6 instruments. Twenty-eight participants reported having attended more than 11 live music events 12 months before taking the listening test. Visual inspection confirmed by a Kruskal-Wallis rank sum test showed no systematic differences between the musical sophistication of participants randomly assigned to listen to each of the songs, $H(3) = 2.23$, $p = .51$.

More than half of the participants (53%) reported completing the test at home, in their bedroom, living room, or kitchen. The next highest proportion of participants (37%) were in the office or workplace; the remainder were in a recording studio, taxi, café, airport, shopping mall, train, university, library, outside, or train station. Thirteen percent of participants reported that they were in a noisy location and 11% were in a silent location. Three percent said they were in a relaxed state and 39% said they were alone when they took the test.

Despite random assignment of songs a one-way ANOVA revealed a small but significant effect of song on participants' rated trait empathy, $F(3,128) = 4.56$, $p = .004$, $h^2=.096$. Tukey post-hoc tests showed that DBD listeners scored higher on the eight items from the IRI (Davis, 1983) compared to TCN listeners ($p<.005$), and TST listener higher than TCN listeners ($p=.02$). There were significant correlations between Empathy and ratings of Nostalgia, $r=.71$, CI .46−.85; Interest, $r = .51$, CI .18−.73; Joy, $r = .56$, CI .25−.77; and Affection, $r = .66$, CI .39−.82 (all $p < .001$). Neither listening behavior nor musical sophistication was significantly correlated with any of the other scales we administered.

The time-log of the page showed that the vast majority of participants did not use the possibility to replay the assigned song. Excluding one outlier of 6760 s, the mean length of time spent listening to the song was 129 s (SD 31 s) and the median 128 s. The outlier was one TCN participant who reported listening alone, without recognizing the song or experiencing VMI.

Experiences of VMI

Of the 135 participants, 98 or 73% reported experiencing VMI. A chi-squared test showed that this was significantly higher than chance, $\chi^2 = 27.6$; df = 1; $p < .002$. As shown in Table 2, the groups with the highest numbers and percentages of participants reporting VMI listened to DBD (29/36 or 80.6%) and TNC (28/36 or 77.8%) but there was no significant difference between songs ($\chi^2 = 4.4$; $df = 3$; $p = .22$).

Table 2. Frequencies and percentages of participants who experienced VMI.

Song	Partici-pants	Familli-arity	VMI Yes	VMI No
DBD	36	0	29 (80.6%)	7 (19.4%)
TNC	36	0	28 (77.8)	8 (22.2%)
TST	35	0	21 (60%)	14 (40%)
MOD	28	1	20 (71.4%)	8 (28.6%)
Total	135	1	98 (72.6%)	37 (27.4%)

The content and detail of participants' descriptions of the VMI evoked by each song varied but had some similarities. They included references to scenery, to film, and to the sounds of the music and the instruments that were played. VMI elicited by DBD had a predominantly positive or neutral valence:

> A grand entrance scene by a beautiful young woman (fairy?). The start builds suspense, quickly builds into a high near crescendo (when I can see the camera revealing her face) and then the subsequent rise and fall of the tempo and volume leads me to visualize her walking across a large frozen lake. Don't know why I visualized a frozen lake - could have been a verdant green landscape - but I visualized a frozen white lake. (ID775: DBD, aged 55 from India)

According to another participant: "There is no gravity. I can float. Everything is floating in a dark and empty space. Sometimes there is a light, a flash, like a star. Everything is chill" (ID521: DBD, aged 19 from Italy).

By contrast, participants who listened to TNC often reported scenes with more negative connotations, such as "Mordor and goblins" (ID887: TNC, aged 26 from Greece).

> Initially, scanning across a desert plain with rocky cliffs in the background, as someone rode on a horse. As the noise built, it turned to a battle scene, with swords clashing and canons/gunshots. Later it morphed into a picture of a prison with cell bars being rattled and prisoners shouting riotously. (ID384: TNC, aged 27 from United Kingdom).

Some participants who listened to MOD described VMI in which the valence was mixed or changed, such as "Rolling hills of a countryside with an upbeat and positive tone however turns dark and ominous as it crosses a more mountainous region when there is some impending event." (ID818: MOD, aged 29 from Australia).

Content of VMI

According to the coding and content analysis described above, participants' descriptions of VMI fell into ten categories:

Nature: Phenomena of the physical world generally, including plants and animals as opposed to humans or human creations.

Places and settings: A particular position, location, point, or area. Places or surroundings in which something is positioned, or where an event takes place.

Objects: Material things that can be seen and touched.

Time: A point or description of time as measured, culturally used, or seen.

Movements and events: An act of moving or an event occurring.

Color(s): Sensations on the eye as a result of the way something reflects or emits light, including one, or any mixture, of the constituents into which light can be separated along a spectrum or in a rainbow.

Humans: Any relations to or characteristics of humankind.

Affects: Strong feelings deriving from individuals' circumstances, mood, or relationships with others, and emotional states or reactions.

Literal sound: Visualized sound and music made by objects or humans within the description of the sound imagery, for example "I saw a new age band performing" (ID376: TST, aged 46 from USA), and "I visualize the drums" (ID256: MOD, aged 25 from Germany).

Film: Using the vocabulary of film, references to a story or event recorded by a camera as a set of moving images and shown on film or television.

The codes contributing to each of the categories are shown in Table 3, revealing high frequencies of *Nature* codes (e.g., waves, the sky/clouds, sea/ocean, and mountains) for DBD, TST, and MOD. There were much higher frequencies of *Humans* codes for TNC than DBD, and the codes derived from participants' descriptions of VMI for TNC also had more negative connotations (e.g., slaves, prisoners, warriors, soldiers, riots, and hooligans).

Table 3. INSERT LONG TABLE WITH VMI CODES AND CATEGORIES HERE.

Codes and categories for each category and song with frequency (if >1) given in parenthesis for each code, and total of codes for each category and song in bold.

The distribution of categories is illustrated in Figure 1, showing the numbers of codes contributing to each category as percentages of the total number of words in participants' descriptions of VMI for each song.

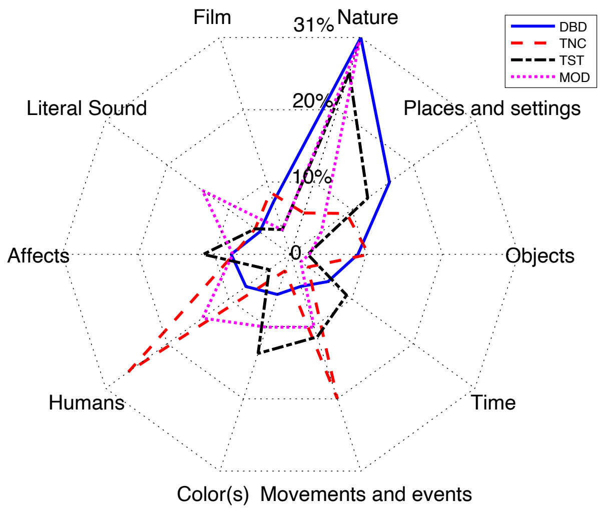

Figure 1. Distribution of categories for each song. Values represent percentages of words included in descriptions of VMI contributing to each category.

All the terms used in the card-sorting task were selected at least once but the frequency with which they were selected differed widely, both overall and between songs. These frequencies are shown in Table 4 for the 10 terms that were most frequently selected by participants who reported experiencing and those who reported not experiencing VMI. While Peaceful was selected by 24 participants who listened to DBD and TST, corresponding to the VMI reported for these songs, it was selected by only two participants who listened to TNC and six who listened to MOD. Tribal, however, was selected by 21 participants who listened to TNC and 14 who listened to MOD.

Table 4. The 10 terms most frequently selected by participants who reported experiencing (and not experiencing) VMI for all songs and for each song. The total number of terms selected is shown in the bottom row.

Category	TOTAL	DBD	TNC	TST	MOD
Quality					
Floating	56	21(4)	0(0)	13(7)	6(5)

Peaceful	56	19(5)	1(1)	19(5)	3(3)
Tribal	36	0(0)	18(3)	0(1)	10(4)
Settings					
During a ritual	41	2(0)	12(7)	1(1)	11(6)
Color and luminance					
Light	36	9(3)	2(0)	9(5)	4(4)
Dark	38	3(0)	17(4)	1(1)	10(3)
Nature					
In the forest	31	4(0)	7(2)	7(4)	6(1)
Planet earth	33	9(1)	2(2)	3(5)	8(3)
Weather					
Sunny	30	11(2)	2(0)	8(4)	2(1)
Warm	36	12(2)	5(1)	7(4)	4(1)
of total selected	1000	277	250	244	229

The distribution of categories in the card-sorting task is illustrated in Figure 2, again showing the number of terms selected as a percentage of the total number of terms for each song. Again, there are clear overlaps between the distributions for DBD and TST. These contrast with the distributions for TNC, with a high prevalence of terms contributing to the *Settings* category, while MOD is characterized by similarities to all three of the other songs.

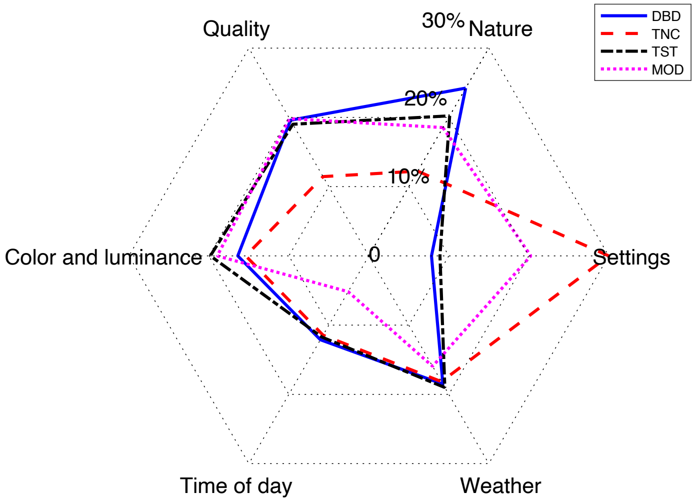

Figure 2. Distribution of chosen terms for the different songs, sorted according to *a priori* categories. Values indicate category-wise percentages of the total number of terms used for each song.

Rated scale items

The highest correlations for rated emotion dimensions were between Valence and Joy, $r = .85$, CI.70−.92; Valence and Tension, $r = −.81$, CI −.91−-.63; Interest and Liking, $r = .81$, CI.63−.90, and Joy and Affection, $r = .71$, CI .46−.85 (all p <.001).

One-way ANOVAs revealed effects of song on participants' ratings for Valence, $F(3,130) = 15.91$, $p < .001$, $h^2 = .27$; Tension, $F(3,130) = 28.11$, $p < .001$, $h^2 = .39$; and Happiness, $F(3,131) = 11.16$, $p < .001$, $h^2 = .21$. Kruskal-Wallis rank-sum tests revealed main effects for Nostalgia $H(3) = 24.12$, $p < .001$, $h^2 = .16$, and Affection, $H(3) = 42.01$, $p < .001$, $h^2 = .30$. There were no significant differences between groups for ratings of Energy, $F(3,129) = 1.89$; Melancholy, $F(3,131) = .79$; Interest, $H(3) = 2.27$; or Liking, $F(3,131) = .63$.

Table 4 shows results from pairwise post-hoc comparison tests, along with the central tendency (mean or median) for each song and dimension. Overall, DBD was rated as more Tender and having higher

Valence than both MOD and TCN, but not compared to TST. While MOD received lower Valence ratings than DBD, it received higher ratings than TCN. Also for Tension, MOD ratings were in between, with lower tension than TCN, but higher than both DBD and TST.

Table 5. Omnibus tests for all emotion dimensions; mean/median for each song and differences.

	Central tendency	Song			
		DBD	TCN	TST	MOD
Valence	Mean	4.12 >MOD,* TCN***	2.53 < MOD,* DBD,*** TST***	3.93 >TCN***	DBD*> 3.35>TCN*
Tension	Mean	1.77<MOD,*** TCN***	3.83>MOD,** TST,*** DBD***	2.00<MOD,** TCN***	DBD,*** TST** <2.93<TCN**
Nostalgia	Median	3.3>MOD,* TCN***	1.32<TST,** DBD***	3.48>TCN*	1.94<DBD*
Happiness	Mean	3.24>MOD,* TCN***	1.92< TST,*** DBD***	2.98>TCN***	2.52<DBD*
Tenderness	Median	3.36>MOD*, TCN***	1.24<DBD,*** TST***	2.84>TCN***	2.46>TCN*

* *p*<.05; ***p*<.01; ****p*<.001 All *p* values corrected with Bonferroni adjustment for multiple testing.

Figures 3 and 4 display the (rescaled) ratings of Tension and Valence from participants reporting (blue) and not reporting VMI (yellow). Overall, the ratings of participants not reporting VMI are in line with that of those that did. Tension was rated higher and Valence lower for TNC by both groups of participants.

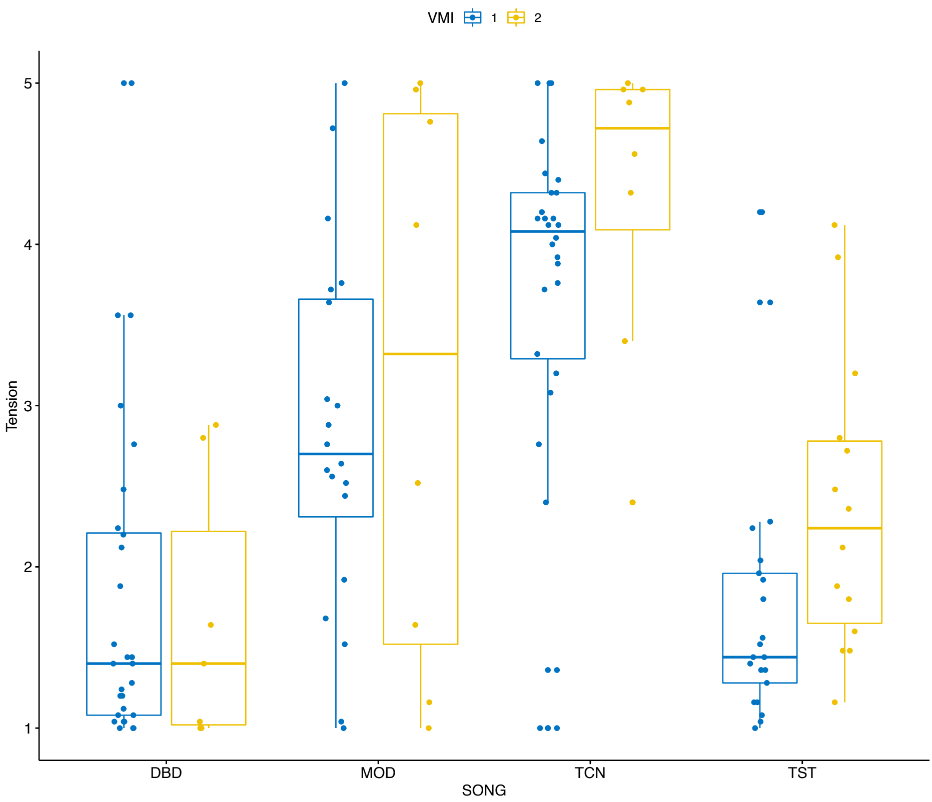

Figure 3. Ratings of Tension for the four songs by participants experiencing (blue) and not experiencing VMI (yellow).

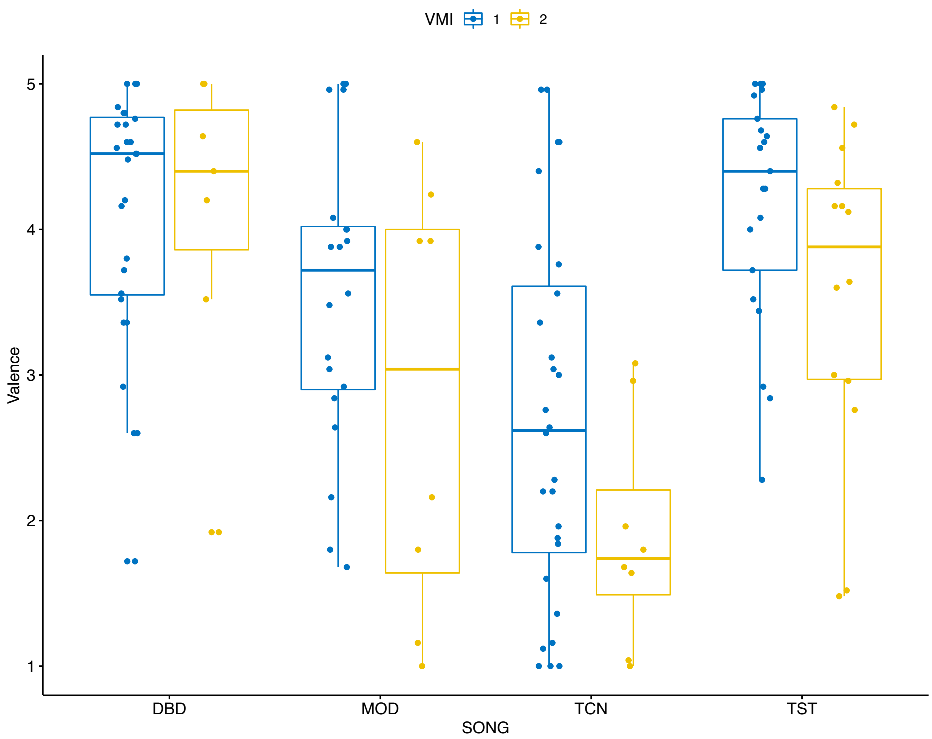

Figure 4. Ratings of Valence for the four songs by participants experiencing (blue) and not experiencing VMI (yellow).

Discussion

The objective of this exploratory study was to investigate the frequency and content of VMI elicited by music chosen and composed with specific musical and acoustical characteristics in mind (see stimuli and Supplementary material). We here discuss our results with respect to our research questions. Regarding RQ1, the majority of listeners to all songs (60-81%) reported VMI, which is higher than reported by Osborne (1981), but on average a bit lower than later work (77%, Küssner & Eerola, 2019; 80% Vuoskoski & Eerola, 2015). Considering that Küssner and Eerola (2019) asked about participants' general (previous) VMI experience, and Vuoskoski and Eerola (2015) promoted VMI by providing narratives, our results seem to align with their findings.

Coding and content analysis of their descriptions of VMI also produced categories aligned with those reported previously (Day & Thompson, 2019; Martarelli et al., 2016; Osborne, 1981; Presicce & Bailes, 2019; Taruffi et al., 2017; Hashim et al., 2021). Regarding RQ2, the data revealed effects of the sound and musical structure on VMI reported, as well as on how listeners rated the emotional dimensions for each song. VMI for DBD, TST, and MOD frequently referred to *Nature* while VMI for TNC referred most often to *Humans*, and *Movements and events* (see Figure 1 and Table 3). There were significant effects of songs on several of the emotion dimensions. For ratings of Tension and Valence, DBD and TST were rated as happier, having more positive valence, and less tension than did TCN and MOD. These results indicate that the composed songs were perceived as intended.

Regarding RQ3, the codes and themes from reported VMI indicate that the same musical characteristics evoked similar VMI in different listeners (Table 3). For instance, codes referring to water were more frequent for DBD and TST than TCN. The results of the card-sorting task confirmed that, to a considerable extent, different listeners agreed on the use of similar terms for the same song. The emotion dimension ratings were also in line with our assumption that compositions with similar musical and acoustical characteristics would influence listeners' VMI and associations for TST and MOD.

It should be noted that the stimuli in this study were relatively simple with less melodic complexity than many stimuli used in earlier studies. The songs conveyed what might be described as atmospheres, sometimes calm and sometimes tense or anxious (cf. Markert & Küssner, 2021). Although there were no differences between participants' ratings of the Energy of the four songs, there were differences between the ratings of Valence such that those for DBD and TST were more positive than those for TNC. Although reported VMI for the four songs aligned with these ratings and our expectations, we have no way of knowing whether VMI is the result of the listener modelling the state or intention behind the music (Leman et al., 2018) or, for instance, emotional contagion leading to a particular kind of engagement with the music (Day & Thompson, 2019; Presicce & Bailes, 2019).

While we avoided alluding directly to movement in the descriptive elements used as terms in the card-sorting task (see Table 1), descriptions of VMI frequently included references to *Movements and events* (see Table 3 and Figure 1). Thirty-five codes contributed to this category for TNC, in particular, with battle (8), ritual dance (6) and dancing (4), occurring most frequently. No doubt the clear rhythmic characteristics of the song played a role here. However, all four songs elicited descriptions of VMI that mentioned dancing and locomotion. This indicates that action-perception coupling arising from the rhythmic movement of sonic forms (e.g, the side-chained bass in TCN and drums in MOD, see Supplementary material A) is translated into an everyday repertoire of human movement (Leman, 2008; Leman et al., 2018), such as a "breathing" or "pumping" effect. Such rhythmic use of side-chain compression is common among electronic dance music producers (Brøvig-Hanssen et al., 2022). Similar translations are likely to occur with some of the other sonic forms present in the songs (Godøy, 2003; Godøy & Leman, 2010).

Several earlier studies that we have cited deliberately selected music associated with high- or low-valence emotions, such as happiness and sadness, and many used predominantly Western art or film music (some exceptions being Osborne 1981; Herff et al., 2021; and Taruffi, 2021). Emotional music can influence the meta-awareness (Taruffi et al., 2017), valence, and vividness of VMI, thereby affecting relaxation, liking (Martarelli et al., 2016), and aesthetic appeal (Belfi, 2019). In previous research, survey data suggested that music can be used for its soothing and relaxing effects (Küssner & Eerola; Vroegh, 2019), but an alteration in an individual's state of awareness or level of absorption is not necessarily attributable only to music that has a clearly positive or negative valence. It can thus be assumed that much of the music that we listen to and that evokes VMI is not just happy or sad.

To the best of our knowledge, ours was the first study in which the characteristics of songs in the genre of popular music were manipulated in a between-group design, thus removing the risk of order effects on the VMI experienced by individuals. TST was composed and produced with the aim of eliciting VMI similar to those evoked by DBD, and MOD combined the musical and acoustical characteristics of both DBD and TNC; these new stimuli permitted us to compare participants' responses to distinctly different songs. While our manipulation was successful in eliciting the kinds of descriptions of VMI that we expected, our new stimuli were not comparable to professionally produced songs, as was pointed out by some participants.

The study also had some limitations. Because we used an online survey format, we could not control participants' age or listening environments. Adolescents and adults may have differed with respect to VMI and mind-wandering (Herbert & Dibben, 2018; Maillet et al., 2018). We did not observe any systematic differences between younger and older participants in our study. Only one participant was younger than 18, who described the VMI as "tribal ritual" (ID627: MOD, aged 14, Italy), which was in line with other MOD reports. Another potential bias was that participants could listen to the song multiple times. Also, we could not know whether participants closed their eyes while listening or if they were distracted by carrying out other tasks. While more than half of the participants reported taking the survey at home, only 3% indicated that they were in a relaxed state before listening to the song. Thus, different states of relaxation could also have affected Tension ratings.

While online surveys can be distributed widely, it can be difficult to maintain participants' engagement with them. In this exploratory study, we wanted to collect data on participants' listening behaviors, trait empathy, and musical skill, while avoiding the difficulties of recruiting participants to a lengthy experiment. Since only a few items from the scales measuring trait empathy and musical sophistication were used, the results cannot be directly compared to those of previous studies or interpreted with the same level of confidence. We acknowledge that the truncated scales may have produced data less valid than those that would have been obtained from the original scales, although generally the use of truncated scales can still reveal potential differences between groups. As exemplified by the detected differences in empathy responses between groups, unintended systematic differences can occur even with random assignment of songs. The results of the present study should therefore be interpreted with caution. The effect size was small, but individuals with high trait empathy have been reported to experience stronger VMI (Vuoskoski & Eerola, 2012) and this might have contributed to higher VMI reports for DBD (Table 2).

Like several earlier studies, the present study mostly relied on self-reports of post or recall VMI and, while these were necessary for us to gain access to participants' VMI, this approach has clear limitations (Taruffi & Küssner, 2019). Music-evoked VMI can be very difficult to measure, as it is difficult for the participants to articulate everything they see (Kahneman et al., 1999). This means that researchers are provided with a selected and limited understanding of the actual VMI. Also, participants may not have the vocabulary to provide verbal descriptions of VMI. Presicce & Bailes (2019) reported that some of their participants found it easier than others to rate their experience of VMI or describe its content. Our participants, too, varied in the amount of detail they provided. The card-sorting task was particularly valuable for countering this limitation. Although the terms available could not fully describe participants' experiences of VMI they provided a basic vocabulary that enabled us to compare (albeit crudely) participants' imagery for each song. To echo Taruffi & Küssner (2019), the shortcomings of self-reports should be addressed in future research. For example, participants in a lab-based study could be screened in advance for trait empathy. Such a study would control for age and listening environment, use continuous psychophysiological measures, and collect think-aloud protocols to monitor participants' mind-wandering. Future studies could also include musical excerpts designed in such a way to mix the order in which musical and acoustical characteristics are introduced and varied (e.g., a song starting with TCN characteristics and ending with DBD).

To conclude, the present work has replicated the prevalence of spontaneously occurring VMI from earlier studies and shown how musical and acoustical characteristics can evoke visual imagery with shared associations.

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Supplementary material

A. Music Stimuli

Deep Blue Day (DBD)

The excerpt from Brian Eno's Deep Blue Day (1983) starts at the beginning and fades out at 2:04. Figure 5 shows the spectrogram of the song, where the repetitive drum pattern of the drums is noticeable along with the reverberant synthesizer patch that characterizes this song and elicits a floating sensation.

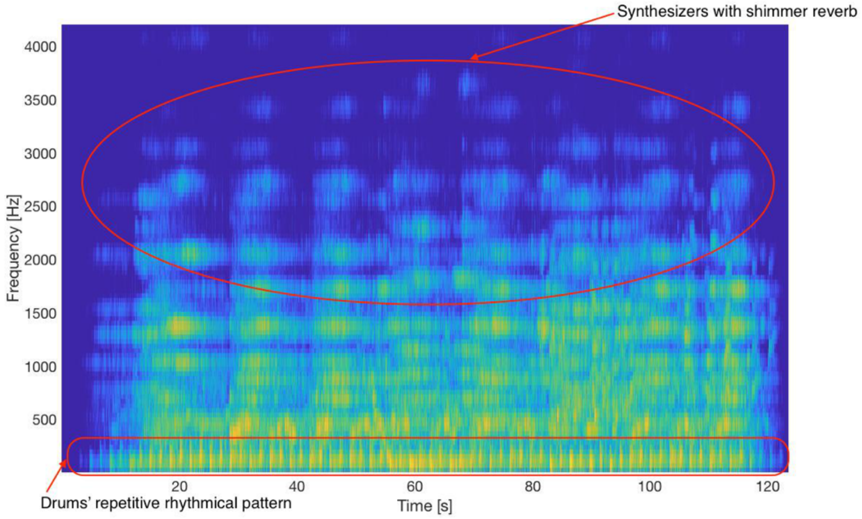

Figure 5. Spectrogram of Deep Blue Day.

0:00-0:28 At the start of the song, all background instruments are faded-in. The synthesizers are first audible, followed by the rhythm guitar, bass, and a set of muffled-sounding drums. The rhythm is calm and peaceful, and the bassline alternates between the dominant and the 5th of the ongoing chord. The spatial image of the synthesizers occupies most of the stereo panorama.

0:29-1:22 The steel guitar riff begins whilst all the background instruments continue playing. The riff consists of an ascending major scale phrase whose last note the same as the first.

1:22-end The lead steel guitar is introduced. It has a brighter tonality than the one playing the riff, and plays a different, non-repetitive melodic part.

1:58-end The background instruments slowly start fading out, shortly followed by two steel guitars.

Tanca (TNC)

The excerpt from Iosonouncane's Tanca (2015) also starts at the beginning and fades out at 2:03. The spectrogram is shown in Figure 6, which illustrates the different instruments that are gradually added to the music.

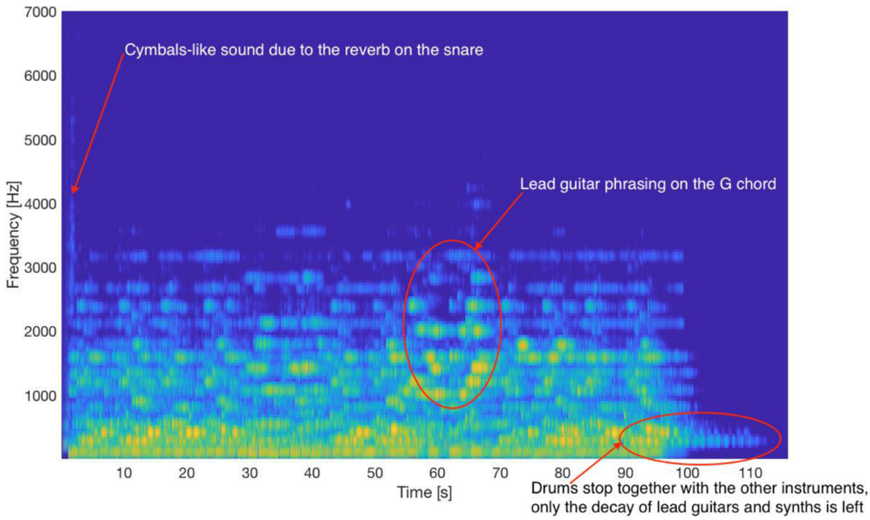

Figure 6. Spectrogram of Tanca (TNC)

0:00-0:40 the song starts with two low-pitched voice drones, resembling chanting monks, which are respectively panned left and right. Next, the drums start with a regular rhythm that plays together with a sidechain-compressed bass synthesizer that 'breathes' with the bass drum. At 0:14 a wood-based percussion instrument doubles the drum rhythm, adding higher frequencies to the rhythm section. At 0:23 another midrange frequency percussion instrument is added to the mix, introducing another rhythmic layer that is panned to the right.

0:41-0:48 Non-pitched percussion resembling clashing metal or seashells, start playing with no specific rhythmic pattern. At 0:43 a clean guitar plays single slide notes closer to the neck.

0:49-1:19 A layer of humans shouting and clamoring that has no recognizable pattern is added.

1:20-1:44 A synthesized high-pitched voice drone starts playing, introducing new rhythmic and melodic content. Together with the voices the clashing rhythmic elements intensify and build tension, with some of the higher-frequency entities alternating between the left and right channels.

1:44- end A Hammond organ-like sound starts playing accentuating the tension.

Test Song (TST)

- The *rhythmic elements* (rhythm guitar, bass, drums) were kept similar to the original song, to prevent its induced VMI from differing too much from DBD. The rhythm guitar is distorted and reverberant. The bass is equalized so that most of its upper harmonics are greatly attenuated. The bass line alternates between the dominant and the 5th of the chord played by the guitar. The drums have a “muffled” sound resembling DBD.

- The *synthesizers* sounds are lush and sustained. They were recorded using Ableton Live native synthesizers. The goal was a sound texture resembling the hall reverb characteristic of DBD. One synthesizer has a piano/glockenspiel-like sound, whilst the other one plays the same notes in a more diffuse sound with gradual attack time and bright tonality. Both synthesizers play notes in the C major scale in no specific pattern.
- The *lead electric guitar* sound (that was replicating the steel guitar) has a long attack time and featured considerable high frequency content due to an octave-doubling effect, followed by reverse delay and a plate reverb effects. The reverse delay time is quite short, while the plate reverb has a long decay. This contributes to the shimmery and watery sonic texture that reminds one of DBD. The lead guitar tone was blended with that of the diffuse synthesizers. The lead guitar follows a mostly ascending melody line in the major C scale.
- A reverberant overdriven guitar accentuates the melodic line and stresses the ascending phrase.

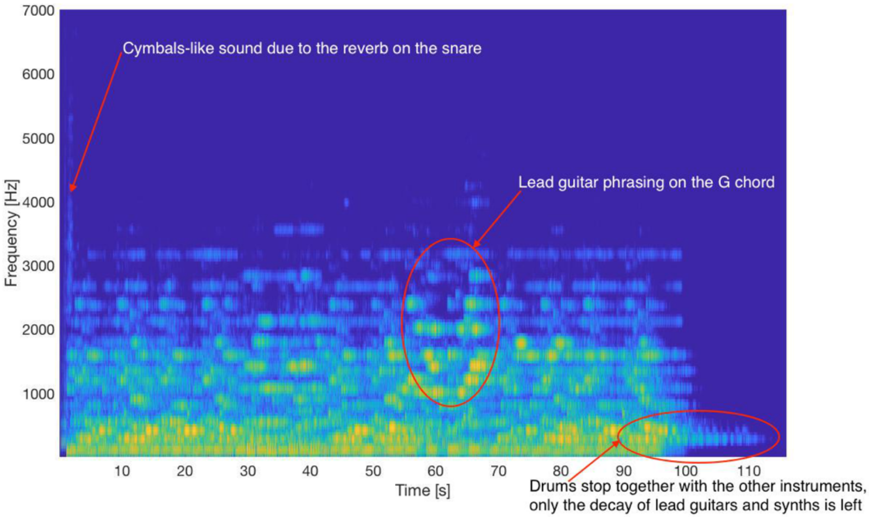

Figure 7. Spectrogram of TST.

Figure 7 shows the spectrogram of the Test Song.

0:00-0:28 The song begins with four snare hits patched to two separate characteristic reverbs whose returns are hard panned to opposite ends of the stereo field. The first one creates a cymbals-like sound, while the second sounds like a pad synthesizer. Thereafter, all drums are low-pass filtered to attain the ”muffled” effect heard in DBD. When all the instruments start, the most discernible ones are the smooth bass, the lead guitar, and the synthesizers. The rhythm guitar plays more of a backing role.

0:28-0:40 There is a chord transition from C to F, but the rhythmic structure stays unchanged. Around 0:39 the lead guitars deviate slightly from their ascending progression without leaving the C major scale.

0:41-1:08 The harmonic progression returns to the C chord until 0:55, where it moves to G. Here, the lead guitars deviate once again from their ascending line (characteristic of DBD), creating some variation iin the melodic pattern.

1:09-1:36 There is a chord transition back to C and all the instruments return to playing the same notes as they did at the beginning.

1:37-1:56 The drums stop and the amplitude envelopes of all the instruments begin to naturally decay. The synthesizers and the clean lead guitar are more evident than the others as they have long decay time.

Modified Song (MOD)

MOD combined characteristics of DBD and TNC. Therefore, the first part of the song is identical to TST, but from 0:27, elements characterizing TNC were added. According to the pilot test responses, these were drums, the drone voices and the bass synthesizer. Specifically:

- Two opposite-panned drone voices were created using the XS24 sampler in Logic Pro X. The notes sung are low-pitched, ‘growly’, long and sustained.
- Drums were also arranged using the XS24 sampler with an extra kick drum layer for greater emphasis. The drums follow a very simple rhythmic pattern throughout the song.
- The bass sound was created using layered Logic native synthesizers and equalized to attain a full, ‘fat’-sounding, gritty, and deep tonality, with notes that could be sustained for very long without losing character.

- Ethnic percussion kits native to Logic Pro were used. Various tambourines were chosen to resemble the clashing seashells sound in TNC. The presence of different percussive instruments, following different rhythms than the main beat of the drum beat also gives the impression multiple performers. This served to complement the human shouts present in TNC.

The drum track was sidechained to the other non-percussion tracks, to reproduce the “breathing” effect heard in TNC.

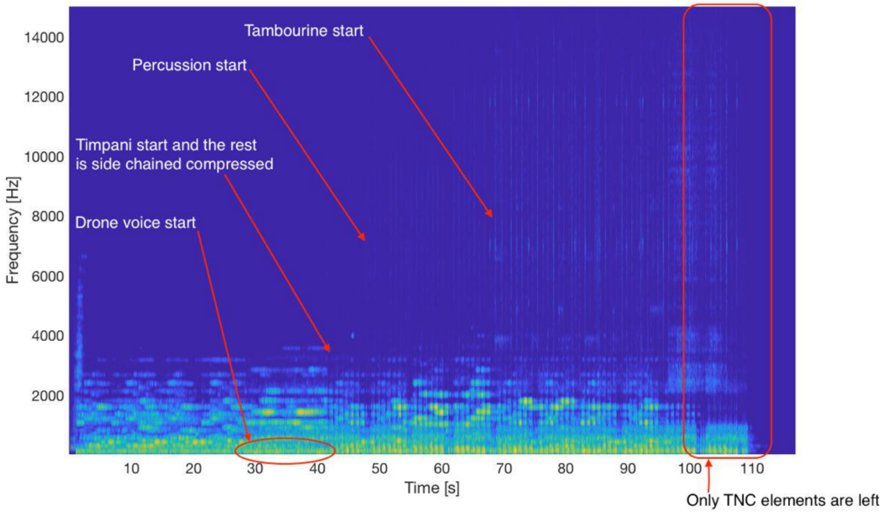

Figure 8. Spectrogram of MOD.

Time analysis of MOD

Figure 8 shows the spectrogram of the Modified Song.

0:28-0:40 Drone voice starts on the left side starts, slightly sooner than the one on the right, and they both start with a C note over an F chord. C is the 5th of the F chord (F A C), but the note is sustained, the resulting sensation is unpleasant.

0:41-0:47 The drums start together with the bass synthesizers. The bass synthesizers play notes present in the chords of TST but alternates them with notes a semitone higher or lower. This resembles TNC while simultaneously creating tension through dissonance (Peretz, 2008). In this section, the chord in TST is C and the bass synths play C and C#. The drone voices follow the bass synthesizers with alternating C and C# notes.

0:48-0:55 Percussion starts.

0:55-1.07 The harmonic progression switches to the G chord while the bass synthesizers and the drone voices play D and C#.

1:08-1:41 There is a TST chord transition back to C. Tambourines begin reinforcing the higher frequency bands of the song spectrum.

1:42-1:57 All the TST elements fade out (freeing up the mid-range) and only TNC elements remain.

Questionnaire items

Q1 How old are you? [open]

Q2 In what area did you grown up (e.g.,” North of Italy”, ”South of Stockholm”)? [open]

Q3 Where are you now? Please write 3 to 10 words to describe the context in which you find yourself at this moment when you are taking the survey (e.g., in a noisy cafe, alone in my´ living room, on a train). [open]

Instruction: Please adjust the volume of your headphones or speakers to a comfortable level by playing this test audio.

Instruction: Please carefully listen to this two-minute song. Feel free to close your eyes if it helps you concentrate.

Q4 Was this song familiar to you? [yes/no]

Q5 When listening to the music, did it make you visualize anything in your mind? [yes/no]

Q5 What did you see? Please describe as best and detailed as you can what you did see. Answer as truthfully as you can. There are no right or wrong answers. [open]

Q6 Please select the words you think best describe a scene or setting that could fit the music you heard. [card selection]

Q7 Did you take part in the pilot test that took place in December 2017? [yes/no/not sure]

Q8 Were there any particular sounds/instrument in the song that made you link to the words you picked? Why? [open]

Instruction: Please click the slider so that it corresponds to how you feel when hearing the song. [visual analogue sliders]

Q9 What type of feeling does the song make you feel? [Positive - Negative]

Q10 How calm or agitated does the song make you feel? [calm/relaxed - tense/agitated]

Q11 How strong or weak does the song make you feel? [strong/energetic - weak/feeble]

Q12 How much nostalgia, wistfulness, or longing does the song make you feel? [not at all - very much]

Q13 How much melancholy or sadness does the song make you feel? [not at all - very much]

Q14 How much interest does the song awake in you? [not at all - very much]

Q15 How much happiness or joy does the song make you feel? [not at all - very much]

Q16 How much tenderness and affection does the song make you feel? [not at all - very much]
Q17 How much did you like the song? [not at all - very much]

Instruction The following statements inquire about your thoughts and feelings in a variety of situations. For each item, indicate how well it describes you by choosing the appropriate value of the scale. [visual analogue sliders]

Q18 -25 Items 1,3,8,15,19,26,28, and 43 from (Davis, 1983). [not at all - very much]

Q26 How many hours do you passively listen to music per week? Passive listening is here defined as listening to music during other activities. [choices less than 1 - up to more than 15]

Q27 What activities do you conduct while passively listening to music? [click all that apply, options including “Other (please specify)”]

Q27 How many hours do you actively listen to music per week? Active Listening is here defined as listening to music for the sake of the music itself, with listening your central task and not doing other activities. For instance, attentive listening to recorded music, concerts, or playing music. [choices less than 1 - up to more than 16]

Q28 Where do you usually actively listen to music? [click all that apply, options including “Other (please specify)”]

Instruction: How musical are you? Answer to every statement by clicking on the line between the two extremes closer to the answer you feel more accurate for yourself.

Q29-35 Selected items from GMSI scales Active Engagement, Perceptual, Singing, Musical Training, and Emotions

Q36 I have attended approximately this amount of live music events as an audience member in the past 12 months. [choices 0 up to 11 or more]

Q37 I can play this number of different musical instruments: [choices 0 up to 6 or more]

Q38 The instrument I play best (including voice) is: [open]

Table 3. Codes and categories for each category and song with frequency (if >1) given in parenthesis for each code, and total of codes for each category and song in bold.

Theme	DBD	TNC	TST	MOD
Nature	Waves (7), sky (5), clouds (4), trees (4), sea (4), grass (4), breeze (4), water (3), Forest (3), mountains (3), lake (3), hills (2), stars (2), sun (2), river, waterfall, ocean, horizon, nature **Total: 54**	Fog (2), jungle (2), wind (2), clouds, water, forest, cliffs, desert, caves **Total: 10**	Stars (5), clouds (3), Sea (2), sky (2), ocean, mountains, the earth, forest, lake, river, waves, nature, leaves, trees **Total: 22**	Sea (4), mountain (3), fog (3), nature (3), trees (2), storm (2), ocean, woods, mist, hills, rocks, water, seaweed, fish, sand, flowers, sun, desert, cave, forest, shrubbery, hares, forest, animals **Total: 35**
Places and settings	field (7), beach (6), countryside (6), America (2), Hawaii (2), tropical, landscape, high school prom, party, supper, dining **Total: 29**	Camp (2), prison, arena, Mongolia, pub, port, football stadium, field, street, space, village, central Asia, open landscape, restaurant **Total: 16**	Space (2), beach (2), field (2), Stockholm, shore, Café del mar at Ibiza, oriental city, street **Total: 11**	Tunnel (2), Night club, supreme court, monastery, countryside **Total: 6**
Objects	guitar (3), Lights (3), dress (2), disco-ball (2), cars, gold, fountains, pina colada, roses, teacup **Total: 16**	Fire (6), weapons (2), swords (2), armours, canons, cell bars, shaman's tent, glass bottles, metal, saddles, wood. **Total: 18**	Silk scarves, broken tape record, **Total: 2**	Fire, rope, sports gear **Total: 3**
Time	summer (4), sunset (2), sunrise, evening, morning, spring, afternoon **Total: 11**	Night (2), past centuries, mediaeval, ancient **Total: 5**	Summer (3), spring, evening, sunset, television news, Christmas **Total: 8**	Sunrise, spring **Total: 2**
Movements and events	walking (3), dancing (3), running, riding horses **Total: 8**	Battles (8), ritual dance (6), dancing (4), fighting (3), combat, war, riding horses, marching, belting, executing, moving, walking, sweeping grass, rowing ship, feeding coal, monitoring, pow-wow **Total: 35**	Floating (3), dancing (2), flying (2), walking, marching, funeral march **Total: 10**	Running (3), dancing (2), rituals (2), impending event, tribal ritual, desk working, computer gaming, diving **Total: 12**
Color(s)	Green (5), blue (2), orange, yellow, dark **Total: 10**	Dark (3), shiny silver **Total: 4**	Black (3), blue (2), dark, gold, swirling lightning, white, pink, neon, grey **Total: 12**	Black (3), dark (3), blue (2), white, spring colors, Disco lights, hallucinogenic colors **Total: 12**
Humans	woman (3), girl (2), face (2), boy, young, eyes, teens, hair, curls **Total: 13**	People (6), slaves (5), singers (5), warriors (4), Vikings (2), tribe (2), men (2), soldiers (2), guards, aboriginals, prisoners, loser, population, sadist, female, Jews, witch doctor, pirates, sailors, hooligans, band, Maori people,	People (2), long-haired performer **Total: 3**	People (6), man (3), tribal (2), Mongolian monks, naked, upper bodies, woman, hair, feet, vein **Total: 17**

		Native Americans, Mongolian, riots, workers **Total: 46**		
Affects	memories (3), feeling (3). peace (2), happy (2), calm, warm, innocent, energy. **Total: 14**	Trance (2), angry (2), darkness (2), hunger, danger, unhappy, afraid, scary, anxiety, threatening **Total: 13**	Relaxed (3), calm (2), alone (2), dreaming, tender, dreamy atmosphere **Total: 10**	Troubles (2), fateful, epic, content, relieved, joyful, serene, dreaming **Total: 9**
Literal sound	sound (6), music (3) **Total: 9**	Drums (4), gunshots, singing, harps, music, sound, instruments **Total: 10**	Instruments (2), electric bass, birds, new age band, **Total: 5**	Singing (3), drums (3), music playing (2), tambourine (2), chants (2), growling, instruments, pop music, bass, heartbeat **Total: 17**
Film	camera (3), scene (2), cowboys (2), western movie, entrance, movie, zombies, aliens, slow motion **Total: 13**	Scene (6), apocalyptic scene (2), night scene, soundtrack, film, Gladiator, setting, monsters, Mordor **Total: 15**	Tropical island scene, blurry effects/ filters, magical creators **Total: 3**	Documentary, Game of Thrones, Lord of the Rings, scene **Total: 4**