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Recognition memory in movie scenes: the soundtrack induces mood-coherent bias, but not through mood induction

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ABSTRACT
Several studies have employed music to affect various tasks through mood induction procedures. In this perspective, music's emotional content coherently affects the listeners' mood, which, in turn, affects performance. On the contrary, in film music cognition, schema theories suggest that music adds semantic information that interacts with the viewers' previous knowledge and influences visual information processing. As in this interpretation the viewers' mood is not deeply considered, it is not clear the extent to which music effects are also due to its power of affecting the viewers' mood or rather a mere cognitive priming-like influence. An experiment ($N =$ 169) on how music biases the recognition memory of a scene was built comparing semantic and emotional effects of soundtracks differing in valence (happy vs scary) during a recognition task. The results show that 1) music affected the viewers' mood coherently with its valence, 2) music led to falsely recognise unseen objects as truly present when coherent with the soundtrack valence; and 3) the effect of music on the biased remembering was not mediated by the viewers' mood, thus suggesting a strong interpretation of the schema theory in film music processing. Finally, a methodological reflection is provided on the issue of the manipulation check in experiments that employ musical stimuli to assess their influence on cognition.

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Introduction

It is widely known that music has the power to affect one's affective state. Indeed, not only did a massive number of studies prove significant changes in mood in dependence of different kinds of music, but the music itself is the core of several mood induction procedures (Ribeiro et al., 2019), the most cited one being the Musical Mood Induction Procedure (Västfjäll, 2001). More recently, it has been proposed that, beyond moods, music can evoke specific emotions[1] (Juslin et al., 2010).

Comparably, films and stories have traditionally been employed for mood induction (Gross & Levenson, 1995) with effective results (Westermann et al., 1996).

Nevertheless, when we sit in a movie theatre watching a movie, we cannot experience the influence of the music and images on our mood as separated; on the contrary, several processes come into play simultaneously. A movie scene, like every audiovisual, is a complex stimulus made of a variety of parts. For instance, according to the last version of Cohen's Congruence-Association model (Cohen, 2013), an audiovisual is made of at least six distinct parts (i.e. text, speech, visual, music, sound effects, kinesthetic) that, together with the expectations and the story grammar stored in our long-term memory, contribute to creating a working narrative of the film, namely the conscious experience of the film. Things are radically complicated because these parts continuously create

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[1]A specification on the use of the terms *mood* and *emotion* throughout the paper: when we deal with the induction paradigm, we always use the term *mood*, as this is what music is certainly able to induce: a vague and rough mood, positive or negative, very seldom a precise emotion. When we refer to more detailed emotional nuances represented by the music (as in the case of the soundtracks that we used: scary vs. happy), we use the term *emotion*. An emotion can surely be represented by the music, but fairly rarely induced. More specifically, many pieces of music are representative of certain emotions that can be conveyed and decodified via psychoacoustic cues (Eerola et al., 2013; Quinto et al., 2014).

dynamic interactions among them. Soundtracks have a pivotal role in building the working narrative of the film; indeed, they have been proved to substantially affect the parasocial interaction of the recipients with the characters on the screen (Ansani et al., 2020; Hoeckner et al., 2011), characters' moral judgments (Steffens, 2020) and personality traits (Ansani et al., 2020; Bravo, 2013), plot anticipations (Shevy, 2007), the perception of the environment (Ansani et al., 2020; Yamasaki et al., 2015), time perception (Ansani et al., 2021), and, most notably to the present of the current study, the subsequent remembering of the scene (Boltz, 2001; Boltz et al., 1991).

The question of whether and how music affects memory is far from being answered univocally; on the contrary, a multiplicity of theoretical frameworks and experimental paradigms exist that might be considered. A harvest of studies has focused on the theme; nevertheless, Kämpfe et al. (2011) and Nguyen and Grahn (2017) conclude that background music might produce only minor detrimental effects on memory or no effects.

Additionally, things become more complex when adding a third component to the dyadic relationship between music and memory: the mood evoked or represented by music.

Mood and memory

Several studies during the 80s have deeply investigated how mood impacts memory. If it is impossible to sum up all the theoretical frameworks that have been proposed during the years (for a review, see Forgas & Koch, 2013), just a few notes need to be mentioned on some models on the phenomena that more or less straightforwardly prove whether and how mood influences memory. For starters, Foa and colleagues (1989) summarise the three main hypotheses at hand: the first one is the *mood state dependent hypothesis*, claiming that when the mood at encoding and recall is the same, memory retrieval is higher than when they are different. The second one is the *encoding mood-congruent hypothesis*, according to which information semantically related to mood at encoding is retrieved more readily than information unrelated to mood at encoding. Lastly, the third hypothesis is the *recall mood-congruent* one, which proposes that information semantically related to mood at recall is retrieved more readily than information unrelated to mood at recall. Although Foa and colleagues (1989) did not find evidence for any of these three hypotheses, other researchers succeeded. For instance, Teadsale and colleagues (1980) found that people in a depressed mood were more likely to remember sad memories than happy ones, and similar results were also found through hypnosis procedures (Bower, 1981). Another tradition of studies exploited word retrieval procedures, finding that while experiencing a negative mood, people tended to remember a greater number of words related to negative more than happy personality traits (Bradley & Mathews, 1983) or negative more than happy words in general (Knight et al., 2002).

To conclude, two memory effects seem to be relevant to explaining the influence of mood on memory: one is the mood congruence effect – we are in a negative mood, and we tend to remember the worst things of our lives; the other is the mood dependence effect – we tend to remember some memories better when the mood at encoding and retrieval are coherent.

But are there mood-related memory effects in audiovisual stimuli such as movie scenes?

Audiovisual stimuli: music, mood, and memory

Over the last decades, there has been a heated debate on the relationship between music and memory in film and television. Much of the debate belongs to humanities and psychoanalysis (Nagari, 2015); notwithstanding this, lately, a growing number of psychological studies have paved the way to a new and more empirically grounded way of addressing such a topic. A tradition of studies has insisted on the retrospective memories of scary and romantic movies (Harris et al., 2004; Valkenburg et al., 2000) and mass media presentations (Cantor, 2008); another direction of the studies on soundtrack and memory is devoted to more contingent phenomena, such as the congruency between the visual and auditory contents of the scene (Cohen, 2013). Such a congruency can be formal or semantic. Formal congruency might be considered a physical phenomenon at its greatest level when audio and video are synced; this is what happens when viewing a ball bouncing while hearing the sound of its bouncing right as it should be.

Semantic congruency, on the other hand, is about meanings; that is, music and images convey similar contents from the emotional perspective. For instance, Boltz and colleagues (1991) showed that the visual content was better remembered when the soundtrack accompanying a scene was congruent with its outcome. Conversely, incongruent music in a foreshadowing condition led to a higher remembering of the scene, even more when the outcome was negative.

Such results clarify that music is far from constituting a mere emotional accessory of the scene; conversely, it provides a proper frame and priming helpful to the recipients' process of building and shaping a narrative interpretation.

Furthermore, music's influence on memory is not confined to soundtracks and movies; it involves other visual stimuli and face processing. For instance, through a face recalling task, Woloszyn and Ewert (2012) proved that happy faces were more likely to be remembered as sad when a sad piece was played during the encoding, while the opposite happened for sad faces with a happy piece in the background. With a similar experimental protocol, Kamiyama et al. (2013) found that incongruencies between facial expression and background music elicited a larger N400 component than congruent pairs (facial expression / musical mood). Coherently, through an ERP analysis with paired emotional sounds and pictures, Gerdes et al. (2013) found that emotional sounds modulate the early stages of visual processing. Other studies found that emotionally touching music increased correct facial recognition (as opposed to rain sound or silence) (Proverbio et al., 2015a, 2015b), thus leading to the interesting hypothesis that "listening to emotionally touching music leads to an emotionally-driven audiovisual encoding that strengthened memory engrams for faces, whereas listening to either rain or joyful music produced interfering effects by overloading perceptual channels during face encoding" (Proverbio & De Benedetto, 2018, p. 165). We will return to this hypothesis in the following paragraphs because, given its relatedness to the main object of the current study, we plan to test it (see H_2).

All these findings suggest a close kinship between auditory and visual processing in memory processes. Furthermore, if the results of Woloszyn and Ewert (2012) suggest an apparent distortion effect of the recall due to the background music in the encoding phase, with the present study, we want to raise the bar by checking a further hypothesis, namely that music can bias our memory, and not necessarily due to a mood. In other words, we claim that under the right circumstances, with proper manipulation of a scene, a recipient can be misled and report to have seen absent objects or characters that are coherent with the musical mood.

Something similar had already been proposed by Boltz in a long-term memory task (2001), although with some differences. In the case of Boltz's elegant study, the participants returned to the laboratory a week after having seen an ambiguous scene with positive or negative valenced music. The experimenter proposed a list of positively and negatively valenced words describing objects which could be either present in the scene they had seen or new (i.e. previously unseen) but coherent with the valence of the soundtrack they had listened to. Coherently with the hypotheses, the participants who watched the scene with a piece of negative music (i.e. a piece of music able to induce a negative mood) in the background falsely remembered a greater number of objects that were coherent with the emotional valence of the soundtrack, and the opposite was true with the positive music. The author explained her results in terms of the activation of cognitive schemas elicited by the music that might have encouraged specific false memories in a mood-coherent fashion. Furthermore, given the coherency of these results with those of other studies that prove autobiographical events (Miranda & Kihlstrom, 2005), self-perceptions (Sedikides, 1995), and interpretation of TAT stimuli (Bower, 1981) to be consistent with the particular mood state of the individual, it is plausible, although not yet proved, that the mood experienced by the individual, fostered by the emotional valence of the soundtrack, might be the responsible for the subsequent biased remembering of the scene. But is that the case?

The role of musically induced mood

Two main orders of criticisms might be brought forward against the hypothesis that the mood elicited by music influences the remembering of the scene:

(1) Does music always affect the mood state of an individual?
(2) Assuming it does, is this the cause of the biased remembering of the scene?

As for the first criticism, although numerous studies have collected significant evidence about how specific musical features are related to listeners' perception of emotion (Juslin & Laukka, 2004), frequently via biologically grounded psychoacoustic cues (Eerola et al., 2013; Quinto et al., 2014), a crucial difference has been pointed out concerning music between experienced (or felt) emotions and perceived (or represented) emotions (Gabrielsson, 2001). The former are the emotions that an individual feels when listening to music and are thus genuine emotions (e.g. "the music makes me feel happy"); this has also been referred to as the internal locus of emotion (Schubert, 2013). The latter are the emotions that music represents, that is, the emotional contents of the music (e.g. "the music is happy"). These are not proper emotions; in fact, they are not necessarily experienced by the individual; rather they constitute cognitive representations of emotion (in his thorough review, Schubert, 2013 defined this as the external locus of emotion).

A somewhat funny and yet effective example to better grasp the difference between Gabrielsson's (2001) typologies of emotion can be found in Woody Allen's *Manhattan Murder Mystery* (Allen, 1993), when his character, Larry Lipton, famously claims: "I can't listen to that much Wagner, you know? I start to get the urge to conquer Poland". That case is prototypical, as Larry's urge to conquer Poland can by no means be conceived as an emotional content of the music, as it is not represented or expressed; on the contrary, it is genuinely experienced by the agent, thus belonging to the experienced (or felt) emotions.

The difference between these two approaches to accounting for emotion is reflected in the philosophy of music debate by the difference between emotivism and cognitivism. While emotivism claims music to be capable of proper emotional responses in listeners, cognitivism supports an expressive or representation nature of the emotions of music. A more recent and mature reflection by Scherer and Zentner (2001) maintained such a difference but in the light of an integration in which music might both represent and induce emotions depending on several factors.

Gabrielsson (2001) proposed that four patterns of relationship exist between felt and perceived emotions (positive relationship, negative relationship, no systematic relationship, and no relationship); indeed, felt and perceived emotions do not always overlap. Such a difference is particularly evident in the pleasure one experiences when listening to sad music (Kawakami et al., 2014).

Concerning the second criticism, let us assume that music is truly capable of affecting the mood state of the movie scene recipients. Can we attribute the cause of the biased remembering of the scene to this musically induced mood beyond any reasonable doubt? It would not be trivial to assume – as the cognitivists do – that other cognitive mechanisms could be in play and affected. In this regard, a tradition of studies has proved music to be effective in influencing a variety of cognitive abilities such as verbal memory (Taylor & Dewhurst, 2017); learning (Lehmann & Seufert, 2018); work performance (Lesiuk, 2005); and time perception (Ansani et al., 2021; Droit-Volet et al., 2010).

Dealing more directly with audiovisuals, several studies have provided some insight into the fact that soundtracks substantially modify the way our gaze behaves while watching a scene (Ansani et al., 2020; Mera & Stumpf, 2014), thus suggesting the involvement of selective attention phenomena, but also the ability of soundtrack to increase or decrease the subjective saliency of given film objects (Millet et al., 2021).

To sum up, music has proved to affect mechanisms pertaining to both cognitive and affective domains. Given the opposition between mood induction-related explanations and those referring to more cognitive processes, akin to priming and cognitive schema theories (Boltz, 2001; Herget, 2019; Shevy, 2007, 2008), we plan to clarify this issue in the audiovisual domain by directly checking whether the influence that music exerts on the remembering of a scene is mediated by the mood induced in the recipients (H_{4a}) or the other way around (H_{4b}).

The present study

With this study, we want to deepen the triadic relationship between music, mood, and memory within an audiovisual context. In greater detail, we plan to do so by testing four hypotheses:.

First, we hypothesise that music affects the mood experienced by the recipients while viewing the scene:

> H_1: Music will affect the recipients' affective state coherently with the emotional valence and intensity conveyed.

Secondarily, given the results mentioned above of Proverbio and De Benedetto (2018) on face processing, we want to check whether an emotionally-driven encoding could also be operating within an audiovisual narrative context, thus favouring a better recall[2] in the presence of music as opposed to no music:

> H_2: Favouring an emotionally-driven encoding, music will improve recognition memory as opposed to no music condition.

As a third step, we wish to replicate the results on the mood-coherent false memories elicited by music that Boltz (2001) achieved on a long-term memory task. Nevertheless, as opposed to the mentioned study, whose participants performed the recognition task a week after the viewing session, we plan to employ a recognition task that immediately follows the encoding phase, proving that:

> H_3: Music will bias the remembering coherently with the mood evoked by the soundtrack, even when the recall is immediately after the encoding.

Lastly, concerning the debate between explanatory theories referring to mood-induction vs. mere cognitive schemas activation, we are willing to explore two mutually exclusive hypotheses:

> H_{4a}: The mood experienced by the recipients will mediate the effect of the music valence on the remembering of the scene (i.e. mood induction biases recognition).

Or alternatively,

> H_{4b}: The effects of the soundtrack on remembering are not due to the mood induced by music. (i.e. cognitive schemas bias recognition)

In conclusion, while H_2 can stand on its own, given that it is the only prediction that deals with the quality of the recognition (regardless of any valence), H_1, H_3, and $H_{4a\text{-}b}$ together constitute a unified framework (for a better understanding, please see Figure 6).

Materials and methods

In her review on how music conveys meaning in audiovisuals, Herget (2019) stressed the urgent need to improve the ecological validity of the designs. For this purpose, aiming at a better ecological setting, we decided to build an online procedure. By accessing a single un-reusable link[3], the participants could run the experiment directly from home on their laptops, smartphones, or tablets, just as if they were watching an on-demand tv series.

We designed a between-subjects paradigm in which participants watched a modified version (01′ 30″) of a short movie called *On lockdown* (Macdiarmid, 2020) (Figure 1).

Three versions of the scene were created – the three experimental conditions - with the video accompanied respectively by a happy piece (*Appalachian spring - VII: doppio movimento)* by A. Copland), a suspenseful piece from Original Motion Picture Soundtrack of the film *Proxy* (*Murder* by the Newton Brothers) or by no music at all (control condition). The two pieces were selected based on the findings of Juslin and Laukka (2004), Eerola et al. (2013), and subsequent studies listed by Cespedes-Guevara and Eerola (2018) concerning several psychoacoustic parameters associated with emotional expression in music. Copland's piece can represent feelings of joy due to its high pitch (Eerola et al., 2013), bright and sharp timbre of violins and wind instruments (Scherer et al., 2015), and fast tempo (Quinto et al., 2014). On the contrary, the Newton Brothers' track's large volume variability could be linked to fear (Juslin & Laukka, 2004). Furthermore, its increasingly louder intensity could convey agitation, tension, restlessness (Fabian & Schubert, 2003) or fear, anger (Scherer et al., 2015), and scariness (Eerola et al., 2013). Moreover, the double basses' vibrato articulation can be related to fear (Quinto et al., 2014). Moreover, the musical pieces were validated in a previous study (Ansani et al., 2021).

After providing the informed consent, each participant was randomly assigned to one of the three conditions. The first screen instructed the participants to watch a short scene and answer some simple questions about it.

A demographic section followed, and then the scene started in full-screen mode. Before the viewing, the participants had no clue what they would have answered afterward.

After viewing the scene, we administered the questions related to the affective state they were

[2]Sometimes, for reasons of brevity, we use the term *recall* to differentiate it from encoding; nevertheless, strictly speaking, given that the participants are provided with cues that help them in retrieving the information, we should always be referring to *recognition memory*.

[3]An anti-ballot box stuffing was employed in order to avoid multiple participants from the same device.

experiencing and the recognition task. To avoid sequence effects, the order of the questions was randomised for each participant. After filling out the questionnaire, a final screen displayed the authors' e-mail addresses so that participants could contact them for further information.

Measures

Affective states of the recipients. For assessing the affective state that the participants were experiencing during the view, similarly to Ansani and colleagues (2021), we employed Plutchik's (1980) wheel of emotions (Figure 2). In this model, eight main sectors stand for eight primary emotions (anger, anticipation, joy, trust, fear, surprise, sadness, and disgust). Each sector is divided into three parts incrementing emotional intensity from the outer to the wheel's inner part. The participants could select one of the thirty-two regions by clicking on the corresponding area.

We opted for this assessment tool for several reasons. First, as opposed to Ekman's Basic Emotions theory, Plutchik's wheel provides the respondent with a wider variety of possible emotions, thus increasing assessment specificity. Secondly, instead of Likert-like assessment tools, in which the respondent has to reflect on each listed emotion critically, thus providing a more rationalised answer, a simple click on an image can fit better into an online procedure, where user-friendliness, practicality, and conciseness is key. Furthermore, Plutchik's theory has proven effective in detecting emotional content within online contexts and movie reviews (Mokryn et al., 2020).

Memories. Several steps have characterised the operationalisation of the memories in this experiment. We employed a recognition task with a list of objects: some truly appearing in the scene (real memories, $N = 13$), some not (false memories, $N = 10$). A list with all 23 words appeared to the participant in randomised order (Table 1). The participants had to tick a box if they had seen the correspondent item or leave it blank if they had not.

As for what we call real memories, we simply chose 13 objects and characters present within the scene. The short movie did not narrate a specific story, and there was no continuity between the scenes; on the contrary, each scene was about a different perspective depicting urban environments (e.g. inside – bathroom; outside – empty crossroad; outside – balcony; outside – night landscape, etc.). For this reason, no object was inherently more important than others, and all of them were neither visually nor narratively central within the scene.

Figure 1. Illustration of four representative scenarios of the scene.

Note. Clockwise: (Scenario 1) Inside – Bathroom; (Scenario 3) Outside – Empty crossroad; (Scenario 4) Outside – Balcony; (Scenario 7) Outside – Night landscape.

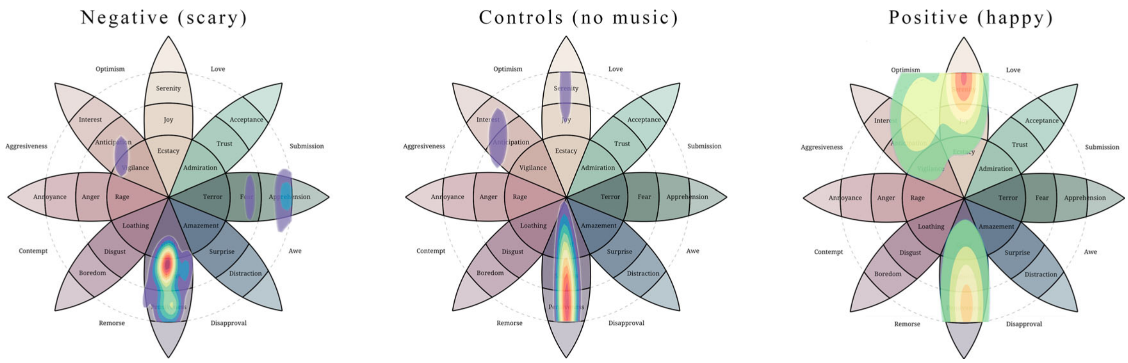


Figure 2. Heatmaps of the participants' affective state as a function of the condition

Table 1. List of items and relative valence.

Present objects	Valence	Absent objects	Valence
lamppost	.42	someone hiding	.21
traffic light	.49	wheelchair	.24
toothbrush	.52	ghost	.26
stairway	.56	razor	.26
curtains	.61	knife	.34
man in his hat	.61	jogging guy	.73
tv set	.62	car	.75
moon	.67	cradle	.77
birds	.73	fireworks	.78
plant	.73	puppy	.91
fan	.78		
painting	.79		
lady	.85		

Note. Valence scores are referred to absent objects and represent a continuum from 0 (absolutely negative) to 1 (totally positive). The scores are taken from Mohammad's (2018) NRC Valence, Arousal, and Dominance lexicon.

Concerning the previously unseen objects (i.e. "false memories"), we resorted to the NRC Valence, Arousal, and Dominance lexicon (Mohammad, 2018), namely a list in which 20000 English words are rated for their valence, arousal, and dominance (from 0 to 1). From this lexicon, we chose ten words describing objects that could be plausible within the scene; valence was the main criterion. We chose 5 words with positive valence (>.70) and 5 with negative valence (<.30). We also balanced them for arousal so that, in each of these categories, there was an equal number of highly arousing, neutral, and scarcely arousing words (the same thresholds as valence were used).

Participants: power analysis and preliminary sample data analysis

An a priori power analysis was run through G*Power (Faul et al., 2007) to detect the correct sample size.

For H_1, we employed the contingency tables function with $(1 - \beta) = .80$ and $w = .30$ (i.e. medium effect size). The required sample was 133 for emotional valence ($df = 4$) and 152 for emotional intensity ($df = 6$).

For H_2, two ANCOVA tests were hypothesised, with identical parameters, that is, $(1 - \beta) = .80$ and $f = .25$ (i.e. medium effect). With $df = 1$ (the factors were the presence/absence of the music for the first ANCOVA and scary/happy music for the second), the required sample was 128.

For H_3, we were interested in an interaction effect condition × memories valence. Thus, we computed the sample size hypothesising $(1 - \beta) = .80$ and $f = .25$ (i.e. medium effect size). The required sample was 42.

Finally, as for the path analysis related to H_4, we regarded the model as being equivalent to a linear multiple regression with two predictors (i.e. soundtrack emotional valence and emotional score). Therefore, we assessed the required sample size hypothesising $(1 - \beta) = .80$ and $f^2 = .15$ (i.e. medium effect size). The required sample was 68.

All power computations considered, we recruited 200 Italian participants through university mailing lists and social media. Later, to improve the reliability of our sample, we performed some exclusions based on several pre-established criteria:

(1) a multiple-item Likert scale was presented as an attention check, with an explicit instruction to avoid filling it out; thus, we excluded all those participants who compiled this scale.
(2) A measure of the time spent on the scene screen was added to exclude those who did not watch the whole video. The time count was visible to the experimenter only. All those participants who completed the task in less or more than the mean duration ± 2SD were excluded.

(3) All those who did not complete the task were excluded from the analyses to avoid missing data.

After such exclusions, our sample decreased from 200 to 169 valid participants (100 females, mean age = 23.36 SD = 7.57). The gender distribution among the conditions was balanced, $\chi^2(2, N = 169) = .58$, $p = .74$ (Table 2). According to the previous power analyses, the sample should consist of more than 152 participants; thus, it was satisfactory. The final distribution of the valid participants was 52 in the control group, 58 in the happy group, and 59 in the scary group (Table 2).

Results

For the statistical analyses, IBM SPSS 26.0 was used; the path analysis was run on Mplus 8.5 (Muthén & Muthén, 2017). For each test, the effect size is provided by using η or η^2 (eta and eta squared), depending on the nature of the test. Post-hoc tests were performed with Bonferroni correction. In the results of the path analysis, the reader will find the standardised path coefficient (β), the level of statistical significance (*p-value*), and the 95% bias-corrected bootstrap Confidence Interval ($95\%_{BC}$CI). The heatmaps have been built through R (ggplot2 package) and superimposed onto Plutchik's wheel using GIMP 2.10.

H_1 – Music has an impact on the affective state of the recipients coherently with its emotional valence

The reader could look at the heatmaps as a preliminary and intuitive glimpse of the participants' affective states in the three experimental conditions (Figure 2). An emotional core emerges, which is common to all the conditions, namely that of the six o'clock region of Plutchik's wheel of emotions. This axis includes pensiveness, sadness, and grief. What is more interesting is that the soundtracks add or remove several diverse emotional nuances compared to the no-music condition. For instance, comparing the controls with the happy group, the serenity/joy region becomes more salient. When considering the scary condition, the serenity/joy axis loses importance, while the expectancy area remains active, and apprehension and awe gain saliency.

For a more detailed analysis, given that each of our participants simply clicked on the Plutchik's wheel of emotions image in correspondence with the emotion they were feeling, two emotional scores were created, one for valence and one for intensity. As for valence, the score was created by assigning 1 point to the participants who chose a positive valence emotion, 0 points to non-valenced emotions (i.e. expectation, interest, surprise, and distraction), and −1 point to negative valence emotions.

Concerning intensity, coherently with Plutchik's (1980) conceptualisation of the wheel, a score of 3 was assigned to the participants who clicked on the inner circle (namely, the maximal degree of emotional intensity), 2 points were assigned to those who clicked on the central circle (i.e. joy, trust, fear, surprise, sadness, disgust, anger, and anticipation), whereas 1 point was assigned to the participants that clicked on the outer region of the wheel, namely, the minimal degree of intensity (i.e. serenity, acceptance, apprehension, distraction, pensiveness, boredom, annoyance, and interest).

We then ran a chi-square test to check for the distribution of the emotional valence in dependence of the condition, finding it to be significant, $\chi^2(4, N = 169) = 30.46$, $p < .001$, $\eta_{(condition)} = .30$ (Figure 3a). The same chi-square test was run for intensity, finding a significant distribution, $\chi^2(6, N = 169) = 23.11$, $p = .001$, $\eta_{(condition)} = .09$ (Figure 3b).

We can thus state that H_1 was verified, namely that the emotional content of the soundtrack had a coherent impact on our participants' mood.

H_2 - Music improves recognition memory

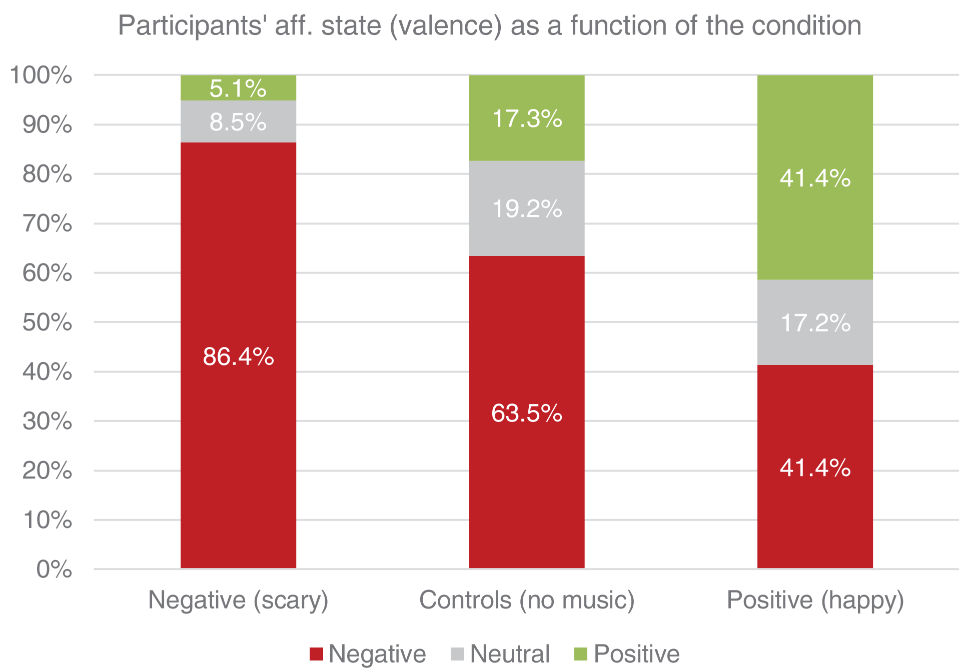
To analyze the remembering of the objects, we resorted to a classic signal detection analysis, which can be considered the golden standard in memory tasks and psychological responses to the media (Shapiro, 1994). Typically, for each participant, *d* prime (i.e. *d'*) should be computed, namely the standardised difference between the means of the Signal Present and Signal Absent distributions, namely:

$$d' = z(False\ alarms) - z(Hit\ rate)$$

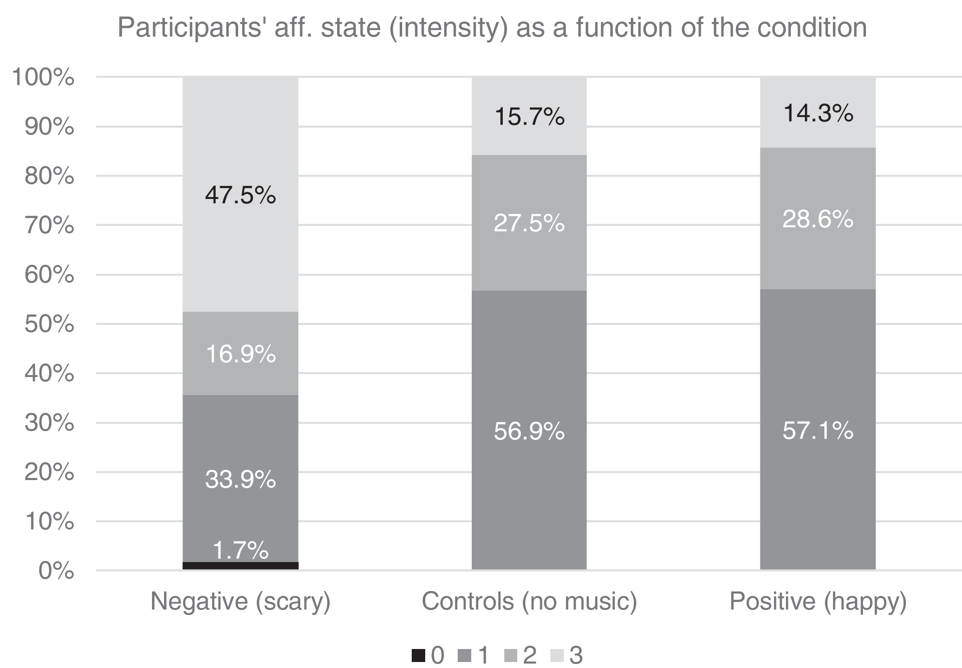
Greater absolute values of *d'* mean that a participant is more sensitive to the difference between the

Table 2. Gender and condition distribution.

		Controls	Happy	Scary	Total
Gender	M	20	26	23	69
	F	32	32	36	100
Total	52	58	59	169	



(a)



(b)

Figure 3. a. Distribution of the affective state (valence) of the participants as a function of the condition. b. Distribution of the affective state (intensity) of the participants as a function of the condition.
Note: (a) $\chi^2(4, N = 169) = 30.46$, $p < .001$, η(condition) = .30; (b) $\chi^2(6, N = 169) = 23.11$, $p = .001$, η(condition) = .09.

Signal Present and Signal Absent distributions. Conversely, *d′* values approaching zero indicate chance performance.

In this specific case, as the distributions of False alarms (i.e. F) and Hit rate (i.e. H) significantly diverged from normality (Shapiro-Wilk's test $p < .003$), the non-parametric version of d', namely, A', was computed, as suggested by Rae (1976) (subsequently reported by Snodgrass & Corwin, 1988), as follows:

$$A' = \frac{(H^2 + F^2 + 3H - F - 4FH)}{[4H(1 - F)]}$$

The values of A' typically range from .5, which indicates that signals cannot be distinguished from noise, to 1, which corresponds to perfect performance (Stanislaw & Todorov, 1999, p. 140).

Furthermore, Grier's (1971) B'' was calculated to measure response bias. Such value can range from – 1 (i.e. extreme bias in favour of *yes* responses) to 1 (i.e. extreme bias in favour of *no* responses). A value of 0 signifies no response bias.

An ANCOVA was run with the presence/absence of the soundtrack as the between factor, A' as the dependent variable, and the positioning of the memory task as a covariate. The test did not reach the statistical significance, $F(1,165) = 1.52$, $p = .21$, $\eta^2 = .009$. The memory task positioning did not affect the performance ($p = .22$). In both groups, A' was close to .8, indicating average performance, with a slightly major value for the music conditions ($A'_{\text{music}} = .82$ S.E. = .007; $A'_{\text{no-music}} = .80$ S.E. = .010). The same ANCOVA was run for B'' to check whether music could bias the answers toward yes or no responses, finding no significance, $F(1,165) = 2.48$, $p = .12$, $\eta^2 = .015$. In greater detail, both groups exhibited slight bias toward no responses, ($B''_{\text{music}} = .52$ S.E. = .029; $B''_{\text{no-music}} = .61$ S.E. = .044).

For these reasons, H_2 cannot be confirmed; the mere presence of a soundtrack does not improve or worsen recognition memory.

H_3 – Music biases the remembering coherently with its emotional content

To test H_3, we ran a mixed ANOVA with the condition as the between factor, the emotional valence of the objects as the within factor, and the false recognition scores as the dependent variable (i.e. the scores of the positive- and negative-valenced falsely remembered objects). As expected, we found no condition or valence effects. However, and as hypothesised, a large interaction effect condition × memories valence emerged, $F(2,166) = 12.65$, $p < .001$, $\eta^2_p = .13$.

We subsequently ran the interaction post-hoc analyses with Bonferroni correction, proving that: within valence, the positive-happy condition elicited a higher amount of positive valenced false memories than negative valenced ($p = .026$) and control conditions ($p = .014$). Coherently, the negative-scary condition fostered a higher amount of negative valenced false memories as opposed to positive ($p < .001$) and control conditions ($p = .031$). More importantly, within the conditions, while controls reported no significant difference between positive and negative valenced false memory recognition scores, both in the positive-happy and negative-scary musical conditions, such difference was significant ($p < .005$) and coherent with the emotional valence of the soundtrack (Figure 4).

H_4 – Is there a mediation effect of the mood?

As for exploring H_{4ab}, we performed a path analysis testing a partial mediation model (Agler & De Boeck, 2017) through a transmittal approach (Memon et al., 2018).

First, we created a variable that considered both emotional valence and intensity by multiplying the valence and intensity scores (i.e. valence × intensity) (see H_1). Besides the merit of considering valence and intensity together, this procedure had the secondary benefit of enlarging the variability within the emotional score.

The emotional valence of the soundtrack was the only exogeneous variable; it was codified as a three-level variable (−1, 0, 1) in which the negative (scary) valence was the lowest level, the controls the central one, and the positive (happy) valence was the highest level. There were three endogenous variables: the emotional score, codified as mentioned above, was the mediator, whereas the percentages of negative and positive valenced falsely remembered objects were the dependent variables (Figure 5). As a partial mediation model assessed via transmittal approach, direct and indirect effects were calculated together. To increase the power of detecting a potential mediation effect, a bootstrap procedure (10000 samples) was performed to assess indirect effects (Hayes, 2018), and 95% bias-corrected confidence intervals were provided.

The effect of the emotional valence on the emotional score proved to be significant (effect a: $\beta = .43$, $95\%_{\text{BC}}$CI [.27, .55], $p < .001$). The direct effect of the emotional valence of the soundtrack on the recognition (c′) was significant both in the case of the positive ($\beta = .24$, $_{95\%\text{BC}}$CI [.07, .40], $p = .012$) and negative false alarms ($\beta = -.26$, $95\%_{\text{BC}}$CI [−.40, −.11], $p < .001$). On the contrary, the effect of the emotional score (*b* effect) was not significant, for neither positive ($\beta = -.08$, $p = .373$) nor

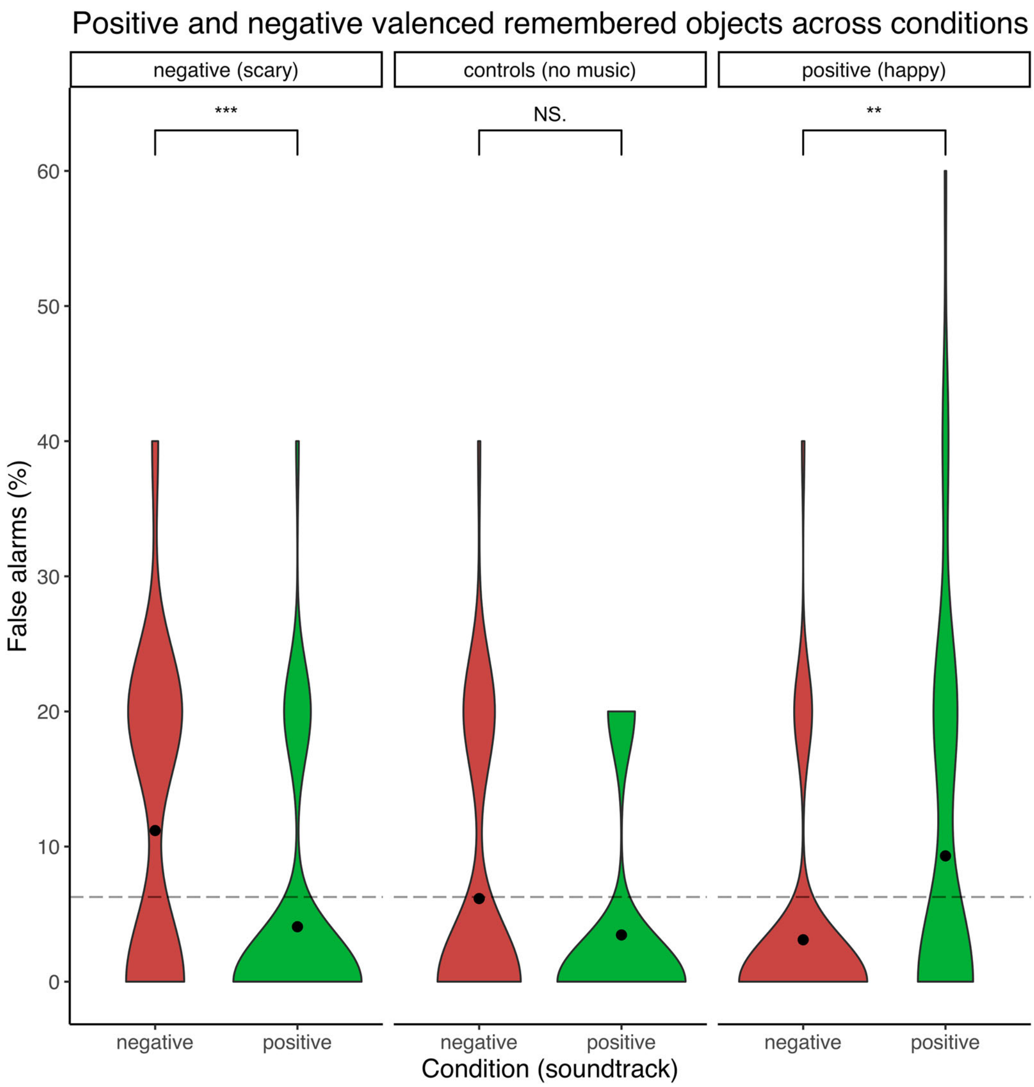


Figure 4. Positive and negative valenced remembered objects across conditions (violin plot).

Note. The mean difference between negatively and positively valenced false alarms is significant both in negative and positive conditions with *** $p < .001$ and ** $p < .005$ (two-tailed, Bonferroni-corrected). The same mean difference is not significant in the control condition. The horizontal dashed line stands for the grand mean. The black points indicate mean values.

negatively valenced ($\beta = -.13$, $p = .090$) false alarms. Finally, the total effect of the emotional valence of the soundtrack was significant on the positive valence false alarms ($\beta = .20$, $95\%_{BC}$CI [.05, .35], $p = .002$) and the negative valence false alarms ($\beta = -.31$, $95\%_{BC}$CI [–.45, –.17], $p < .001$), whereas the indirect effects were not significant (positive valence false alarms: $\beta = -.03$, $95\%_{BC}$CI [–.02, .05], $p = .377$; negative valence false alarms: $\beta = -.05$, $95\%_{BC}$CI [–.03, .05], $p = .104$).

To be safer, we also built a double parallel mediation model that considered valence and intensity as two parallel mediators (see Supplementary material). The results are overlapping, in that the soundtracks significantly impacted on both valence ($\beta = .41$, $p < .001$) and intensity ($\beta = -.27$, $p < .001$) perceived by the participants; the direct effect on the soundtrack was still observed both for positive ($\beta = .21$, $p = .025$) and negative ($\beta = -.26$, $p = .001$) valenced false alarms. Finally, and most importantly, no direct effect of valence or intensity on the false alarms was found.

In other words, even though the emotional valence of the soundtrack significantly influenced the mood of the participants coherently with its emotional valence (H_1), and even though the false memories of the participants were coherent with the mood expressed by the music (H_3) (Figure 5), the path analysis showed no effect of the induced mood on the falsely remembered positive and

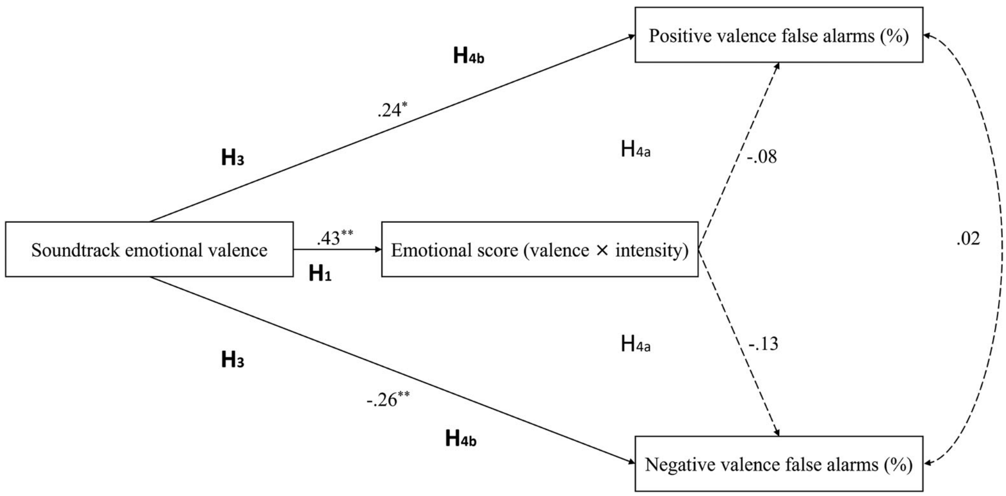


Figure 5. Path analysis model.

Note. Verified hypotheses are in bold. Parameters estimates are standardised. Dotted lines represent insignificant paths. Continuous lines represent significant paths. * $p < .015$ (two-tailed); ** $p < .001$ (two-tailed).

negative valenced objects. Because of these non-significant paths (Figure 5), the self-reported induced mood can by no means be considered a mediator within the model. On the contrary, the emotional valence of the soundtrack exerted a direct influence on remembering. In terms of our mutually exclusive hypotheses, we can state that these findings go in the direction of confirming H_{4b} to the detriment of H_{4a}.

Discussion

This study has shown that music influences a recognition task by leading the participants to falsely remember objects that were not present in a movie scene but whose valence is coherent with that conveyed by the music mood (H_3, Figure 4). Moreover, and more importantly, the observed pattern of the falsely remembered objects is coherent with the soundtracks' emotional contents (i.e. the emotional nuances represented by the music), but this is not caused by a mood induction, thus confirming the cognitive schema theory.

As for the emotionally-driven encoding hypothesis (H_2), coherently with Boltz and colleagues (1991), the presence of a soundtrack (regardless of its emotional valence) does not seem to increase nor decrease the recognition scores.

As concerns H_{4ab}, the issue needs to be described in greater detail. Traditionally, music has been considered capable of inducing specific moods in listeners, so much so that it is used as a proper mood inductor through specific mood induction procedures (Västfjäll, 2001). A vast spectrum of studies analyzing various psychological constructs has explained the effects of music on several tasks in terms of a three-step process such as:.

$$Music \rightarrow Individuals'mood \rightarrow Task$$

For instance, a plethora of studies analyzed how priming by some pieces of music differing in emotional valence influenced many cognitive and affective mechanisms: moral judgments (Ansani et al., 2019; Seidel & Prinz, 2012), perception of facial emotion expression (Woloszyn & Ewert, 2012), behavioural intentions to donate money (Strick et al., 2015). All these studies more or less straightforwardly explained their results in terms of mood induction.

Coherently, most of these studies reported a manipulation check proving that music affected the mood and thus the task at hand; or, more rarely, finding no effect of mood at all (Ziv, 2016). Only a study proposed a mediation model with mood as the mediator between the music and the task performance (Krahé & Bieneck, 2012).

Thus, if we exclude those studies with an indirect and therefore relatively more reliable assessment of the listeners' affective state (see fMRI studies like Oetken et al., 2017), one can never be sure, strictly speaking, that the observed effects must be attributed to a musically induced mood.

Indeed, this problem is not new. As self-report measures are by far the most used ones (Västfjäll, 2011), some criticisms about their unreliability have already been raised. First, demand

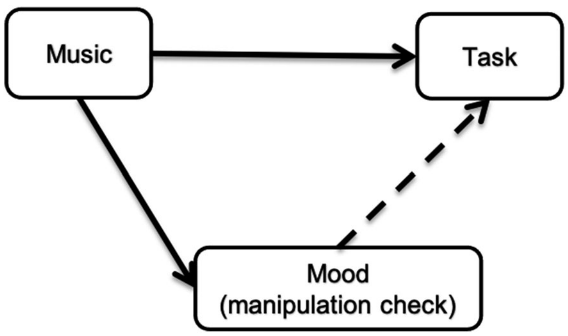


Figure 6. Methodological issue.

Note. Most studies check for the paths represented by continuous lines but not for those represented by the dotted line.

characteristics can be responsible for the mood effects found (Scherer & Zentner, 2001); secondly, Kivy (1989) has argued that listeners make a classic attribution error as they often take the expressive properties of the music for what they actually experience. Furthermore, Zentner et al. (2000) proved that subjects reported very different scores when asking them to score the emotions they perceived instead of feeling.

Lastly, from a purely methodological standpoint, as in the great majority of cases the experimental paradigms are built to prove the effects of music on the task and the mood, but not those of the mood on the task (Figure 6), one cannot exclude the presence of other intervenient variables.

When it comes to audiovisuals, it has been convincingly proposed that the musical score promotes the activation of cognitive schemas (Boltz et al., 1991), which in turn facilitate or dampen certain interpretations in general, and memory encoding in particular. Nevertheless, so far, no investigation has been carried out on the role of the viewers' mood during memory encoding in the audiovisual domain. More specifically, no direct comparison has been made between schema theory (i.e. semantic priming) vs. mood induction (i.e. affective priming).

It is impossible to deny the emotional aspects of music semantics; namely, music can be a truly effective carrier of emotions, whether represented or, more rarely, experienced. Furthermore, it is unthinkable to negate music's well-proven capability of inducing moods. Nevertheless, it can be argued that music has too often been considered capable of *nothing but* affective priming (i.e. mood induction) because of its very nature and history. However, as proved by research on visual processing and audiovisuals, there are contexts wherein music exerts a more cognitive influence on high-level top-down processes (e.g. eye movements, expectations, memory). We believe that such cognitive influence can go in parallel with affect or even bypass it in a more radical interpretation, especially within the above-mentioned top-down processes. The case of the influence of film music on memory may weigh in favour of the last interpretation, as soundtracks could elicit semantic priming in an associative or conceptual fashion through the activation of cognitive frames proper (or scripts/schemas).

In this perspective, the fact that the falsely recognised objects are coherent with the mood expressed by the musical content can be considered epiphenomenal; that is, the causal chain that leads to biased remembering does not involve a mood induction effect. On the contrary, a direct effect of the musical contents is observed. Using a more cognitive framework, it might be claimed that the effects of music on memory that were found could be not so dissimilar from those known in the traditions of shopping behaviour (Jacob, 2006) and semantic priming experiments (McNamara, 2005). In those contexts, an individual might better recall a green object merely due to a prior exposition to words describing green objects, without experiencing a "greenness" caused by the exposition. Comparably and coherently with the schema theory proposed by Boltz (2001) in a long-term memory context, music might increase the cognitive availability of semantic networks of words related to its semantic contents by activating cognitive frames. Briefly stated, viewers who watch a scene with a piece of scary music tend to report a higher number of negatively valenced falsely remembered objects because of the horror/creepy frame elicited by the music and not because they feel frightened.

We firmly believe that this issue should be taken into more serious consideration when analyzing the effect of music on various tasks. Furthermore, the current work enriches a growing wealth of studies that contradict the more reductionist philosophical approaches to music and emotion (for a review of such approaches, see Kania, 2020) and move in the direction of acknowledging the role of the semantic processing of music (Koelsch et al., 2004). The time is now ripe to acknowledge that music constitutes a complex auditory stimulus whose effects go way beyond mere affect.

Limitations

To conclude, four main limitations should be listed, the first being the concept of false memories or false remembering. *Stricto sensu*, one should be allowed to speak about false memories when an actual memory is developed about something the agent has never perceived or done (Newman & Lindsay, 2009). In our recognition task, our participants did not declare to have or have not seen a given object; they merely ticked a box within a precompiled list of objects whether they remembered seeing that object in the scene. This paves the way for the use of associative heuristics to make choices. In other words, it is not that one ticks a box indicating a given object because they are genuinely convinced of having seen that object; on the contrary, there is a heuristic at work. We propose that such a heuristic is caused by the activation of associative cognitive schemas, which are by no means related to mood induction.

The second limitation deals with a point that still needs to be addressed in further studies: the possible presence of this valence-biased remembering for objects that actually appeared in the scene. As mentioned above, we resorted to the NRC Valence, Arousal, and Dominance Lexicon (Mohammad, 2018) to obtain the Valence ratings for the objects. We chose the unseen objects according to this lexicon; on the contrary, for the present objects, we had to stick to those visible within the scene, which were few in number, and not balanced enough to make positive/negative valence comparisons. In future studies, an effort should be made to build the visual stimuli professionally so that they can be better controlled from an experimental standpoint without compromising on ecological validity.

As a third limitation, we should consider that the video was not perceived as neutral from an affective point of view; indeed, if we consider the control condition, 63.5% of the participants reported a negative mood. Further research should explore the impact of music on different videos by manipulating the interaction between the mood conveyed by a scene's visual and the musical components involved.

Lastly, we acknowledge two main issues with Plutchik's wheel of emotion: the first one is that we used it in a suboptimal way, namely, through a 3-level codification of valence and intensity. Even though such a tool eases the task to a considerable extent, we are convinced that, with a higher number of participants, we could have improved the measurement by resorting to more sophisticated analyses similar to those typically performed on Schwartz's quasi-circumplex structure of basic values (Perrinjaquet et al., 2007). The second issue regards the inherent impossibility of grasping the eventual coexistence of two or more divergent emotions within a single participant, as every participant could click on the wheel only once.

Author contributions

Conceptualization, A.A.; methodology, A.A.; validation, L.M. and M.M.; formal analysis, A.A.; investigation, A.A.; data curation, A.A.; writing—original draft preparation, A.A.; writing—review and editing, A.A. and M.M.; supervision, L.M. and I.P. All authors have read and agreed to the published version of the manuscript.

Data availability statement

The questionnaire and the data supporting this study's findings are available in OSF at https://osf.io/n4bc2/?view_only=041bac11842f4f8baf96f84654a50005.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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