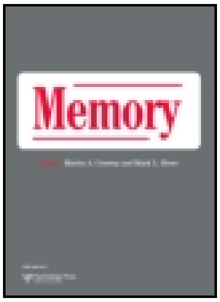

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The effects of emotion on memory for music and vocalisations

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The effects of emotion on memory for music and vocalisations

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Music is a powerful tool for communicating emotions which can elicit memories through associative mechanisms. However, it is currently unknown whether emotion can modulate memory for music without reference to a context or personal event. We conducted three experiments to investigate the effect of basic emotions (fear, happiness, and sadness) on recognition memory for music, using short, novel stimuli explicitly created for research purposes, and compared them with nonlinguistic vocalisations. Results showed better memory accuracy for musical clips expressing fear and, to some extent, happiness. In the case of nonlinguistic vocalisations we confirmed a memory advantage for all emotions tested. A correlation between memory accuracy for music and vocalisations was also found, particularly in the case of fearful expressions. These results confirm that emotional expressions, particularly fearful ones, conveyed by music can influence memory as has been previously shown for other forms of expressions, such as faces and vocalisations.

Keywords: Music; Fear; Emotion; Memory; Vocal expressions.

We all remember songs from the past, particularly when these are emotionally loaded. In most cases the emotion associated with the song is related to an autobiographical event (e.g., first kiss) rather than to the tune itself (Janata, Tomic, & Rakowski, 2007). Yet music can convey emotional information through its intrinsic features, in the absence of any context or association to a specific, personal event (Vieillard et al., 2008). To date the mechanisms underlying this phenomenon remain unclear. In particular there is no consensus on whether emotional music constitutes an innate, biologically prepared stimulus class (such as faces and vocal expressions) or instead is a result of culture and learning. Empirical support for the biological view comes from studies showing that emotions expressed by music are, at least to some degree, recognised across cultures (Balkwill & Thompson, 1999; Fritz et al., 2009) and that musical emotions engage core brain structures devoted to emotional processing, such as the amygdala (Koelsch, 2010) and ventral striatum (Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011), even in newborns (Perani et al., 2010).

However, because music is evolutionarily recent and has little, if any, survival value, it has been argued that music "invaded" or recycled (Dehaene & Cohen, 2007) emotion circuits that

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evolved for processing biologically relevant stimuli (Peretz, 2010). In particular, one likely emotional system for neural invasion is the one involved in emotional vocalisations. Indeed, musical emotions share fundamental acoustic cues with vocal emotional expressions (Bowling, Gill, Choi, Prinz, & Purves, 2010; Juslin & Lauka, 2003) and appear to recruit overlapping neural circuits (Koelsch, 2010), leading to the proposal that music may represent a *super-expressive voice* (Juslin & Laukka, 2003; Juslin & Västfjäll, 2008). According to this view one would predict a similar influence of emotions on memory for music to that observed for vocalisations; that is, an enhanced recognition accuracy for various emotions, including happiness, fear, and sadness, relative to neutral stimuli (Armony, Chochol, Fecteau, & Belin, 2007). Moreover, memory for vocalisations should predict performance with music. In other words, someone with particularly good memory for fearful vocalisations should exhibit a similar enhancement of memory for fearful music. If, instead, the emotional value of music is more culturally based, acquired mainly through exposure and associations, then the effects of emotion on memory for music should be unrelated to those observed for vocalisations.

Here we sought to directly address the following questions: (1) Does emotion modulate memory for music independently of any contextual information? (2) If so, is this effect emotion-, valence-, or arousal-specific? and (3) Is memory for emotional music related to memory for emotional vocalisations? To do so we conducted three related experiments to assess recognition memory for short, unfamiliar pieces of music expressing fear, happiness, and sadness, relative to neutral musical stimuli (Vieillard et al., 2008). We compared these results with those obtained, in the same participants, using nonlinguistic emotional vocalisations. Furthermore, in order to rule out potential confounds we separately controlled for duration, number of events, and expressivity in the music stimuli.

EXPERIMENT 1A

Method

Participants

A total of 51 healthy volunteers (25 females; mean age: 23.8 ± 3.0 years), with no history of hearing impairment participated in the study. None of them had more than 3 years of formal musical training. Two participants were excluded from the final analysis due to poor overall performance (memory accuracy more than 2 *SD* below the average).

Stimuli

Music. A total of 64 unfamiliar instrumental clips were segmented from a previously validated set of musical stimuli written according to the rules of the Western tonal system, based on a melody with an accompaniment and specifically designed to express fear, sadness, happiness, or ‘‘peacefulness’’ (neutral condition) (Vieillard et al., 2008). The stimuli were computer-generated and recorded with a piano timbre (MIDI). The duration of the musical clips was matched to those of vocalisations (mean: 1.5 seconds; *SD*: 0.2 seconds). Physical characteristics of the stimuli are shown in Table 1. The spectral centroid (weighted mean of spectrum energy) reflects the global spectral distribution and has been used to describe the timbre whereas the spectral flux conveys spectro-temporal information (variation of the spectrum over time) (Marozeau, de Cheveigné, McAdams, & Winsberg, 2003). The intensity flux is a measure of loudness as a function of time (Glasberg & Moore, 2002). Expressivity was measured through the average silence ratio, which is an index of articulation, and the strength of the beat (pulse clarity), which reflects how easy it is to perceive the underlying metrical pulsation in music, using the MIR toolbox (Lartillot, Toiviainen, & Eerola, 2008).

Vocalisations. A total of 72 nonlinguistic vocalisations (mean duration: 1.3 seconds; *SD*: 0.4 seconds) were selected from a validated set previously used in behavioural (Fecteau, Armony, Joanette, & Belin, 2005), memory (Armony et al., 2007) and neuroimaging (Fecteau, Belin, Joanette, & Armony, 2007) studies. They consisted of 12 stimuli per emotional category—happiness (laughter), pleasure, sadness (cries), and fear (screams)—and 24 emotionally neutral ones (12 coughs and 12 yawns), each produced by a different speaker half of whom were female.

Procedure

Memory for music and vocalisations was tested in two separate sessions (order counterbalanced

TABLE 1
Main acoustic features of the music stimuli

	Acoustic parameters: Mean (SD)								
Emotion	*Duration (seconds)*	*Number of events*	*Mode*	*Tempo*	*Spectral Centroid (Hz)*	*Spectral Flux (a.u.)*	*Intensity Flux (a.u.)*	*Pulse Clarity (a.u.)*	*Articulation (a.u.)*
Experiment 1A									
Happiness	1.43 (0.15)	9.25*# (1.44)	Major	146*# (26)	1303.7 (61.3)	83.5*# (15.3)	355.98* (56.39)	0.5279 (0.532)	0.2064*# (0.074)
Fear	1.48 (0.16)	5.10* (2.24)	Minor	83# (33)	1179.1 (155.4)	63.6*# (23.4)	359.31 (58.04)	0.3346* (0.194)	0.3065 (0.129)
Sadness	1.49 (0.12)	3.00 (0.51)	Minor	56* (12)	1238.4 (113.0)	39.3 (14.2)	389.30 (41.00)	0.4177 (0.171)	0.3121 (0.113)
Neutral	1.45 (0.18)	4.10 (0.99)	Major	77 (20)	1242.8 (76.0)	47.6 (10.0)	375.03 (55.08)	0.5083 (0.097)	0.2816 (0.086)
Experiment 1B									
Happiness	1.56 (0.17)	9.25*# (1.44)	Major	146*# (26)	1171.76 (80.99)	86.95 (13.37)	252.01*# (50.74)	0.3829 (0.104)	0.3593 (0.099)
Fear	1.59 (0.18)	5,06* (2.24)	Minor	83# (33)	1056.43 (214.07)	65.41 (12.45)	327.04 (129.04)	0.2283 (0.134)	0.3641 (0.133)
Sadness	1,63 (0.15)	3.00 (0.52)	Minor	56* (12)	962,27 (153,99)	45.15 (10.43)	410.01 (125.88)	0.3074 (0.101)	0.3610 (0.095)
Neutral	1.50 (0.18)	4.19 (0.98)	Major	77 (20)	1025,11 (100,11)	48.12 (11.95)	366.62 (70.51)	0.2860 (0.107)	0.3129 (0.093)
Experiment 2									
Happiness	0.57*# (0.16)	3.30 (0.48)	Major	146*# (26)	1300.3 (103.8)	90.4*# (22.2)	328.54* (50.89)	n/a§	0.1805# (0.092)
Fear	1.42# (0.42)	3.31 (0.70)	Minor	83# (33)	1151.9 (167.1)	67.6# (27.7)	337.74 (55.93)	0.2823*# (0.191)	0.2794 (0.142)
Sadness	1.49* (0.12)	3.00 (0.51)	Minor	56* (12)	1238.4 (113.0)	39.3 (14.2)	368.83 (59.47)	0.4177 (0.171)	0.3121 (0.113)
Neutral	1.25 (0.23)	3.31 (0.48)	Major	77 (20)	1262.2 (107.9)	49.7 (9.4)	329.52 (51.79)	0.4397 (0.159)	0.2478 (0.092)

Significantly different from *neutral and #sad ($p < .05$, Bonferroni corrected). §Stimuli were too short for analysis. a.u. = arbitrary units.

across participants) spaced by a few days ($M = 3.8$, $SD = 1.8$). Stimuli were presented through Professional Beyer Dynamic DT770 headphones in a sound-treated room at a comfortable volume level. During the encoding phase half of the stimuli (counterbalanced across participants) were presented twice, in two successive blocks with different incidental tasks designed to ensure participants' attention to each stimulus. For music, participants were instructed to determine whether the clip had faster or slower tempo than the previous one and, in the second block, if it had higher or lower pitch. For vocalisations, participants' tasks were to make a gender decision (i.e., male or female) about the person producing each sound and then to determine whether s/he was older or younger than 30 years of age (Armony et al., 2007). Within each block, stimuli were presented in a pseudo-random order (no more than two consecutive presentations of the same emotion and no more than three vocalisations or musical clips) in a self-paced manner. In the recognition phase all stimuli (music or vocalisations) were presented in a pseudo-random order. Participants were asked to decide whether or not they had heard each stimulus before (old/new judgement) and how confident (1–3 scale) they were about their response. After the memory test participants listened again to all stimuli and rated them on both emotional valence (−50: *very negative to* 50: *very positive*) and emotional intensity/arousal (0: *not at all intense to* 100: *very intense*) using a visual analogue scale. E-prime software was used for stimulus presentation and response recording.

Memory performance was calculated according to the Two-High Threshold Model (Snodgrass & Corwin 1988) by means of the discrimination index Pr = H-FA, where H and FA represent hit and false alarm rates, respectively. In addition we computed the response bias Br = FA/1-(H-FA)-0.5, which is an index of the overall tendency to respond "old" or "new" regardless of accuracy. Positive values indicate a tendency to say "old" (i.e., a familiarity bias), whereas the negative side of the scale represents a novelty bias (that is, a propensity to say "new"). Importantly, Pr and Br are independent (Snodgrass & Corwin 1988).

Results

Ratings confirmed that all stimuli were judged to have valence and intensity values consistent with their a priori assignment to a specific emotional category (Figure 1). As expected, there were significant main effects of emotional category in valence and intensity rating for vocalisations, $F(3, 68) = 335.5$, $\eta^2 = 0.94$ and $F(3, 68) = 86.8$, $\eta^2 = 0.79$, respectively; $p < .001$. and music $F(3, 60) = 283.3$, $\eta^2 = 0.93$ and $F(3, 60) = 46.2$, $\eta^2 = 0.70$, respectively; $p < .001$. For vocalisations, all post-hoc pairwise comparisons were significant (ps < .001) except for fear vs sad valence and fear vs happy intensity ratings (ps = .9). In the case of music, all post-hoc pairwise comparisons for valence rating were significant (ps < .001; fear vs sad, $p = .005$), whereas all pairwise comparisons of emotional intensity were significant ($p < .001$) with the exception of fear vs happy and sad vs neutral stimuli (ps = .9).

In terms of memory performance, measured by hit minus false alarm rates, previous findings were replicated for vocalisations (Armony et al., 2007), namely a memory enhancement for all emotional vocalisations, compared to neutral ones, $F(3, 144) = 13.49$, $\eta^2 = 0.22$, $p < .001$; All post hoc ps < .05. Hit and False Alarm rates for the different categories are shown in Table 2.

There was also an effect of emotional expression on memory accuracy for music, $F(3, 144) = 27.25$, $\eta^2 = 0.36$, $p < .001$. Post-hoc comparisons revealed that this effect was due to better memory for happiness and fear, compared to neutral (ps < .001) and sadness (ps < .001). No difference between sadness and neutral music was found ($p > .05$). Results are summarised in Figure 1. The memory advantage for fearful music stimuli was mainly due to a better identification of new stimuli (i.e., lower false alarm rates) compared to neutral and sad (ps < .001). Additionally, a significant novelty response bias (i.e., tendency to say "new" regardless of accuracy; Snodgrass & Corwin, 1988) was observed for fear stimuli (Br = −0.2, $p < .001$). In the case of happy stimuli, better performance was observed for both new and old stimuli, relative to neutral and sad (ps < .001). No difference was observed in memory performance between fear and happiness for new stimuli ($p = .7$), but recognition accuracy for old items (i.e., hit rates) was greater for happy excerpts ($p < .001$).

The comparison across domains revealed a significant correlation between memory performance for music and vocalisations, $r(47) = 0.50$, $p < .001$, particularly for expressions of fear, $r(47) = 0.32$, $p < .01$.

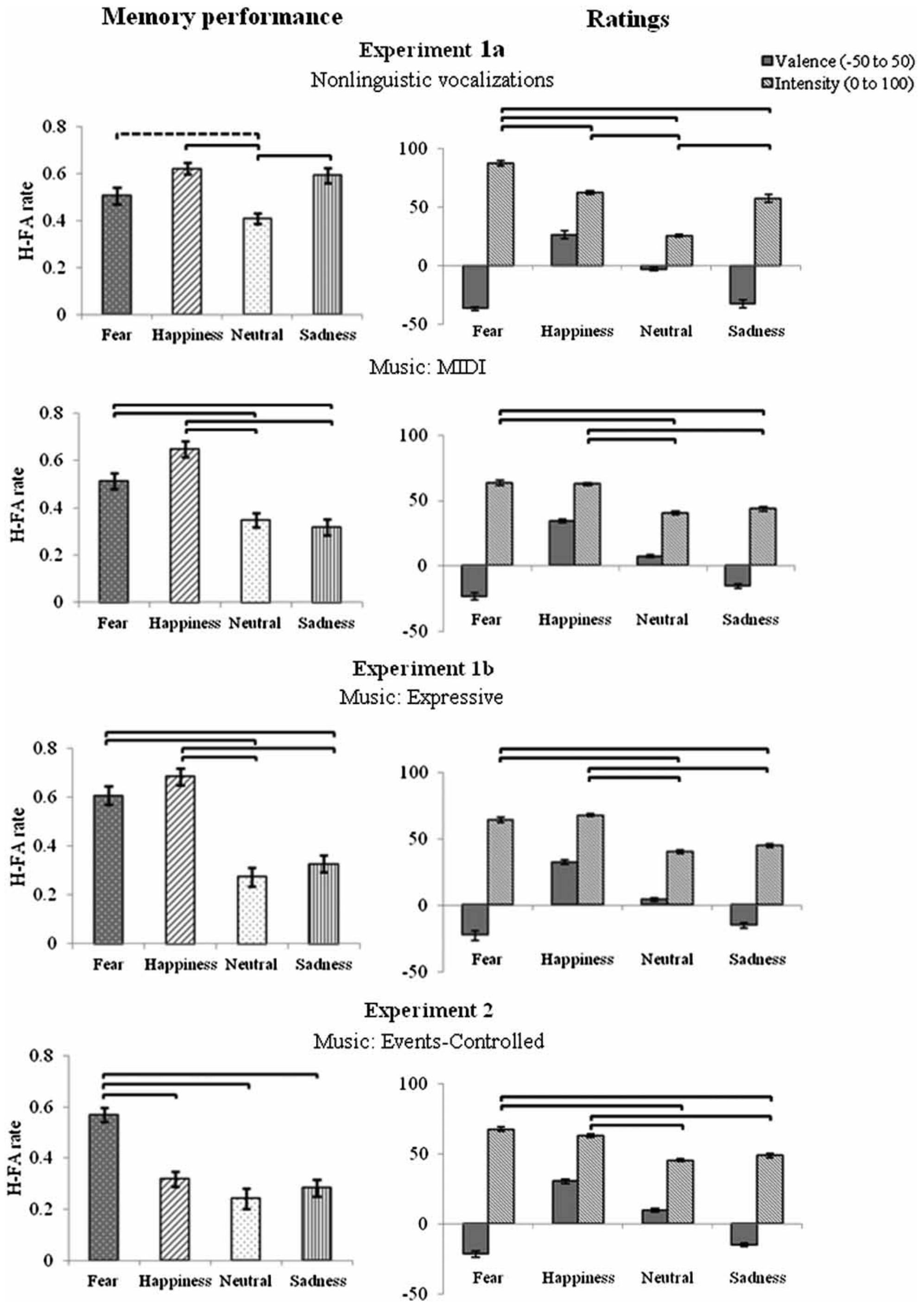

Figure 1. Memory accuracy (hit minus false alarm rates) and emotional ratings. Brackets indicate statistically significant differences between conditions (solid line: $p < .001$, dashed line: $p < .05$). For valence ratings, all pairwise comparisons between emotions were significantly different (ps $< .001$).

Analysis of confidence ratings revealed a main effect of accuracy, $F(1, 39) = 147.37$, $\eta^2 = 0.79$, $p < .001$ for vocalisations, reflecting higher confidence ratings for correct than incorrect responses, but no significant effect of emotion ($p = .08$). For music there was also a main effect of accuracy, $F(1, 42) = 154.6$, $\eta^2 = 0.79$, $p < .001$, as well as an effect of emotion, $F(3, 126) = 13.5$, $\eta^2 = 0.24$, $p < .001$, and a significant interaction, $F(3, 126) = 8.5$, $\eta^2 = 0.17$, $p < .001$. The latter was

TABLE 2
Hit (H) and False Alarm (FA) rates, Mean (*SD*), as a function of emotion for the three experiments

	Fear		*Happiness*		*Neutral*		*Sadness*	
	H	*FA*	*H*	*FA*	*H*	*FA*	*H*	*FA*
Experiment 1a (MIDI)	0.67 (0.18)	0.177 (0.18)	0.82 (0.12)	0.18 (0.18)	0.69 (0.17)	0.34 (0.18)	0.66 (0.19)	0.34 (0.20)
Experiment 1a (vocalisations)	0.84 (0.16)	0.34 (0.22)	0.75 (0.19)	0.13 (0.15)	0.79 (0.15)	0.38 (0.15)	0.77 (0.18)	0.18 (0.18)
Experiment 1b (Expressive)	0.75 (0.19)	0.15 (0.16)	0.84 (0.15)	0.17 (0.17)	0.72 (0.15)	0.45 (0.16)	0.72 (0.14)	0.38 (0.21)
Experiment 2 (events-controlled)	0.66 (0.21)	0.096 (0.11)	0.75 (0.15)	0.43 (0.21)	0.65 (0.18)	0.42 (0.24)	0.66 (0.17)	0.38 (0.20)

due to higher confidence ratings, in the case of correct responses, for fear and happy music compared to both neutral and sad ($ps < .001$), with no significant difference between the latter two ($p > .5$).

Finally there was a significant correlation between memory accuracy for music and emotional intensity, $r(62) = 0.34$, $p = .006$. However, results also revealed a significant correlation between memory accuracy and number of events included in the stimulus, $r(62) = 0.50$, $p < .001$. In fact, when entering both variables in a semi-partial correlation, only the correlation with number of events remained significant. Because duration was controlled, number of events varied among emotional categories, particularly for happiness, as a consequence of the different tempi being used (fast tempo included more events than slow tempo).

EXPERIMENT 1B

The previous experiment demonstrated an influence of emotion on memory for music. However, the musical clips used were generated by a computer and, although ratings suggest that participants correctly perceived the intended emotion expressed by each stimulus, it is possible that some of the differences with vocalisations (i.e., the lack of an enhanced memory for sad musical stimuli) could have been due, at least in part, to the differences in the ''naturalness'' or ''expressivity'' of the emotion expressed by music and voice, as the latter were all produced by real people. Indeed, although mode and tempo are crucial features in perception of emotion in music (Hevner, 1936; Peretz, Gagnon, & Bouchard, 1998), dynamic features such as timbre (e.g., attacks and frequency spectrum) also play an important role (Hailstone et al., 2009). Therefore in this experiment we sought to determine whether the effects of emotion on memory for music were the same or not when the stimuli were produced by a professional pianist rather than a computer.

Method

A professional pianist played each clip with variable degree of expressiveness and was recorded on a grand Bösendorfer piano through two DPA 4011 (X/Y) and two DPA 6006 microphones (ORTF stereo technique). The best rendition of each musical clip was edited and normalised in order to match the corresponding MIDI stimulus used in Experiment 1A using Adobe Audition.

A total of 21 new participants (14 females; mean age: 23.4 ± 3.2) with similar inclusion criteria as in Experiment 1A participated in this study. The memory procedure was identical to that of the previous experiment except that the expressive musical set was used (vocalisations were not presented). The rating procedure included both the MIDI and the expressive clips in order to compare both set of stimuli on valence and intensity scales.

Results

As expected, acoustic analysis revealed a significantly higher level of articulation for the expressive clips compared to MIDI, $F(3, 60) = 19.94$; $\eta^2 = 0.25$, $p < .001$. In addition, MIDI clips were on average significantly more precise on pulse clarity, $F(3, 60) = 52.29$; $\eta^2 = 0.47$, $p < .001$. However, MIDI and expressive musical clips were similarly evaluated in terms of valence and intensity (Figure 1). There was no main effect or interaction on either valence, $F(3, 90) = 0.62$, $\eta^2 = 0.02$, $p = .57$, or intensity, $F(3, 90) = 0.68$, $\eta^2 = 0.02$, $p = .51$. Memory scores were also very similar to those obtained in Experiment 1A using the MIDI versions of the stimuli (see Figure 1 and

Table 2); namely we found a main effect of emotion on memory accuracy, $F(3, 60) = 16{,}37$; $\eta^2 = 0.45$, $p < .001$, due to better memory for happiness and fear compared to neutral stimuli ($p < .01$, $p < .05$, respectively), and no difference between sadness and neutral music ($p > .05$). There was also a correlation between memory accuracy and emotional intensity, $r(62) = 0.56$, $p < .001$, as well as a correlation between memory accuracy and number of events, $r(62) = 0.51$, $p < .001$, consistent with results obtained in Experiment 1A. Results also revealed that participants were more confident when they correctly recognised the expressive musical clips, $F(1, 16) = 69.88$, $\eta^2 = 0.81$, $p < .001$, than when committing an error and were also more confident in their recognition of fear and happy clips compared to both neutral and sad ones (ps $< .05$), with no difference between the latter two ($p = .88$).

EXPERIMENT 2

In Experiment 1A and 1B, the length of the musical clips was equated across emotional categories, as we had previously done for vocalisations (Armony et al., 2007; Fecteau et al., 2007). While duration is arguably an important acoustic characteristic to control for in auditory research, in music, it introduces differences in other potentially important features. For example, happy musical clips contained more events than stimuli in the other categories because of their faster tempo (see Table 1). Thus it is possible that the enhanced memory observed for happy clips was, at least in part, due to the larger number of events in these stimuli. Here we matched the musical clips for number of events between emotional categories instead of duration.

Method

A total of 56 new volunteers (30 females; mean age: 24.2 ± 3.2), with similar inclusion criteria as in the previous experiments, participated in this experiment. The procedure was identical to that of Experiment 1 except that the musical clips were modified so as to contain the same number of events on average across emotional categories (Table 1). MIDI versions of musical stimuli were used as similar results were obtained with expressive musical clips in Experiments 1A and 1B. Moreover, synthesised stimuli are easier to edit than natural ones. Vocalisations were not presented.

Results

Despite the shorter duration of the musical clips, especially for those expressing happiness, each emotion category was accurately judged in terms of valence and intensity (Figure 1). As in the previous experiments we observed a main effect of emotion on memory accuracy, $F(3, 165) = 28.3$, $\eta^2 = 0.20$, $p < .001$. This time, however, the emotion effect was entirely due to a better memory for fearful stimuli ($p < .001$), as no differences between happy and neutral or sad stimuli were observed (ps $> .5$), respectively (Figure 1 and Table 2). There was also a correlation between memory accuracy and emotional intensity, $r(62) = 0.31$, $p < .01$. No significant correlation between memory accuracy and stimulus length was observed, $r(62) = 0.04$, $p = .77$. Again, participants were more confident when they were accurate in their judgement, $F(1, 53) = 188.36$, $\eta^2 = 0.78$, $p < .001$. Interestingly, they were also more confident for fearful and happy clips, despite the lack of a better memory for the latter, compared to sad and neutral clips (ps $< .001$), with no difference between these latter two ($p = .58$). As in Experiment 1a, a novelty bias was observed in the case of fear due to a significantly better accuracy in identifying new stimuli. In contrast, the previously observed better performance for new happy music expressions, compared to neutral and sad, was no longer present (ps $> .2$).

GENERAL DISCUSSION

Results from our experiments show, as hypothesised, that memory for unfamiliar short pieces of music can be modulated by their intrinsic emotional value. Specifically, we observed a consistent memory advantage for fearful musical expressions across a variety of stimulus conditions, namely changes in number of events, length, and expressivity. This finding is consistent with previous results obtained for other forms of emotional expressions, such as faces (Sergerie, Lepage & Armony, 2005) and vocalisations (Armony et al., 2007; see also Experiment 1a). The enhanced memory for fearful expressions regardless of modality is in accord with their important survival value, as they serve to inform others about the presence of impending danger (Sah & Westbrook, 2008), and the growing evidence that processing of different types of fear stimuli may engage overlapping neural regions (Peelen, Atkinson, & Vuilleumier, 2010), in particular the amygdala (for a review, see Armony, 2013). Moreover, the findings that the memory advantage for fearful music was mainly due to a better performance in identifying new stimuli is in accord with the proposed role of the amygdala in emotional novelty detection (Armony, 2013). Finally, the significant correlation in memory performance between music and vocalisations, especially for fear, lends some support to the music ‘‘invasion’’ hypothesis described earlier (Peretz, 2010). Nonetheless our results also highlight important differences in emotional processing between music and vocalisations, as different effects on memory are obtained for other emotions, particularly sadness. Interestingly, we previously observed decreased memory accuracy for sad faces, compared to neutral ones. Thus, taken together, these findings suggest that whereas certain emotions, such as fear, have common effects on memory regardless of how they are expressed, others, including sadness and happiness, have very different effects depending on the modality used to express them. Future studies, especially using neuroimaging and/or lesion techniques should provide further insights on the common and distinct neural systems involved in the processing of different emotions across modalities and domains. In particular they should help assess the possible role of the amygdala in the enhancement of memory for emotional auditory stimuli, as it has been shown in the case of visual material (Dolcos & Cabeza, 2002; Sergerie, Lepage, & Armony, 2006).

It has been suggested that stimulus arousal, or emotional intensity, might partially account for the enhancement of memory for emotional material (LaBar & Cabeza, 2006). However, our results do not support this hypothesis: although we found increased memory for happy stimuli in Experiment 1, this effect was no longer present in Experiment 2—when the number of events was similar across emotions—even though intensity ratings were similar between happy and fearful stimuli. Likewise, our results are not consistent with a valence-specific effect on memory, as there was no memory enhancement for sad stimuli despite being judged as negative as fearful ones.

Interestingly, memory accuracy was not different between the expressive (played by a pianist) and the computer-generated (MIDI) versions of the same stimuli. This provides further support to the notion that it was the intrinsic emotional information contained in the stimuli that produced the modulation of memory obtained here. Nonetheless, although the two sets differed on some acoustic parameters typically associated with expressivity (Vieillard, Roy, & Peretz, 2010), we cannot rule out a potential effect of this factor on emotional memory for music, as the stimuli used in this study were very short (around 1.5 seconds) and thus the potential added effect of expressivity on emotional evaluation and memory is likely too small. Indeed, participants did not judge the expressive clips any differently from the MIDI ones (free of musical expressiveness) in terms of valence or intensity.

Confidence ratings were also modulated by emotion: participants were more confident in their correct answers for fearful and happy musical clips in all three experiments (mechanic, expressive length-controlled, and events-controlled). This was even maintained when there was no memory advantage for happy stimuli (Experiment 2). Furthermore, participants were somewhat more confident in their correct answers for sad music stimuli in Experiments 1B (expressive length-controlled) and 2 (events-controlled), although the differences failed to reach statistical significance ($ps < .1$). These findings suggest that emotion enhances the ‘‘feeling of remembering’’ in general (Sharot, Delgado, & Phelps, 2004), even when there is no net effect on objective accuracy.

Although all stimuli were novel and thus unfamiliar to the participants, we cannot rule out the possibility that, in some cases, participants might have made an association between a given stimulus and a familiar melody to facilitate memory formation for that item. Furthermore, even though the observed enhanced memory for fearful music stimuli cannot be accounted for by any one of the basic acoustic parameters we measured (see Table 1), it remains to be determined which are the acoustic features shared among the fearful stimuli that are different from those of the other emotions, and which underlie the observed increased memory performance.

In summary, the experiments presented here demonstrate that emotion can modulate recognition memory for short, unfamiliar music excerpts, as has been shown for other types of material. Moreover, they provide further support for the proposed ''privileged'' processing of threat-related information (LeDoux, 2000). Finally our results lend some tentative support to the hypothesis of a common underlying system for the processing of emotional music and vocalisations, although further studies are needed to fully address this issue.

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