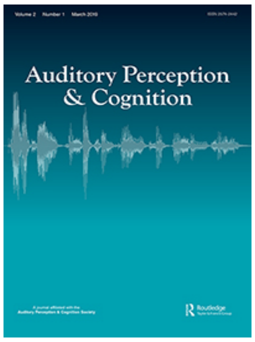

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Contextual Distinctiveness Affects the Memory Advantage for Vocal Melodies

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ABSTRACT
Memory is affected by stimulus salience. For example, vocal melodies are remembered better than instrumental melodies, presumably because of their status as biologically significant signals. We asked whether the memorability of inherently salient vocal melodies is affected by local factors such as contextual distinctiveness. In Experiments 1A and 1B, three conditions differed in the prevalence of vocal renditions (sung to *la la*) relative to piano renditions– 25%, 50%, or 75%. After asingle exposure to 24 unfamiliar folk melodies, listeners rated their confidence that each of 48 melodies (half heard previously) was old or new. In Experiment 2, contextual distinctiveness was manipulated by blocking melodies (half vocal, half piano) by timbre during exposure with mixed timbres at test, or timbres mixed at exposure and blocked at test. In Experiments 1A and 1B, the memory advantage for vocal melodies was largest when the melody set was 25% vocal, smaller but still evident when 50% vocal, and absent when 75% vocal, even with three different vocalists. In Experiment 2, both conditions yielded a similar voice advantage. The results replicated the recognition advantage for vocal melodies and revealed that contextual distinctiveness involving the prevalence of vocal melodies influenced this advantage but blocking by timbre did not.

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Recognition; distinctiveness; music; voice; timbre

Music has functioned as a mnemonic tool throughout history, as evident in the epic ballads of oral cultures and the counting and alphabet songs of childhood (Rubin, 1997). Words sung or chanted rather than spoken are recalled readily (McElhinney & Annett, 1996; Rainey & Larsen, 2002; Tillmann & Dowling, 2007; Wallace, 1994). Indeed, the melodies and words of childhood songs and chants are often recalled accurately in adulthood (Calvert & Tart, 1993; Rubin, 1977, Experiment 4). Instrumental melodies are also memorable. After two exposures to novel instrumental melodies, listeners recognize them one week later (Schellenberg & Habashi, 2015). Remarkably, melody recognition is affected minimally by as many as 100 intervening melodies between a single exposure and subsequent recognition test (Herff, Olsen, & Dean, 2018). The resilience of melodic memory to such interference contrasts with the adverse consequences of intervening items on memory for words (Bui, Maddox, Zou, &

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Hale, 2014), faces (Rakover & Cahlon, 2001), and common objects (Konkle, Brady, Alvarez, & Oliva, 2010). In short, memory for melodies is robust (Halpern & Bartlett, 2011), and in some cases irrepressible (e.g., earworms; Beaman, 2018; Jacubowski, Finkel, Stewart, & Müllensiefen, 2017).

What makes some melodies more memorable than others that are heard equally often? Structural features such as distinctive motifs (Margulis, 2014; Müllensiefen & Halpern, 2014), isochronous rhythms (Hannon & Trehub, 2005), and culturally familiar musical styles (Demorest, Morrison, Beken, & Jungbluth, 2008) influence the encoding and retention of melodies. The cross-cultural ubiquity of other features such as a limited pitch set, small intervals, two- or three-beat subdivisions, and arched contours (Savage, Brown, Sakai, & Currie, 2015) is likely to stem from ease of processing and intergenerational transmission (Trehub, 2015). Surface features of performances also contribute to the memorability of melodies. For example, vocal melodies without lyrics (*la la*) are remembered better than instrumental melodies by adults (Weiss & Peretz, 2019; Weiss, Schellenberg, & Trehub, 2017; Weiss, Trehub, & Schellenberg, 2012) and children (Weiss, Schellenberg, Trehub, & Dawber, 2015b).

Although infants exhibit long-term memory for vocal and instrumental melodies (Mehr, Song, & Spelke, 2016; Plantinga & Trainor, 2005), their memory for vocal melodies is remarkably detailed and enduring. For example, 6- and 7-month-old infants remember the original pitch level (i.e., the familiarization stimulus) of vocal melodies (Volkova, Trehub, & Schellenberg, 2006) but not instrumental melodies (Plantinga & Trainor, 2005). After 5-month-old infants are exposed to a song for 1 or 2 weeks, they recognize it several months later, successfully differentiating it from a song with a contrasting melody but identical lyrics and timing (Mehr et al., 2016).

Greater familiarity of vocal than instrumental signals for listeners of all ages and backgrounds coupled with the biological significance of the voice should promote enhanced processing of vocal stimuli (Fecteau, Armony, Joanette, & Belin, 2004). In fact, there is evidence of distinctive neural activation for vocal and instrumental music (Belin, Zatorre, & Ahad, 2002; Belin, Zatorre, Lafaille, Ahad, & Pike, 2000) as well as instrument-specific responses (Pantev, Roberts, Schulz, Engelien, & Ross, 2001). Moreover, there is speculation that the perception of music involves some degree of action simulation (e.g., Leman & Maes, 2015). Action simulation at any level of the nervous system would favor vocal over instrumental melodies except for listeners with high levels of instrumental training. On the basis of familiarity and motor representations, one would expect highly trained instrumentalists to exhibit a memory advantage for instrument-specific melodies. Nevertheless, professional pianists show the usual memory advantage for vocal over instrumental melodies and no advantage for piano melodies over banjo or marimba melodies (Weiss, Vanzella, Schellenberg, & Trehub, 2015a).

Although vocal and instrumental performances in the aforementioned studies of memory for melodies were relatively inexpressive or neutral, vocal melodies elicited greater arousal than instrumental melodies, as indicated by pupil dilation (Weiss, Trehub, Schellenberg, & Habashi, 2016). Enhanced arousal is consistent with the notion that the human voice – a conspecific, communicative signal – has natural incentive salience that rewards engagement, akin to biologically based attentional preferences for conspecific vocalizations in other species (Maney, 2013). Stimulus salience can be modulated by local or contextual factors that make some stimuli more prominent than others (Hunt, 1995; Surprenant & Neath, 2009). It is possible, then, that contextual factors could enhance or reduce the memorability of vocal melodies.

Contextual distinctiveness can be manipulated by changing the composition of study materials or lists. In fact, such manipulations have pronounced effects on memory for arousing pictures (Talmi & McGarry, 2012). Specifically, recall for negative pictures is enhanced when lists of negative and neutral pictures are mixed but not when blocked. Memory advantages that are reduced or even reversed by blocked rather than mixed lists have also been observed for word lists (McDaniel & Bugg, 2008). Changes in the prevalence of items in a list can have similar effects. For example, familiar word pairs (e.g., yellow, banana) are remembered better than novel word pairs (e.g., purple, banana) when the prevalence of familiar word pairs in the exposure list is low or balanced – 5%, 22%, or 50% – but not when prevalence is high – 78% or 95% (Reggev, Sharoni, & Maril, 2017).

Other factors that influence memory also interact with distinctiveness. The *production effect* refers to enhanced recall of words that are spoken, written, or typed rather than simply read silently during exposure (for review see MacLeod & Bodner, 2017). The effect is evident if the produced words are infrequent or balanced (20% or 50%), but not if they are frequent (80%; Icht, Mama, & Algom, 2014). This effect also disappears if *all* words in a subsequent list are produced (i.e., spoken), presumably because spoken items in the first list become less distinctive (Ozubko & MacLeod, 2010). In short, local or contextual factors such as list composition (i.e., item distinctiveness, blocked versus mixed lists) can have dramatic effects on memory.

In the present investigation, we sought to determine whether the memory advantage for vocal melodies is entirely attributable to the inherent distinctiveness of the voice, or whether aspects related to contextual or local distinctiveness (i.e., list composition) also play a role. In previous studies, participants heard mixed lists (vocal and instrumental timbres) with equal numbers of items presented in each timbre (Weiss et al., 2017, 2015b, 2012, 2016, 2015a), obscuring potential influences of list composition. To test for such contextual effects, we manipulated the prevalence of vocal and instrumental melodies. Prevalence variations also made it possible to document listeners' estimates of the relative frequency of occurrence of vocal and instrumental stimuli. According to the *availability heuristic* (Tversky & Kahneman, 1973), judgments of the frequency or probability of events are skewed by perceivers' ease of access to those events. The inherent and contextual salience of vocal melodies were expected to promote ease of processing and, in turn, overestimates of the prevalence of vocal melodies.

Previous studies of memory for vocal and instrumental melodies used either two timbres (voice, piano), for a vocal-melody prevalence of 50% (Weiss et al., 2015b, 2016), or four timbres (voice, piano, banjo, marimba), for a vocal prevalence of 25% (Weiss et al., 2017, 2015b, 2012, 2015a). A recognition advantage for vocal melodies was evident in both circumstances. In Experiment 1A of the present study, we used two timbres, voice and piano, and varied their distribution such that the prevalence of vocal melodies was 25%, 50%, or 75%. If contextual distinctiveness influences memory for inherently salient stimuli, then the memory advantage for vocal melodies should be greatest when their prevalence is lowest (e.g., 25%). In Experiment 1B, we considered whether the effects of a 75% vocal list would be similar with three vocalists (each 25%). In other words, we asked whether prevalence effects are speaker-specific rather than voice-specific.

If vocal melodies become more memorable when presented among instrumental melodies, this could be a consequence of *improving* memory for vocal materials, *inhibiting* memory for instrumental materials, or both. Study lists that are blocked at encoding, each followed by a memory test, control for this aspect of contextual distinctiveness. In the case of the production effect, blocking entire lists of words read aloud or silently eliminates the effect, whereas mixing words read aloud with words read silently in the same list enhances subsequent memory for the spoken words (Hopkins & Edwards, 1972; MacLeod, Gopie, Hourihan, Neary, & Ozubko, 2010).

Although blocking stimulus materials in this way eliminates *contextual* distinctiveness, *inherent* distinctiveness (e.g., biologically significant materials) should be unaffected except under conditions of desensitization. Nevertheless, sequential blocking alters the task from incidental encoding (i.e., an unexpected memory test) to directed encoding. After all, if participants are tested for recall following one incidental learning task, they will expect to be tested again. An alternative means of handling this issue is to block items during encoding but mix them at test, or to mix items at encoding but block them at test. The two approaches could have different consequences for encoding and retrieval processes, but little is known about the effects of these kinds of contextual manipulations. In Experiment 2, listeners received vocal and piano melodies either in blocked-timbre lists at exposure and a mixed-timbre list at test (recognition), or a mixed list at encoding and blocked lists at test. A reduction of the vocal-melody advantage by blocked trials at exposure would suggest that the advantage is due in part to competition for processing resources from one melody to the next based on its timbre. If competition for processing resources plays a limited role, then blocking should have no effect.

Experiment 1A

Vocal melodies that are mixed with instrumental melodies in the same stimulus set benefit from the inherent distinctiveness of voices and perhaps also from context or list-specific distinctiveness. In Experiment 1A, we manipulated the incidence of vocal melodies relative to instrumental (piano) melodies. We predicted that vocal melodies would be more memorable when their prevalence was low rather than high relative to instrumental melodies. To test the possibility that enhanced processing of vocal melodies results in overestimation of their prevalence, listeners were asked to estimate the prevalence of vocal melodies after completing the memory task. We expected overestimates when vocal melodies had low prevalence (and greater distinctiveness) but not high prevalence.

Method

Participants

Participants were 96 young adults (66 female, M = 20.2 years, SD = 2.2), who were assigned at random to one of three conditions that varied in the prevalence of vocal melodies: 25% vocal (n = 31; 23 female), 50% vocal (n = 32; 23 female), and 75% vocal (n = 33; 20 female). Based on the effect size for the vocal advantage observed in a similar study (partial η^2 = .11, f = .35, Weiss et al., 2016), a sample of 30 per condition was required to have 95% probability of correctly rejecting the null hypothesis.

Formal music training averaged 3.8 years (*SD* = 3.8, range: 0–15). A one-way ANOVA confirmed that participants had similar training across conditions, $F < 1$. In any event, musicianship had no effect on the voice advantage in previous research (Weiss et al., 2015a). Three additional participants were tested but excluded for self-report of partial deafness ($n = 1$), below-chance performance on the memory task ($n = 1$), or age more than three *SD*s above the mean ($n = 1$). Participants received partial course credit or token remuneration for their time.

Stimuli

The stimuli were the same 48 melodies used in Weiss et al. (2016), with the same recording and pitch-correction methods, but a different amateur female vocalist sang the melodies in the same manner (i.e., *la la*) and at the same pitch level. The change was prompted by lesser liking of vocal than piano performances for the original vocalist, but comparable liking for the new vocalist (Weiss et al., 2017). Regardless, memory for these melodies was unaffected by differential liking of timbres or singers (Weiss et al., 2017, 2012). The piano performances were identical to those used in Weiss et al. (2016). All stimuli are available online (utm.utoronto.ca/~w3psygs/#publications).

Apparatus

A customized program created with PsyScript (version 2.3; Slavin, 2007) on an Apple computer presented stimuli and recorded responses. Participants listened to the stimuli over high-quality headphones at a comfortable volume.

Procedure

Participants were tested individually in a sound-attenuating booth (Industrial Acoustics). During an initial exposure phase, they heard half of the stimulus melodies ($n = 24$), which were divided between vocal and piano timbres. In the 25% vocal condition, there were 6 vocal melodies and 18 piano melodies in the exposure phase, corresponding to the relative prevalence of vocal melodies in previous studies with four timbres (e.g., Weiss et al., 2012). In the 50% condition, there were 12 vocal melodies and 12 piano melodies, as in one previous study (e.g., Weiss et al., 2016). In the 75% condition, there were 18 vocal melodies and 6 piano melodies. To date, no studies of memory for vocal and instrumental melodies featured a stimulus set with more vocal melodies than instrumental melodies. To ensure attending, listeners rated their liking of each melody on a scale from '*1–Dislike*' to "*5–Like*," but these ratings were of no theoretical interest and not considered further. [As noted, in previous research (Weiss et al., 2017, 2012), liking was independent of memory.] Listeners were unaware that they would be tested subsequently on their memory for the melodies. Assignment of stimulus melodies to timbre and exposure level (old or new) was randomized separately for each individual. Melodies were also presented in a different random order for each participant.

After the exposure phase, participants completed a background questionnaire for approximately 5–10 min. The subsequent test phase featured all 24 previously heard (old) melodies and 24 novel (new) melodies presented in random order. The assignment of new melodies to timbre maintained the relative prevalence of vocal and instrumental melodies in the exposure phase (e.g., 6 vocal melodies and 18 piano melodies for the 25% condition). Listeners judged whether each of the 48 melodies was old or new on a scale from 1 (*definitely new*) to 7 (*definitely old*). After the memory test, participants were asked to estimate the percentage of melodies that were sung (0–100%).

Results

Memory

Four scores were calculated for each participant by averaging recognition ratings during the test phase according to timbre (voice, piano) and exposure level (old, new) (see Figure 1).[1] The number of original ratings used to calculate each average differed according to condition and timbre, but for each participant it was identical for old and new melodies. A mixed-design ANOVA with timbre (voice, piano) and exposure level (old, new) as repeated measures, and vocal prevalence (25%, 50%, 75%) as a between-subjects factor, revealed a significant three-way interaction, $F(2, 93) = 12.52$, $p < .001$, partial $\eta^2 = .212$, which motivated separate consideration of each of the three conditions.

For the 25% condition, a two-way (timbre, exposure level) ANOVA revealed significant main effects for exposure level, $F(1, 30) = 150.05$, $p < .001$, partial $\eta^2 = .833$, and timbre, $F(1, 30) = 7.92$, $p = .009$, partial $\eta^2 = .209$, which were qualified by a significant interaction, $F(1, 30) = 55.22$, $p < .001$, partial $\eta^2 = .648$. The difference in recognition ratings between old and new melodies was greater for vocal melodies than for piano melodies (see Figure 1(a)). In other words, the results replicated the memory advantage for vocal melodies (see Figure 1(b)). For the 50% vocal condition, there were again significant main effects for exposure level, $F(1, 31) = 154.70$, $p < .001$, partial $\eta^2 = .833$, and timbre, $F(1, 31) = 6.60$, $p = .015$, partial $\eta^2 = .176$, and a two-way interaction, $F(1, 31) = 8.93$, $p = .005$, partial $\eta^2 = .224$. As in the 25% condition, there was a larger difference between old and new ratings for vocal than for piano melodies – another successful replication (Figure 1(a,b)). For the 75% vocal condition, however, there were significant main effects of exposure level, $F(1, 32) = 177.92$, $p < .001$, partial $\eta^2 = .848$, and timbre, $F(1, 32) = 11.29$, $p = .002$, partial $\eta^2 = .261$, but no interaction, $p = .140$. Listeners assigned higher recognition ratings to old than to new melodies, and to vocal than to piano melodies (both old *and* new), but there was no recognition advantage for vocal melodies.

We also tested whether differences in the magnitude of the vocal advantage were associated primarily with response patterns for old melodies or for new melodies. Two mixed-design ANOVAs with factors for timbre (voice, piano) and vocal prevalence (25%, 50%, 75%) compared ratings separately for old and new melodies. For old melodies, there was a significant main effect of prevalence, $F(2, 93) = 5.50$, $p = .006$, partial $\eta^2 = .106$, a significant main effect of timbre, $F(1, 93) = 63.43$, $p < .001$, partial $\eta^2 = .406$, and a significant interaction between prevalence and timbre, $F(2, 93) = 3.11$, $p = .049$, partial $\eta^2 = .063$. As shown in Figure 1(c), old vocal melodies elicited higher ratings than old piano melodies overall, but confidence that a vocal melody was old

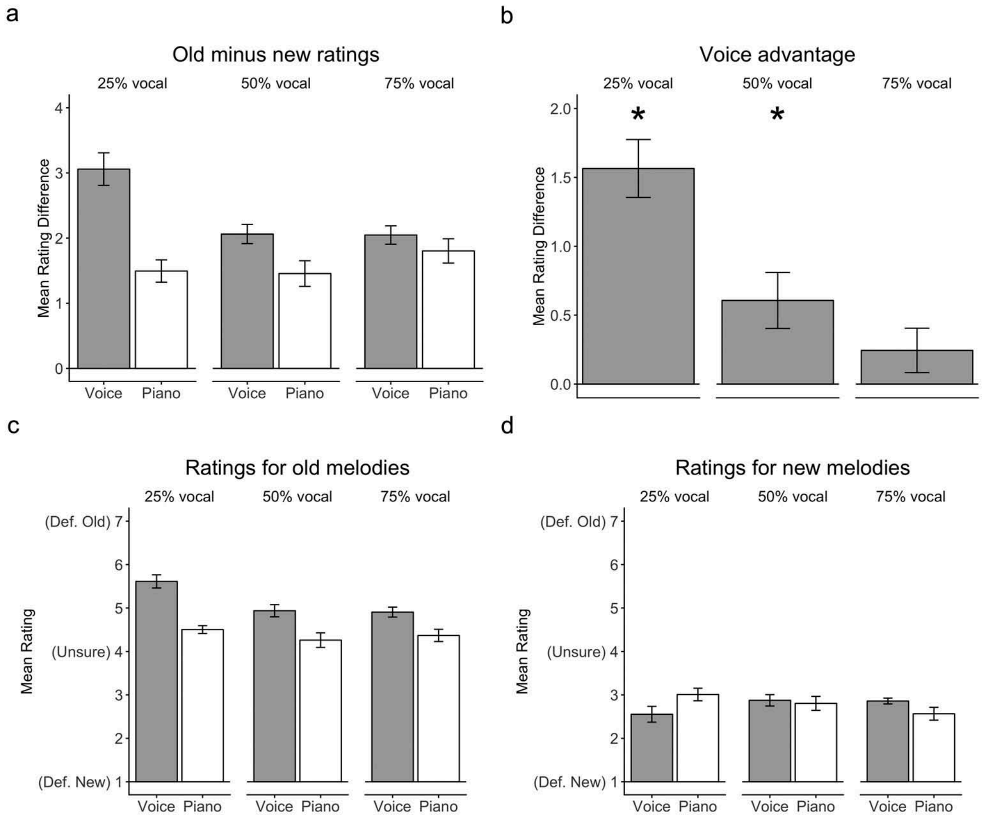

Figure 1. Descriptive statistics from Experiment 1A separately for each condition (25%, 50%, 75% vocal). Panel A: Memory as measured by mean difference in ratings for old minus new melodies, by timbre. There was a significant interaction between timbre and condition. Panel B: A voice advantage was calculated as the difference between voice and piano scores in Panel A, such that positive scores represent better memory for vocal melodies, and zero represents no difference in memory by timbre. The voice advantage was significantly greater than zero for the 25% and 50% vocal conditions but not the 75% vocal condition. Panel C: Mean ratings for old melodies by timbre. There was a significant interaction between timbre and condition. Panel D: Mean ratings for new melodies by timbre. There was a significant interaction between timbre and condition. Error bars are S.E.M.

decreased as prevalence increased. For piano melodies, ratings were similar regardless of vocal prevalence. For new melodies, there was no main effect of prevalence, $F < 1$, and no main effect of timbre, $F < 1$, but there was a significant interaction between condition and timbre, $F(2, 93) = 6.24$, $p = .003$, partial $\eta^2 = .118$. Figure 1(d) reveals that as the prevalence of vocal melodies increased, confidence that a melody was new decreased for vocal melodies but increased for piano melodies. Taken together, these results suggest that the memory advantage for vocal melodies stemmed from responses to old *and* new melodies.

In sum, vocal melodies were remembered better than piano melodies when vocal prevalence was 25% and 50%, but not when it was 75%. Differences across conditions were a function of more confident recognition of previously heard melodies as well as more confident rejection of new melodies. Finally, when we restricted the main analysis to the 25% and 50% conditions, the three-way interaction remained evident, $F(1, 61) = 10.73$, $p = .002$, partial $\eta^2 = .150$. Thus, the recognition advantage for vocal melodies was particularly strong when those melodies occurred less frequently than piano melodies (see Figure 1(b)).

Estimated Incidence of Vocal Melodies

A one-way ANOVA confirmed that estimates of the incidence of vocal melodies varied reliably across conditions, $F(2, 93) = 90.19$, $p < .001$, $\eta^2 = .660$. Tukey's tests revealed that estimates were higher in the 75% vocal condition than in the 50% vocal condition, $p < .001$, and higher in the 50% vocal condition than in the 25% vocal condition, $p < .001$. In all conditions, listeners' estimates of the prevalence of vocal melodies were not correlated with the memory advantage for the voice, *p*s > .1.

To derive an error (or bias) score separately for each participant, we subtracted the actual incidence (25%, 50%, or 75%) from the estimated incidence (Figure 2). One-sample *t*-tests revealed that listeners *overestimated* the incidence of vocal melodies (mean error score significantly greater than 0) in the 25% (by 10.6%), $t(30) = 4.22$, $p < .001$, and 50% (by 8.6%) conditions, $t(31) = 3.94$, $p < .001$, but not in the 75% condition, $p = .867$. An ANOVA confirmed that errors varied reliably across conditions, $F(2, 93) = 7.84$, $p = .001$, $\eta^2 = .144$, with listeners in the 75% condition being more accurate than those in the 25% and 50% conditions, *p*s < .01, which did not differ, $p = .779$.

Discussion

The prevalence of vocal melodies in a stimulus set of vocal and piano melodies had notable effects on memory. Specifically, the voice advantage was enhanced by increasing

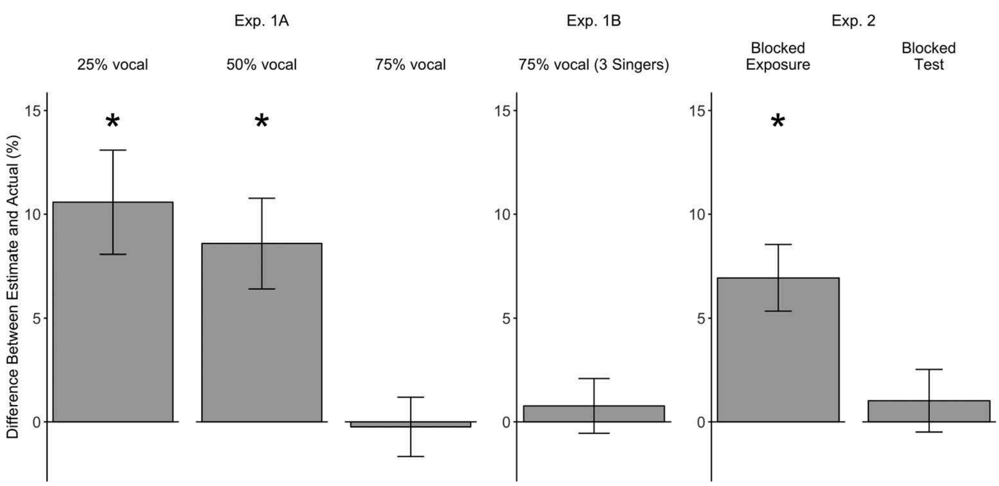

Figure 2. Mean difference between estimated and actual incidence of vocal melodies (i.e., estimation error) across all experiments and conditions. Positive scores represent overestimates of the incidence of vocal melodies. Asterisk represents significant difference from zero. Error bars are S.E.M.

the distinctiveness of vocal melodies (lower prevalence), but it was attenuated by decreasing their distinctiveness (higher prevalence). By contrast, no piano advantage resulted from the low prevalence of piano melodies. Clearly, contextual distinctiveness influences but does not account fully for the magnitude of the vocal advantage, confirming the joint contributions of inherent distinctiveness and contextual distinctiveness.

Individual differences in the prevalence estimates of vocal melodies did not predict melody recognition. Nonetheless, listeners overestimated the prevalence of vocal melodies when their prevalence was 25% or 50% – providing independent confirmation of the salience of the voice – but not when the prevalence was 75%. Future research could examine prevalence estimates over a larger range, documenting the point at which overestimates disappear (e.g., between 50% and 75%) or are maximal (e.g., < 10%).

Listeners in the 75% condition did *not* exhibit a memory advantage for the voice nor did they overestimate the prevalence of vocal melodies. Although vocal distinctiveness was reduced successfully, the factors underlying the reduction are unclear. One possibility is that the increased prevalence of vocal melodies reduced the distinctiveness of vocal material overall. Alternatively, the high prevalence of a specific voice (i.e., one singer) may have reduced distinctiveness because of neural adaptation to that individual's vocal features (Belin & Zatorre, 2003), with adverse consequences for memory. To rule out the possibility that the results in the high-prevalence condition were attributable to the use of a single vocalist, Experiment 1B compared memory for vocal and piano melodies when the prevalence of vocal melodies was high (75%) but consisted of equal numbers of melodies from each of three voices (25% each). If reduced distinctiveness and memory in Experiment 1A resulted from adaptation to a specific singer, then a voice advantage should emerge with three different singers.

Experiment 1B

Method

Participants

The sample comprised 31 participants who received course credit or token remuneration for their time. On average, they were 18.0 years of age (*SD* = 1.1; 23 female), with 2.3 years of formal music training (*SD* = 3.9, range = 0–15.5). Two additional participants were tested but excluded from the sample for deviation from experimental protocol (n = 1) or age more than three *SD*s above the mean (n = 1).

Stimuli and Apparatus

The same 48 melodies from Experiment 1A were used in the current experiment. In addition to the female vocalist and piano recordings, vocal recordings from two additional singers (one male, one female) were added from stimuli used in a previous study (Weiss et al., 2017). Male renditions were seven semitones lower than the female renditions, but all other aspects of the recordings were identical. Weiss et al. (2017) replicated the voice advantage with different vocalists but similar instruments (voice, piano, banjo, marimba). Importantly, vocal melodies were remembered better than instrumental melodies regardless of the individual singer or pitch level. In addition, no differences were observed in memory across singers.

The apparatus was identical to Experiment 1A.

Procedure

The procedure was identical to the 75% condition in Experiment 1A (i.e., melodies were 75% vocal, 25% piano) except that vocal melodies were assigned equally to three different vocalists (i.e., 25% each). The set of 48 stimulus melodies was divided equally with 12 melodies per timbre (voice 1, voice 2, voice 3, piano), and half of the melodies in each timbre ($n = 6$) were old or new. Assignment of melodies to timbre and exposure level (old or new) was randomized separately for each individual.

Results

Memory

Eight scores were calculated for each participant by averaging recognition ratings during the test phase according to timbre (voice 1, voice 2, voice 3, piano) and exposure level (old, new), with each score calculated from six original ratings. A repeated-measures ANOVA was conducted with factors for timbre (voice 1, voice 2, voice 3, piano) and exposure level (old, new). A main effect of exposure level, $F(1, 30) = 112.78$, $p < .001$, partial $\eta^2 = .790$, was driven by higher ratings for old than new melodies (Figure 3(a)). A main effect was also observed for timbre, $F(3, 90) = 3.69$, $p = .015$, partial $\eta^2 = .110$, indicating an overall bias in responses across timbres. Pairwise comparisons (Bonferroni) of all ratings (i.e., collapsed across old and new melodies) revealed lower ratings for the piano ($M = 3.60$, $SD = 0.79$) than the additional female voice (i.e., Voice 2 in Figure 3), $p = .012$, and no other differences among timbres, $ps > .075$. Finally, no interaction was observed between timbre and exposure level, $F < 1$, indicating no difference in memory across timbres. As a final confirmation, the difference in ratings between old and new melodies across *all* voices (i.e., collapsed for each individual) was compared to the difference in ratings between old and new piano melodies. In absolute terms, vocal melodies were recognized with more confidence than piano melodies (see Figure 3(b)), but this difference was not significant, $p = .337$. When considered alone, ratings for old melodies differed by timbre, $F(3, 90) = 3.24$, $p = .026$, partial $\eta^2 = .098$ (see Figure 3(c)). Pairwise comparisons (Bonferroni) revealed a difference between the additional female voice (i.e., 'Voice 2' in Figure 3) and piano, $p = .050$, but not between other timbres, $ps > .078$. Ratings for new melodies did not differ as a function of timbre, $F < 1$ (see Figure 3(d)).

Estimated Incidence of Vocal Melodies

Estimates of the incidence of vocal melodies ($M = 75.77$, $SD = 7.34$) did not differ from the actual prevalence (75%) as measured by a one-sample t-test, $p = .561$. The magnitude of the memory advantage for vocal melodies was not correlated with incidence estimates, $p = .567$.

Discussion

The results closely replicated the response patterns observed in the 75% condition of Experiment 1A. Participants were aware of the high prevalence of vocal melodies, which

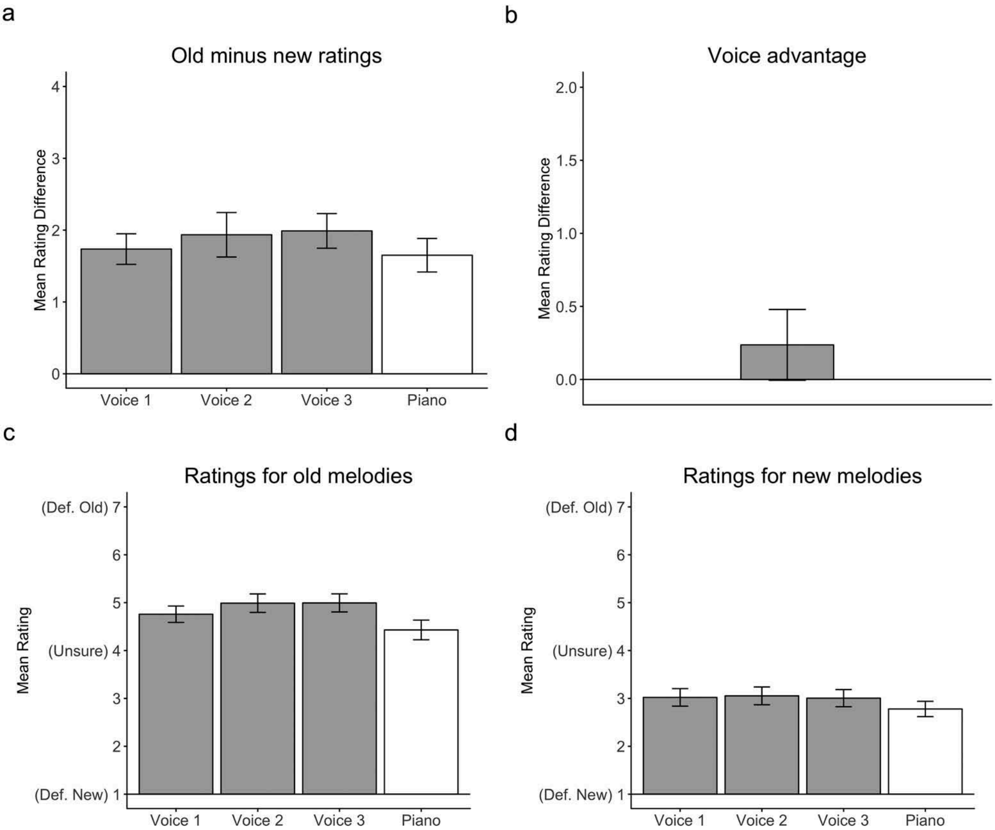

Figure 3. Descriptive statistics from Experiment 1B, which was a replication of the 75% vocal condition from Experiment 1A, but with multiple voices (Voice 1 = voice from Experiment 1A; Voices 2 and 3 = additional female and male voices, respectively). Panel A: Mean difference in ratings for old minus new melodies, by timbre. Panel B: An overall voice advantage was calculated as the difference between the average voice and piano scores in Panel A, such that positive scores represent better memory for vocal melodies, and zero represents no difference in memory by timbre. As in the 75% vocal condition of Experiment 1A, the voice advantage was not significantly greater than zero. Panel C: Mean ratings for old melodies by timbre. Panel D: Mean ratings for new melodies by timbre. Error bars are S.E.M.

were recognized no better than piano melodies. We conclude, therefore, that the absence of a vocal advantage in Experiment 1A stemmed from the decreased distinctiveness of vocal melodies overall. As with the results from Experiment 1A, the present findings confirmed that contextual distinctiveness in itself was insufficient for a memory advantage because piano melodies were remembered no better than vocal melodies when their prevalence was low (high distinctiveness).

Considered jointly, Experiments 1A and 1B indicate that increases in the contextual distinctiveness of vocal melodies enhance the vocal memory advantage, whereas reductions in their contextual distinctiveness eliminate but do not reverse the advantage. These results are consistent with the proposal that cognitive factors influence memory for emotional materials (Talmi, 2013), such that memory advantages emerge for arousal-inducing materials when they are presented with neutral materials. One interpretation is that vocal melodies outcompete instrumental melodies for memory resources when vocal melodies are contextually distinctive (i.e., equal or lesser prevalence than other stimuli). What remains unclear is the nature of the competition process. Because stimulus melodies were learned and tested in mixed, randomized lists, differences between timbres from one trial to the next could have made vocal melodies especially distinctive relative to adjacent piano melodies. Alternatively, because memory consolidation is an extended process (McGaugh, 2000), competition for memory resources may occur after initial encoding, with no consequences of contextual distinctiveness at the trial-to-trial level, at least not for our stimulus melodies.

Experiment 2

In Experiments 1A and 1B, the prevalence of vocal melodies in the stimulus set, and hence their contextual distinctiveness, moderated the degree to which these melodies were recognized. In some instances, the contextual distinctiveness of salient stimuli is also affected by stimuli that immediately precede or follow them (Talmi & McGarry, 2012). For example, an image of delicious food may be especially memorable when presented among images of drab buildings, but much less so among other images of food. Because the stimuli in Experiments 1A and 1B were presented in random order at exposure and test, the findings provided no insight into potential contributions of mixed lists to the memory advantage for vocal melodies. In the present experiment, we explored the effects of blocked or mixed lists at encoding and retrieval on memory for vocal and instrumental melodies.

Method

Participants

Participants were 97 young adults (M = 18.6 years, SD = 2.7; 79 female), who were assigned randomly to one of two conditions that blocked melodies by timbre at the exposure phase (n = 48; 36 female) or test phase (n = 49; 43 female). Formal music training averaged 4.3 years (SD = 3.9, range = 0–15) and did not differ across conditions, p = .738. Three additional participants were tested but excluded from the sample for below-chance performance on the memory task (n = 1) or age more than three SDs above the mean (n = 2). Participants received course credit or token remuneration for their time.

Stimuli and Apparatus

The stimuli and apparatus were the same as in Study 1.

Procedure

The procedure was identical to the 50% vocal condition in Study 1 (i.e., equal numbers of vocal and piano melodies) except that melodies were blocked by timbre at exposure or test. For the *blocked exposure* group, 12 vocal melodies were followed by 12 piano melodies or vice versa at exposure, whereas old and new melodies were presented in fully randomized order at test. In the *blocked test* group, melodies were presented in fully randomized order at exposure, but blocked at test such that voice trials (12 old melodies mixed with 12 new) occurred before piano trials or vice versa. For both conditions, the order of blocks (i.e., voice or piano first) was closely balanced across individuals (exposure: 25 of 48 voice first; test: 25 of 49 voice first). After the memory test, participants were asked to estimate the percentage of vocal melodies they had heard (i.e., 0–100%).

As in Experiment 1, assignment of stimulus melodies to timbre and exposure level (old or new) was randomized separately for each individual. Within blocks, melodies were presented in a different random order for each participant.

Results

Memory

Four scores were calculated for each participant by averaging recognition ratings during the test phase according to timbre (voice, piano) and exposure level (old, new), from 12 original ratings per average. A mixed-design ANOVA was conducted with timbre (voice, piano) and exposure level (old, new) as repeated measures, and blocking condition (encoding, recognition) and timbre order (voice first, piano first) as between-participants variables. Significant main effects of timbre, $F(1, 93) = 47.78$, $p < .001$, partial $\eta^2 = .339$, and exposure level, $F(1, 93) = 689.58$, $p < .001$, partial $\eta^2 = .881$, were qualified by an interaction between timbre and exposure level, $F(1, 93) = 34.60$, $p < .001$, partial $\eta^2 = .271$. The interaction was driven by a greater difference in ratings between old and new vocal melodies than between old and new piano melodies (see Figure 4(a)), signifying a recognition advantage for the voice (see Figure 4(b)). There was no main effect of blocking, $F < 1$, and no interaction between blocking and exposure level, $p = .222$, but there was an interaction between blocking and timbre, $F(1, 93) = 24.55$, $p < .001$. As shown in Figure 4(c,d), blocking at encoding led to a greater bias to label all vocal melodies as old relative to piano melodies. In any case, there was no hint of an interaction between blocking, timbre, and exposure level, $F < 1$, which shows that blocking had no appreciable effect on the magnitude of the voice advantage (see Figure 4(a,b)).

No effects were evident involving the order of timbres. Specifically, there was no main effect for timbre order, $p = .112$, no two-way interaction between timbre order and timbre, $F < 1$, or timbre order and exposure level, $p = .108$, no three-way interaction for timbre order, timbre, and exposure level, $p = .169$; timbre order, timbre, and blocking, $p = .055$; or timbre order, exposure level, and blocking,, $p = .094$; and no four-way interaction, $F < 1$. In sum, the memory advantage for vocal melodies did not differ across the four subgroups of participants.

Estimated Incidence of Vocal Melodies

Estimates of the incidence of vocal melodies were higher in the blocked *exposure* condition ($M = 56.94$, $SD = 11.01$) than in the blocked *test* condition ($M = 51.02$, $SD = 10.55$), $F(1, 95) = 7.26$, $p = .008$, $\eta^2 = .071$. For the blocked exposure condition, participants in both orders overestimated the incidence of vocal melodies (piano first: $t(22) = 3.60$, $p = .002$; voice first: $t(24) = 2.52$, $p = .019$). For the blocked test condition, estimates of the incidence of vocal melodies did not differ from the actual

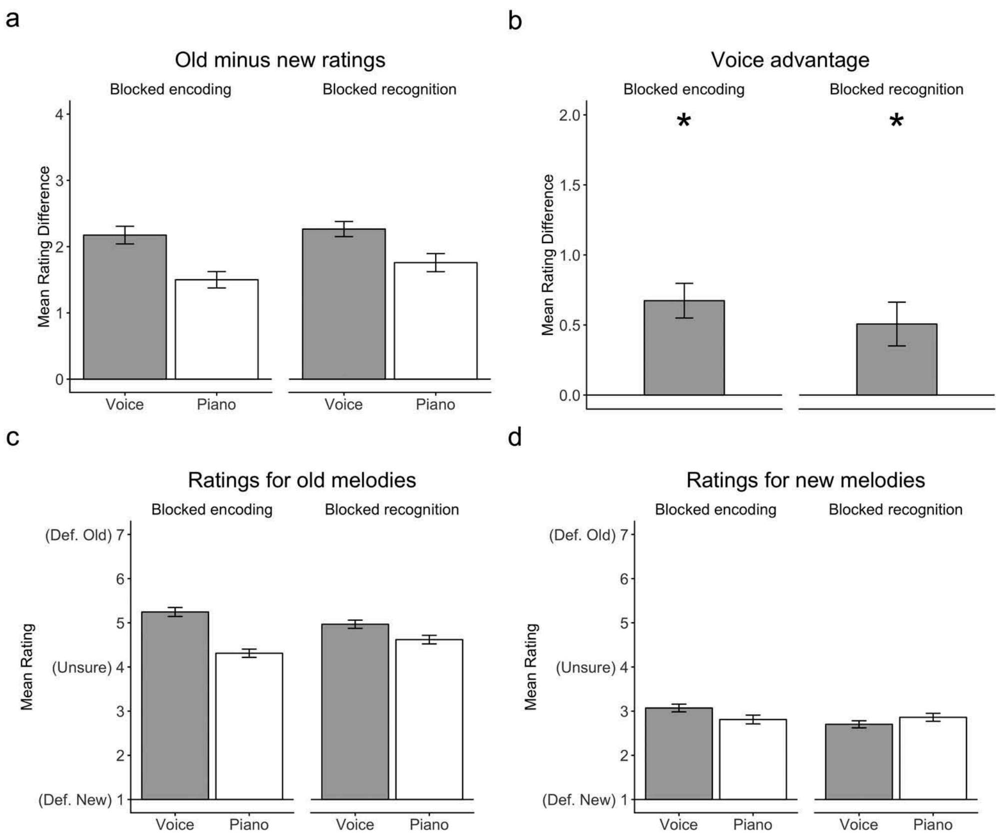

Figure 4. Descriptive statistics from Experiment 2, reported separately for each condition (blocked at encoding, blocked at recognition test). Panel A: Mean difference in ratings for old minus new melodies, by timbre. Panel B: A voice advantage was calculated as the difference between voice and piano scores in Panel A, such that positive scores represent better memory for vocal melodies, and zero represents no difference in memory by timbre. The voice advantage was significantly greater than zero in both conditions and similar in magnitude to the 50% vocal condition in Experiment 1A. Panel C: Mean ratings for old melodies by timbre. Panel D: Mean ratings for new melodies by timbre. Error bars are S.E.M.

incidence in either order, (piano first: p = .187; voice first: p = .669). Perhaps switching timbres halfway through the memory test, which contained balanced numbers of target and foil melodies for each timbre, provided extra cues to these participants. As in Experiments 1A and 1B, estimates of the incidence of vocal melodies were not correlated with the vocal-recognition advantage, p = .266.

Discussion

Blocking melodies by timbre at exposure or test did not alter the magnitude of the memory advantage for vocal melodies. In fact, the magnitude of the voice advantage – the difference between timbres in recognition ratings for old and new melodies – was not reduced here (M = 0.59 across conditions) compared to the 50% vocal condition of

Experiment 1A (M = 0.50), when melodies were presented in mixed lists at exposure and test. In short, contextual distinctiveness arising from trial-to-trial differences between timbres was unrelated to the voice advantage. Instead, the benefits of contextual distinctiveness appear to stem from competition for processing resources during subsequent memory consolidation. The present findings do not rule out the possibility that a fully blocked task (i.e., pure-list encoding followed by pure-list testing) would eliminate the voice advantage. With timbre as a within-participants manipulation, however, listeners would be aware of the second memory test before exposure to the second list.

General Discussion

We assessed the influence of contextual or local distinctiveness on the documented memory advantage for vocal melodies over instrumental melodies (Weiss & Peretz, 2019; Weiss et al., 2017, 2015b, 2012, 2016, 2015a). In Experiment 1A, vocal melodies were mixed with piano melodies at encoding and test in a way that varied the prevalence of vocal melodies relative to piano melodies (25%, 50, or 75%). The memory advantage for vocal melodies was highest when the voice was most distinctive (25% prevalence) and lower but still evident when the voice and piano were equally distinctive. The advantage was eliminated but not reversed when the voice was least distinctive (75% prevalence). This null finding was replicated in Experiment 1B with three voices (each with 25% prevalence) rather than one, which ruled out the possibility that listeners habituated to the single vocalist in Experiment 1A. In Experiment 2, the memory advantage for vocal melodies was unaffected by the blocking of timbres, either at encoding or during the recognition test.

These findings indicate, for the first time, that the memory advantage for vocal melodies is influenced by the *contextual* distinctiveness of the voice in addition to its inherent distinctiveness. In other words, the biological salience of the voice (Poremba, Bigelow, & Rossi, 2013) is not entirely responsible for the documented memory advantage for vocal melodies. Although contextual distinctiveness, as reflected in low prevalence in the stimulus set, enhanced the memorability of vocal melodies, it did not enhance the memorability of piano melodies (Experiments 1A and 1B), which highlights the special status of the voice. Moreover, it should be emphasized that enhanced processing of vocal stimuli was evident in significantly better recognition of vocal melodies than instrumental melodies under conditions of equal contextual distinctiveness in the present study and in earlier work (Weiss et al., 2016).

Previous research suggests that mixed sets of emotional and neutral stimuli elicit a memory advantage for emotional stimuli more readily than blocked stimuli (e.g., Talmi & McGarry, 2012). Nevertheless, the blocking of piano and vocal melodies during encoding or recognition in Experiment 2 did not affect the voice advantage, which implies that perceptual and memory processing continued for several minutes beyond initial encoding. This issue could be addressed by increasing the temporal separation of encoding (or recognition) blocks. Because memory consolidation processes wane after stimulus presentation, competition for processing resources may wane as well. It is also possible that direct competition for perceptual and memory resources (e.g., Mather & Sutherland, 2011) could yield a more robust voice advantage if the vocal melodies *overlapped* with instrumental music, as in cases of vocal melodies with instrumental accompaniment.

It would also be of interest to explore associations between contextual distinctiveness and physiological measures of attention or arousal. Previous research revealed enhanced arousal for vocal melodies relative to instrumental melodies, as reflected in increased pupil dilation (Weiss et al., 2016). It remains to be determined whether the prevalence of vocal melodies affects arousal as well as memory.

Another provocative finding was the overestimated prevalence of vocal melodies in conditions that revealed a vocal memory advantage (25% and 50% vocal conditions in Experiment 1A; blocked-encoding condition in Experiment 2), but accurate estimates in conditions with no voice advantage (75% vocal conditions in Experiments 1A and 1B). One exception was the blocked-test condition in Experiment 2, which yielded a voice advantage as well as an accurate prevalence estimate. In that instance, an additional cue to prevalence was the switching of timbres midway through the test phase. Across all 224 participants (Experiments 1A, 1B, and 2 combined), the correlation between the magnitude of the voice advantage and the overestimated prevalence of vocal melodies did not reach significance, $r = .13$, $p = .052$. Nevertheless, participants' phenomenological experience may offer insight into mechanisms underlying the memory advantage. For example, the inherent salience of vocal materials may increase attention to the stimulus, resulting in elaborated encoding (e.g., thoughts about the singer, performance, or composition) and, consequently, enhanced recognition or recall. In principle, prevalence overestimates for the voice could stem from ease of access to elaborated memory traces (Tversky & Kahneman, 1973). Such an effect could occur in parallel with other memory processes related to distinctiveness.

In view of the effects of contextual distinctiveness on a range of social and emotional stimuli (Barnacle, Tsivilis, Schaefer, & Talmi, 2017; Talmi & McGarry, 2012; Talmi et al., 2012), it would be of interest to ascertain its impact on emotional responses to music (Koelsch, 2014). For example, undergraduate listeners typically prefer happy- over sad-sounding music when tested in the laboratory (Husain, Thompson, & Schellenberg, 2002; Thompson, Schellenberg, & Husain, 2001). This bias disappears, however, when multiple happy-sounding pieces are presented in succession (Schellenberg, Corrigall, Ladinig, & Huron, 2012). Vocal melodies may also become less engaging when listeners hear multiple examples. Other mechanisms that influence emotional responding to music (Juslin & Västfjäll, 2008) could be moderated similarly by contextual distinctiveness.

Models of immediate enhancement of emotional materials emphasize the role of cognitive factors such as attention, stimulus relatedness, and distinctiveness (Talmi, 2013). Delayed effects of emotion are thought to result from more extended processes of memory consolidation (LaBar & Cabeza, 2006). The interaction of cognitive factors and early memory consolidation processes (i.e., 5–10 min break between encoding and test blocks in the present task) seems relevant to mechanisms underlying the current results. The effects of shorter versus longer delays between encoding and test or memory consolidation processes during sleep are important areas for future research on emotional memory enhancement (Baraly, Hot, Davidson, & Talmi, 2017). Such manipulations have yet to be explored with the recognition advantage for vocal melodies.

Conclusion

Our findings provide insight into the memory advantage for vocal melodies by delineating boundary conditions for such an advantage, most notably a contribution of contextual distinctiveness, and confirming that the voice holds dual status as a biological signal and a musical instrument. Conditions that elicit enhanced processing of vocal music may inform the processing of other biologically salient signals such as faces and nonmusical vocalizations. Moreover, these conditions are relevant to everyday experiences with stimuli that elicit arousal, including music in general. The pleasure derived from listening to music depends in part on the anticipation of expected segments and repetition in a composition (Margulis, 2014). Liking for musical pieces tends to increase with repetition, within limits (Szpunar, Schellenberg, & Pliner, 2004), but it is unclear why music holds its charm. Inherent and contextual distinctiveness offer clues to some of the factors that matter.

Note

1. Analyses were performed on ratings of recognition confidence rather than d' because the small number of trials in some cells of the design led to the occurrence of extreme proportions (i.e., 0 or 1) when ratings were converted to hits and false alarms. Moreover, because the number of trials per timbre varied across conditions, standard corrections for extreme proportions could yield different d' scores for the same levels of performance.

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