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More than a feeling: Emotional cues impact the access and experience of autobiographical memories

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Abstract Remembering is impacted by several factors of retrieval, including the emotional content of a memory cue. Here we tested how musical retrieval cues that differed on two dimensions of emotion—valence (positive and negative) and arousal (high and low)—impacted the following aspects of autobiographical memory recall: the response time to access a past personal event, the experience of remembering (ratings of memory vividness), the emotional content of a cued memory (ratings of event arousal and valence), and the type of event recalled (ratings of event energy, socialness, and uniqueness). We further explored how cue presentation affected autobiographical memory retrieval by administering cues of similar arousal and valence levels in a blocked fashion to one half of the tested participants, and randomly to the other half. We report three main findings. First, memories were accessed most quickly in response to musical cues that were highly arousing and positive in emotion. Second, we observed a relation between a cue and the elicited memory's emotional valence but not arousal; however, both the cue valence and arousal related to the nature of the recalled event. Specifically, high cue arousal led to lower memory vividness and uniqueness ratings, but cues with both high arousal and positive valence were associated with memories rated as more social and energetic. Finally, cue presentation impacted both how quickly and specifically memories were accessed and how cue valence affected the memory vividness ratings. The implications of these findings for views of how emotion directs the access to memories and the experience of remembering are discussed.

Keywords Autobiographical memory · Memory organization · Emotion · Retrieval cues

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It is well accepted that emotions impact how we remember our personal past. Research has shown that the emotional *content* of a past experience alters how it is later remembered (for examples, see Berntsen & Rubin, 2002; Rimmele, Davachi, Petrov, Dougal, & Phelps, 2011; Sharot, Verfaellie, & Yonelinas, 2007; St. Jacques & Levine, 2007; Talarico, LaBar, & Rubin, 2004), and a number of studies have compared the impacts of positive and negative emotional cues on the ways that clinical populations access memories (for examples, see Dalgleish et al., 2007; Williams & Broadbent, 1986). Little research, however, has examined how the distinct emotional features of a retrieval cue impact the way that an autobiographical memory is recalled and the circumstances under which this occurs in healthy populations. Understanding how aspects of emotion at retrieval can trigger different experiences of the past is necessary for a true understanding of the link between emotions and memory. To address this knowledge gap, we tested how the emotional characteristics of a retrieval cue (valence and arousal) impact both the cue's effectiveness at triggering remembering and how an event is remembered at recall. We also tested the effects of memory cue emotion under two retrieval circumstances—in one condition we presented blocks of similar emotional cues as means of inducing an emotional retrieval state, and in another the cues were presented randomly. Thus, in the present study we aimed to provide new evidence of how the emotional features of a retrieval cue modulate the way we remember. In the following sections, we review work from two areas of

research—emotional autobiographical memory and emotionally cued retrieval—that inspired the present study.

Emotional autobiographical memory retrieval

A large body of work has indicated that emotional life events are recalled better than nonemotional events and that certain emotional characteristics affect remembering in different ways (e.g., Holland & Kensinger, 2010; Rimmele et al., 2011). Two distinct aspects of emotion that have received much attention in this area of research are emotional *valence* (the positive or negative content of the emotion) and *arousal* (the intensity of the emotion; Ford, Addis, & Giovanello, 2012; for more in-depth discussions of these emotional characteristics, see Posner, Russell, & Peterson, 2005; Russell, 1980).

Research has documented differences between recalling memories of different valences—positive versus negative autobiographical events. This work has indicated that positive events are recalled more easily and directly, due to an overall bias toward accessing positive life experiences (Berntsen, Rubin, & Siegler, 2011; Walker, Skowronski, & Thompson, 2003). Positive and negative events are also thought to differ qualitatively at recall. Whereas some studies have suggested that positive autobiographical memories are remembered less specifically than negative events (e.g., Walker et al., 2003), others have reported enhanced recovery of peripheral sensory and contextual details for positive as compared to negative memories (Berntsen, 2002; D'Argembeau, Van der Linden, Etienne, & Comblain, 2003; Ford et al., 2012; Kensinger & Schacter, 2006; Schaefer & Philippot, 2005). Negative past experiences, on the other hand, tend to be recalled with more focus on the central event and are remembered with greater emotional intensity than positive memories (Berntsen, 2002; Talarico, Berntsen, & Rubin, 2009).

Another area of research has indicated that emotional arousal during an experience leads to better (i.e., more detailed/vivid) recollection. This work has suggested that emotional arousal—not valence—during encoding is the critical determinant of how emotion will modulate autobiographical memory retrieval. For example, the ability to recall emotionally intense events vividly—flashbulb memories—is thought to be due to their high emotional arousal levels (Finkenauer et al., 1998; Talarico & Rubin, 2003). However, other researchers (Schmidt, Patnaik, & Kensinger, 2011) have noted that this conclusion from studies with flashbulb memories may be biased, since most of these memories tend to be negative (e.g., recalling the Challenger explosion or 9/11). It could be that emotional arousal interacts with the valence of a memory to affect the vividness of recall.

One study attempted to disentangle the effects of the valence and arousal levels of a remembered event by asking participants to recall a series of autobiographical memories that ranged in arousal and valence and to rate each of these memories on several retrieval dimensions, including how richly the memory was recalled. A key finding from this study was that the variability among the retrieval dimensions was determined better by the memory's emotional arousal than by its valence (Talarico et al., 2004). A more recent examination looked at the interplay between a remembered event's emotional arousal and valence levels on remembering factors and found that these emotional features interactively affected how a retrieved memory representation was experienced (Ford et al., 2012). Specifically, positive memories, irrespective of arousal, were recalled with high levels of memory specificity and vividness, but only highly arousing negative memories were associated with specific memory recall. This finding, in concert with independent studies that have shown that the valence and arousal levels of a memory affect distinct components of autobiographical retrieval (e.g., Berntsen, 2002; Bohanek, Fivush, & Walker, 2005; Talarico et al., 2009; Talarico et al., 2004), suggests that the interaction between valence and arousal should be studied to understand the effects of emotion on memory. We sought to build off these reports that a remembered event's emotional valence and arousal levels—the emotion present at the time of *encoding*—affect the experience of remembering, in order to test how a retrieval cue's valence and arousal levels—the emotion present at the time of *remembering*—impact the access to and experience of an autobiographical memory.

Emotional retrieval factors and autobiographical memory

An early research example of how emotional factors at retrieval affect the way past events are accessed is mood-dependent remembering, which was popularly described by Bower in the 1980s. In one of his more famous studies, Bower used hypnosis to induce a positive or negative mood in participants, and then assessed the impact of this mood induction on autobiographical recollection. He found that participants in positive or negative moods tended to recall memories that matched their current emotional state—their mood (Bower, 1981). Since Bower's work, investigations have continued to see if mood at retrieval prompts the recall of emotionally similar autobiographical memories, a phenomenon referred to as mood-congruent memory. This phenomenon is often explained as an emotional state at retrieval activating an underlying network that is shared by autobiographical memories of a similar affective state. That is, the emotionally induced activity of one's mood primes memories of a similar emotional quality, making it easier to access these emotionally related events (Blaney, 1986; Lewis, Critchley, Smith, & Dolan, 2005; Matt, Vazquez, & Campbell, 1992).

Mood-congruent memory inspires several questions about how emotion at retrieval can modulate remembering, including if and how emotional retrieval cues impact autobiographical memory retrieval. This follows a larger body of work investigating how aspects of a retrieval cue—from cue modality (Zator & Katz, 2016) to imageability and predictability (Rasmussen & Berntsen, 2014; Williams, Healy, & Ellis, 1999)—modulate the qualitative experience of remembering. In this area of research, a few studies have looked at the influence of the emotional characteristics of a cue on autobiographical memory in clinical samples (e.g., depression) and these studies are often limited to comparing the ability to access autobiographical memories in response to positive and negative cues (Dalgleish et al., 2007; Williams & Broadbent, 1986), making these investigations not well suited to examine the effect of emotional arousal. An effective method to systematically examine the effect of a cue's emotional valence and arousal on remembering is to use musical stimuli (Belfi, Karlan, & Tranel, 2016; Janata, 2009; Janata, Tomic, & Rakowski, 2007). Using musical cues, Schulkind and Woldorf (2005) examined the differential impacts of the valence and arousal levels of retrieval cues on the emotional content of recalled autobiographical memories. They found that a cue's emotional valence related to the valence of the retrieved memories, but there was no match between the cue and memory arousal levels. These results suggest that emotional valence is the predominant organizing factor for the emotional content of autobiographical memories; however, the impact of emotional aspects of a cue on access to other facets of the autobiographical memory retrieval experience was not examined in this experiment. In fact, little work has examined the way emotional characteristics of a cue affect the nature of memory retrieval despite this knowledge being critical for a full understanding of the link between emotion and remembering.

The literature provides some indications that a cue's emotional features—valence and arousal—will affect aspects of remembering beyond emotion. First, the emotional autobiographical memory literature that is reviewed earlier in the introduction suggests that valence and arousal at encoding can distinctly affect how vividly or detailed a memory is recovered (e.g., Ford et al., 2012) as well as the ability (i.e., speed) to access a memory (e.g., Berntsen, 1996). If emotion is operating on memory processes in a similar fashion at retrieval as encoding, then similar findings would be expected when manipulating these emotional features of a cue and when manipulating these features of the memory. Second, remembering serves several adaptive functions, including developing a sense of self (Conway, Singer, & Tagini, 2004) and supporting social functions (Alea & Bluck, 2003), which means that the emotion of a cue may intrinsically sway an individual to recall memories of different content to serve these functions. Regarding valence, positive cues may be more likely to trigger general memories that are social in nature, contributing to a more positive sense of self and social well-being by linking positive feelings with a more encompassing and social view of one's past (Alea & Bluck, 2003). Negative emotions, particularly those that are highly arousing, may be more strongly linked to memories that are unique as a means of compartmentalizing negative past events. Finally, there is also strong evidence that emotional arousal is the key factor in determining how well (i.e., in how much detail) past events are recalled (Anderson, Wais, & Gabrieli, 2006; Knight & Mather, 2009), which would lead to the prediction that arousal levels of a cue will predict how a memory is recalled, regardless of valence.

Overview of the current study and predictions

The overall objective of the present study was to determine how the emotional characteristics of retrieval cues impact the accessibility and qualitative experience of autobiographical memory recall by testing some of the above described predictions. To meet this objective, we contrasted the impact of novel musical cues that were positive or negative in emotional valence and high or low in arousal on three aspects of autobiographical memory retrieval. First, we examined autobiographical memory accessibility through response time estimates. Second, we assessed the relationship between cue and memory valence and arousal by collecting measures of event valence and arousal and relating this to the valence and arousal of the memory cue (Schulkind & Woldorf, 2005). Finally, we examined the quality of the memories by collecting ratings of memory content and experience that are known to vary with music-induced remembering (Belfi et al., 2016; Krumhansl & Zupnick, 2013). With respect to this final issue, we were specifically interested in examining how the emotional characteristics of the cue (valence, arousal) related to the experience of remembering, particularly how memory vividness related to aspects of the remembered event (i.e., the content of the memory) following on findings from Ford et al. (2012) that indicates emotion enhances the richness (vividness) of remembering (see also Ochsner, 2000).

Another issue that we addressed in this study is how manipulating cue presentation can affect the way emotional features of a cue modulate remembering. This fits with a recent study in which emotional stimuli presented over extended blocks resulted in "carryover" emotional effects to subsequent tasks (Tambini, Rimmele, Phelps, & Davachi, 2016). This finding raises questions about how presenting emotional retrieval cues in a blocked or a random fashion affects memory processing. We suggest that presenting stimuli in a blocked but not a random fashion may affect memory at the mood level by altering one's current emotional state (Tambini et al., 2016). To address this issue, half of our participants

recalled memories to cues administered in a blocked fashion (i.e., all high-arousal positive cues together; all low-arousal negative cues presented together), and the other half recalled memories to cues that were presented randomly, so that we could contrast exposure to emotional cues in a fashion that was reminiscent of mood induction techniques (the blocked condition; Vastfjall, 2002) versus exposure to the emotion cue at a shorter interval (randomized condition).

On the basis of the above-reviewed literature, our main predictions were as follows:

1. Given evidence for a bias to recall positive (i.e., happy) memories and life experiences (Berntsen et al., 2011; Walker et al., 2003), we predicted that positive and high arousal—happy—cues would result in quicker and more specific access to autobiographical memories than would cues of different valence and arousal combinations.
2. Following the findings reported from Schulkind and Woldorf (2005), we predicted that emotional valence and not arousal would activate autobiographical memories of similar emotional content, illustrated by a relation between the cue and memory valences, but not between the arousal ratings.
3. We expected that both cue valence and arousal would have distinct influences on nonemotional aspects of the memory. Testing the suggestions listed in the previous section, we expected positively valenced cues to affect the vividness and social content of memories, and negatively valenced cues to affect the uniqueness of the recalled event. Given the reported broad impact of arousal on memory, we predicted that cue arousal would have a generalized effect on memory retrieval vividness, irrespective of valence.
4. Finally, when comparing cue effects under two retrieval circumstances—one in which similar emotional cues were presented over a long interval (akin to mood induction), and one in which a particular type of cue activation lasted only a short time interval—we expected to see that these conditions distinctly linked emotion to remembering. Given the lack of research in this area, this analysis was exploratory in nature.

To test these predictions, 32 music clips that represented all four combinations of high and low valence and arousal (happy, peaceful, scary, or sad) were presented to young healthy participants, who retrieved and reported on the first autobiographical memory that came to mind while they listened to each music clip. Once a memory was accessed, participants provided a brief description of the recalled event and rated their recollection on a series of dimensions that assessed both the nature of the memory retrieval (ratings of memory vividness, the uniqueness of the memory, and the social aspect and energy felt during the remembered event) and the emotional content of the recalled event (ratings of the emotional valence and emotional arousal). We determined how variability in response times and in these ratings was related to the valence and arousal of the cues.

Materials and method

Participants

A total of 48 participants completed the experiment. These participants were recruited through McGill University's Department of psychology human participant pool as well as through advertisements on the McGill University campus. Participants were screened to ensure that they were fluent English speakers, free from known neurological or psychological conditions, and that they had normal or corrected-to-normal vision and hearing. Participants were granted either two course credits or $10/hour in exchange for their participation. All participants gave informed consent. Of these 48 participants, 24 were randomly assigned (mean age = 20.17 years, range = 18 to 25 years, *SD* = 1.76; 20 female, four male) to the blocked condition, and 24 to the randomized condition (mean age = 20.75 years, range = 18 to 25 years, *SD* = 1.67; 22 female, two male).

Stimuli

The memory retrieval cues were selected from Vieillard et al.'s (2008) study, which provided solo-piano classical musical cues that empirically varied in emotional valence (positive or negative) and arousal (high or low), resulting in four retrieval cue conditions: happy (positive, high arousal), peaceful (positive, low arousal), scary (negative, high arousal), or sad (negative, low arousal; Vieillard et al. 2008, ©). Vieillard and colleagues created all of the musical stimuli, so the music was novel and not subject to the effects of musical familiarity. We randomly selected 32 cues from their sample (eight from each condition) that were an average of 12.3 s in duration (range = 8–16 s). The emotional characteristics of the selected cues are presented in Table 1.

Table 1 The average emotional arousal and valence ratings (standard errors shown in parenthesis) for the musical stimuli used as retrieval cues in the present study

Cue Type	Categorization	Valence Rating	Arousal Rating
Happy	Positive, High arousal	6.69 (0.36)	7.88 (0.61)
Peaceful	Positive, Low arousal	6.74 (0.27)	2.61 (0.44)
Scary	Negative, High arousal	3.66 (1.00)	7.5 (0.78)
Sad	Negative, Low arousal	5.34 (0.55)	2.54 (0.58)

The stimuli are courtesy of Vieillard et al. (2008).

Procedure

The experiment was run using E-Prime 2.0 software. In individual testing sessions, participants listened to all 32 musical cues over two testing blocks. In the first block, participants were asked to recall an autobiographical event to each of the 32 musical cues. Participants were instructed to recall events that they were personally involved in, that were specific in place and time, and that lasted no longer than one day. Participants were played each cue for up to 30 seconds (cues were repeated within this time window, with a repetition average of 1.01 times). They made a keypress response while listening to the cue as soon as a memory came to mind. If no memory was recalled within the 30 second cue-playing period, the trial was counted as an omission. Once participants made a keypress response, the musical cue stopped and the participants typed a brief (one to two sentences) description of the accessed memory, indicated where it occurred, and classified when it occurred on a 6-point scale (1 = *Past week*, 2 = *Within the last year*, 3 = *Between 1 to 5 years of age*, 4 = *Between 5 and 10 years of age*, 5 = *Over 10 years of age*, and 6 = *Don't know*). Participants then rated their memory retrieval on the following dimensions:

- Vividness of memory retrieval, rated on a scale from 1 (*no images*) to 6 (*extremely vivid*)
- Uniqueness of the memory, rated on a scale from 1 (*it happens all the time*) to 6 (*once in a lifetime*)
- Social content of the memory, rated on a scale from 1 (*not at all*) to 6 (*extremely social*)
- Energizing nature of the memory, rated on a scale from 1 (*not at all*) to 6 (*extremely energetic*)

The memories themselves were rated on two emotional scales:

- Emotional content of the memory, rated on a scale from 1 (*very negative*) to 6 (*very positive*)
- Emotional intensity of the memory, rated on a scale from 1 (*not at all*) to 6 (*extremely*)

See Fig. 1 for a visualization of this paradigm.

For the participants in the blocked condition, the cues were presented such that all eight cues relating to each cue condition (happy, peaceful, scary and sad) were presented together. The order of the cues within each block was random and the order of the blocks was counterbalanced across participants. For the participants in the randomized condition, all 32 musical cues were presented randomly rather than blocked according to the cue condition.

For all participants, a second testing phase proceeded in which participants listened to the 32 music clips for a second time, which were now presented in random order. Participants were asked to rate how much they enjoyed listening to the music on a scale from 1 (*a little*) to 6 (*extremely*), and to describe the emotion depicted in each clip by typing in an emotion that described their feelings and to rate this feeling for its intensity. These emotion descriptions were not analyzed due to the number of omissions and variations in responses made.

Data analysis

Memory categorization Participant's brief memory descriptions were scored using methods associated with the autobiographical memory test (Williams & Broadbent, 1986). Each description was assigned one of the following five ratings.

- *Specific*: The participants described an event that they personally took part in that transpired in one location and lasted for less than 24 h. An example of a specific memory would be "My sister's 21st birthday party."
- *Extended*: The participant described an event that lasted for longer than 24 h. For example: "The summer I hitchhiked across Canada."
- *Categoric/repeated*: The participant described regularly occurring events. An example of a categoric/repeated event would be "Going to Starbucks to get coffee every morning."
- *Semantic*: The participant did not describe a memory, but a general thought. An example of a semantic recollection would be "This music reminds me of the ocean."
- *Omission*: This rating was assigned if no memory was recalled within 30 seconds.

Given our interest in specific autobiographical memory retrieval, we focused our analyses on the number and retrieval aspects of specific memories that were generated in each cue condition.

Statistical analyses The impact of the valence and arousal of the musical cues on autobiographical memory retrieval was examined using chi-square analyses for categorical data or mixed analyses of variance (ANOVAs) for continuous data with Valence and Arousal as within-subjects factors and Cue Presentation (blocked vs. randomized) as a between-subjects factor. To investigate significant main effects and interactions, we conducted post-hoc *t* tests. We also used regression models to examine the predictors of vividness for each cue condition and to test our fourth prediction, that vividness would be related to different characteristics of a recalled event in each cue condition.

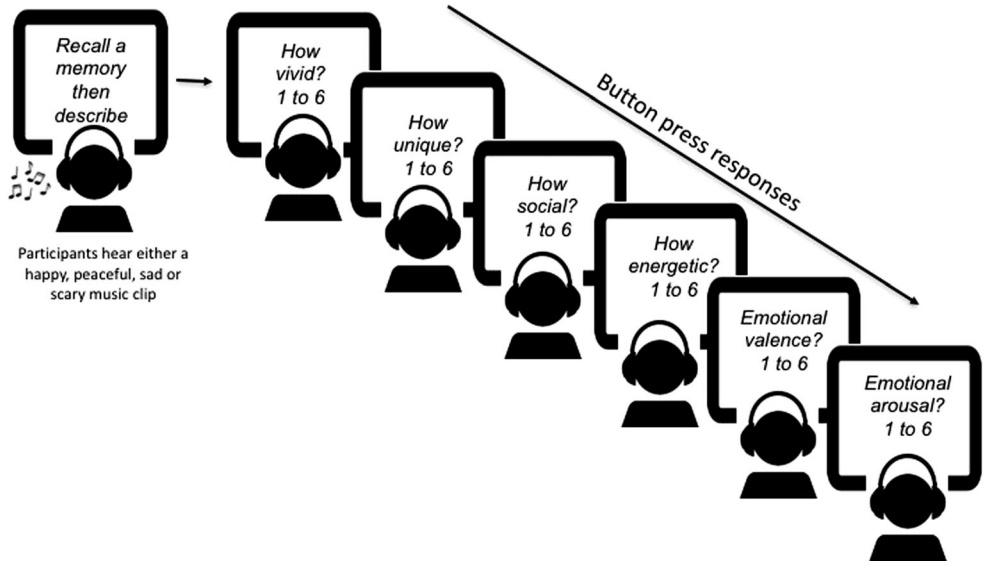

Fig. 1 As chematic of the autobiographical-memory musical cuing procedure used in the current study

Results

The effect of cue on the proportion of specific memories

We ran a mixed-model ANOVA with valence and arousal as within-subjects factors and condition as a between-subjects factor on the average specific-memory proportion rates. The only effect that was significant was a three-way interaction between valence, arousal, and condition [$F(1, 46) = 6.185$, $p = .017$, $\eta_p^2 = .119$]. Following this analysis, we ran separate repeated measures ANOVAs with valence and arousal as factors for each condition. No factors were significant for the randomized condition [$F(1, 23) < 0.001$, $p = .99$, $\eta_p^2 < .001$; $F(1, 23) = 0.301$, $p = .588$, $\eta_p^2 = .013$; and $F(1, 23) = 1.52$, $p = .213$, $\eta_p^2 = .062$, for the valence and arousal effects and the interaction, respectively]. For the blocked condition, the main effect of valence and the interaction effect between valence and arousal was significant [$F(1, 23) = 9.221$, $p = .006$, $\eta_p^2 = .286$; $F(1, 23) = 1.349$, $p = .257$, $\eta_p^2 = .055$; and $F(1, 23) = 5.113$, $p = .034$, $\eta_p^2 = .182$, for the valence and arousal effects and the interaction, respectively]. As is illustrated in Fig. 2 and was confirmed by subsequent significant pair-wise comparisons between the four cue condition types [happy to peaceful, $t(23) = 3.192$, $p = .004$; happy to scary, $t(23) = 3.137$, $p = .005$], this was due to a greater proportion of specific memories being generated to high-arousing positive cues in the blocked condition.

The effect of cues on the time to generate specific memories

The response times to generate specific memories in each musical cue condition are shown in Fig. 3. Visual inspection of the distribution of response times revealed a deviation from normality, so the response times were log-transformed prior to the statistical analyses. Two participants in the randomized condition did not generate any specific memories in one of the four cue conditions, and thus were excluded from the analysis reported below.

To determine how the valence and arousal of the musical cues affected the response times to generate specific memories, we ran a mixed-model ANOVA with valence and arousal as within-subjects factors and condition as a between-subjects factor. The main effects of all three factors were significant [valence, $F(1, 44) = 9.850$, $p = .003$, $\eta_p^2 = .183$; arousal, $F(1, 44) = 5.154$, $p = .028$, $\eta_p^2 = .105$; condition, $F(1, 44) = 4.611$, $p = .037$, $\eta_p^2 = .100$], such that response times to positive cues, more arousing cues, and cues in the randomized condition were faster than response times to negative cues, low-arousing cues, and cues in the blocked condition. No interaction effects with condition were significant; however, the interaction between valence and arousal was significant [$F(1, 44) = 13.548$, $p = .001$, $\eta_p^2 = .235$]. To investigate this interaction effect, we ran pair-wise comparisons between all cue types across the conditions. As is illustrated in Fig. 3, participants were faster to access a specific memory in response to positive and highly arousing musical cues than to any other cue type [happy to peaceful, $t(46) = 4.270$, $p < .001$; happy to sad, $t(46) = 4.991$, $p < .001$; happy to scary, $t(46) = 3.971$, $p < .001$]. The response times to access specific memories cued by peaceful musical cues were no different from those for memories cued by sad [$t(46) = 0.651$, $p = .518$] or scary [$t(47) = 0.625$, $p = .254$] cues, and there was also no significant difference between the response times to specific memories cued by sad and scary musical cues [$t(46) = 1.252$, $p = .217$].

We further investigated the main effect of condition on response times, which showed that the participants in the

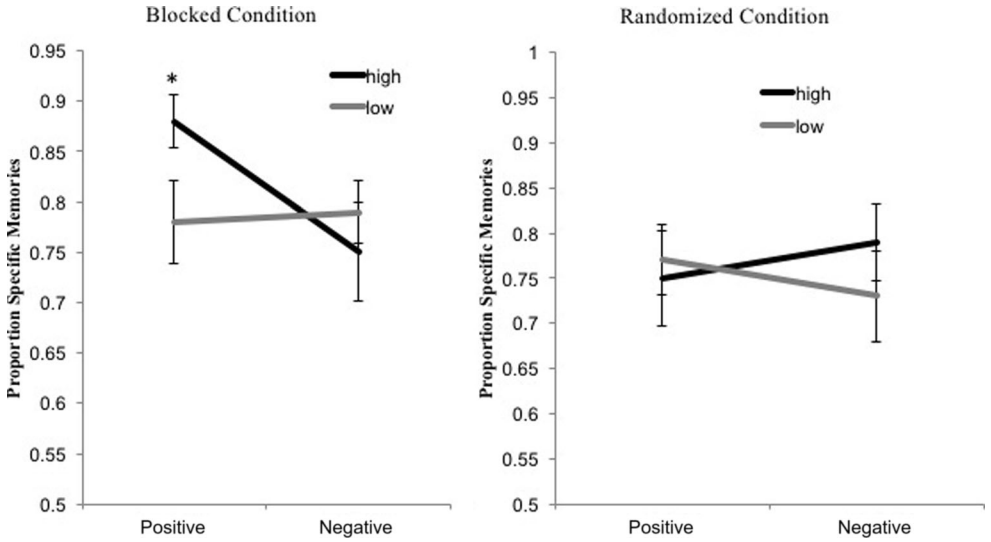

Fig. 2 Proportions of specific memories recalled in the blocked and random conditions as a function of valence for high-arousal cues (black bars) and low-arousal cues (gray bars). Standard error bars are shown

randomized condition were quicker to access specific memories than were those in the blocked condition (randomized, mean = 12.3 s, *SD* = 2.84; blocked, mean = 13.8 s, *SD* = 2.22) [$F(1, 45) = 4.079$, $p = .049$]. One reason for this effect could have been the habituation to the emotion of a musical cue that came with repeated exposure to similar-sounding music in the blocked condition. To explore this potential explanation, we compared the average response times (log-transformed) to generate specific memories to the first four cues versus the last four cues in the blocked condition, and found that participants were faster to generate memories to the first four cues (mean = 13.1 s, *SD* = 2.68) than to the last four cues (mean = 14.6 s, *SD* = 2.56) [$t(23) = 2.980$, $p = .007$]. Next, we contrasted the response times from these two time bins in the blocked condition to the average response time to generate specific memories when the cues were presented randomly, and found no difference in the response times between the first four cues in the blocked condition and the randomized condition average [$F(1, 47) = 0.723$, $p = .400$], but there was a difference between the last four cues from the blocked condition and the randomized condition average

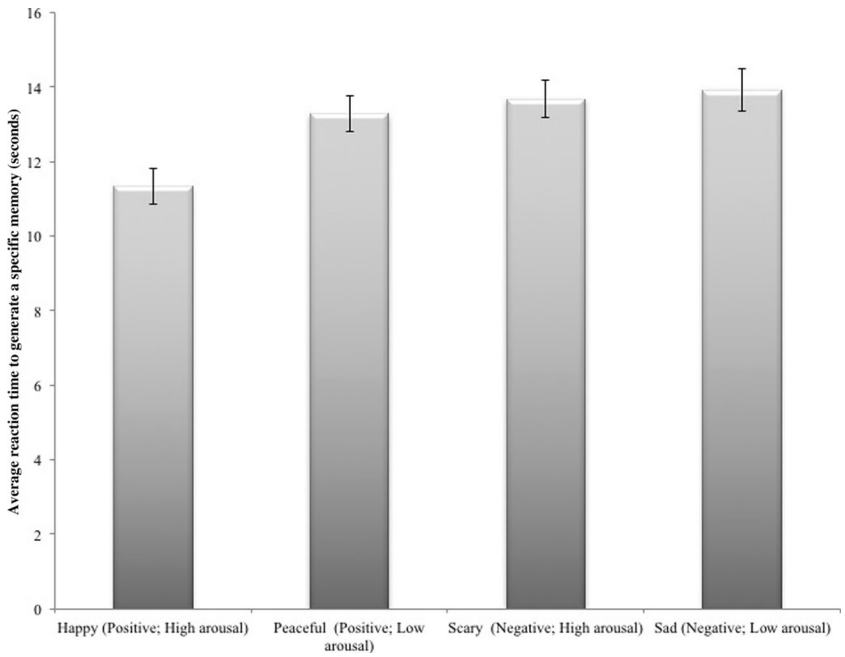

Fig. 3 Average response times to generate specific memories to each of the musical cue conditions. Standard error bars are shown

[$F(1, 47) = 8.303$, $p = .006$], such that the later cues were associated with slower access in the blocked than in the randomized condition.

The effect of cues on the memory retrieval ratings

We investigated, in two independent analyses, both the link between the emotional characteristics of the cue and of the accessed memory and the effects of the emotional cue characteristics on the ratings of memory quality (i.e., measures of the type of memory accessed). We did this so we could directly compare how the cues' characteristics influenced the emotional content of the memories by comparing the categorical values of valence and arousal and how the emotional cue characteristics affected the continuous ratings of memory quality.

Emotional retrieval ratings To investigate the relation between the emotional characteristics of the cue and the emotional content of the retrieved memory, we recoded the memory ratings to reflect the categorical dimensions of the cues, which is an approach we have used in the past (Lenton-Brym, Kurczek, Rosenbaum, & Sheldon, 2016). For memory ratings of emotional content (rated as 1–6, from *very negative* to *very positive*), we recoded responses of 1, 2, and 3 as "negative" and responses of 4, 5, and 6 as "positive." We also recoded the memory ratings of emotional intensity into "low" (responses 1–3) and "high" (responses 4–6). Table 2 illustrates the counts and percentages of memories accessed in these categories. We ran a chi-square test of independence to determine whether these counts of positive and negative memories differed between positive and negative musical cues for each condition.

Table 2 Counts and percentages of specific memories rated as positive or negative, as a function of cue valence and condition, or as high or low in arousal, as a function of cue arousal and condition

Cue Type	Memory Ratings	
	Positive	*Negative*
Blocked		
Positive	297 (89.2%)	36 (10.8%)
Negative	99 (30.7%)	223 (69.3%)
Randomized		
Positive	294 (87.2%)	43 (12.8%)
Negative	142 (45.2%)	172 (54.8%)
	Low Arousal	*High Arousal*
Blocked		
Low Arousal	120 (37.5%)	200 (62.5%)
High Arousal	122 (36.4%)	213 (63.6%)
Randomized		
Low Arousal	103 (32.2%)	217 (67.8%)
High Arousal	124 (37.6%)	206 (62.4%)

We found a significant difference between the numbers of positive and negative memories generated for cues of different valences for both the blocked [$\chi^2(1, 655) = 233.9$, $p < .001$] and randomized [$\chi^2(1, 651) = 129.7$, $p < .001$] conditions. A greater percentage of the memories generated to positive cues were rated as positive (blocked condition, 89.2%; random condition, 87.2%), and a greater percentage of the memories generated to negative cues were rated as negative (blocked condition, 69.3%; random condition, 54.8%). A chi-square test on the counts of high- and low-arousing memories generated to high- and low-arousing musical cues was not significant for either the blocked [$\chi^2(1, 655) = 0.082$, $p = .774$] or the randomized [$\chi^2(1, 651) = 2.075$, $p = .150$] condition. Participants recalled memories that matched the eliciting cues in terms of valence, but not necessarily arousal.

Retrieval characteristic ratings The average ratings for each measure collected for the quality of the recollected specific memories are reported by cue conditions in Table 3. To estimate the effects of the emotional characteristics of the cue on these ratings (i.e., the type of memory that was retrieved), we ran a repeated measures multivariate analysis of variance (MANOVA) test with cue valence and arousal as within-subjects factors, condition as a between-subjects factor, and the ratings of vividness, uniqueness, social content, and energizing nature as dependent variables. We found no main effect of condition [$F(4, 44) = 1.110$, $p = .365$, $\eta_p^2 = .098$]; however, both within-subjects factors were significant [$F(4, 44) = 25.197$, $p < .001$, $\eta_p^2 = .711$, and $F(4, 44) = 21.710$, $p < .001$, $\eta_p^2 = .679$, for valence and arousal, respectively], as was the interaction between valence and condition [$F(4, 44) = 2.915$, $p = .033$, $\eta_p^2 = .221$]. Univariate tests indicated that cue arousal significantly affected all ratings, such that higher cue arousal led to lower ratings of vividness (high arousal, mean = 4.2, $SE = 0.11$; low arousal, mean = 4.4, $SE = 0.10$) [$F(1, 44) = 4.506$, $p = .039$, $\eta_p^2 = .093$] and of uniqueness (high arousal, mean = 4.0, $SE = 0.11$; low arousal, mean = 4.2, $SE = 0.10$) [$F(1, 44) = 4.17$, $p = .047$, $\eta_p^2 = .087$], but to higher ratings of social content (high arousal, mean = 3.5, $SE = 0.11$; low arousal, mean = 3.1, $SE = 0.10$) [$F(1, 44) = 14.706$, $p < .001$ $\eta_p^2 = .251$], and energizing content (high arousal, mean = 4.0, $SE = 0.09$; low arousal, mean = 2.9, $SE = 0.09$) [$F(1, 44) = 68.373$, $p < .001$, $\eta_p^2 = .608$].

When we followed up on the significant effect of valence on these ratings, univariate tests revealed that cue valence had significant effects on both the social content [$F(1, 44) = 53.742$, $p < .001$, $\eta_p^2 = .55$] and energizing content [$F(1, 44) = 72.855$, $p < .001$, $\eta_p^2 = .623$] ratings, such that these were rated as higher for positively than for negatively valenced cues (positive valence: social, mean = 3.8, $SE = 0.11$; energizing, mean = 4.0, $SE = 0.10$; negative valence: social, mean = 2.8, $SE = 0.10$; energizing, mean = 3.0, $SE = 0.09$). Given that the valences of the cue and memory were related (as we noted above), we ran separate regression models across all trials for social and energizing content ratings with both measures of

Table 3 Average ratings collected for all specific memories generated to each cue type for the blocked and randomized conditions

Condition	Memory Rating	Positive		Negative	
		Arousal: High	Arousal: Low	Arousal: High	Arousal: Low
Blocked	Vividness	4.26 (0.10)	4.34 (0.10)	4.10 (0.10)	4.10 (0.11)
	Uniqueness	4.05 (0.11)	4.15 (0.11)	3.87 (0.13)	4.32 (0.11)**
	Social	4.22 (0.13)	3.63 (0.14)**	2.90 (0.14)	2.53 (0.12)*
	Energetic	4.45 (0.10)	3.61 (0.12)**	3.30 (0.13)	2.15 (0.11)**
Randomized	Vividness	4.14 (0.10)	4.43 (0.10)*	4.45 (0.08)	4.50 (0.09)
	Uniqueness	3.77 (0.11)	4.08 (0.11)*	4.01 (0.11)	4.09 (0.12)
	Social	3.94 (0.13)	3.47 (0.13)*	3.23 (0.14)	2.70 (0.12)**
	Energetic	4.41 (0.10)	3.61 (0.12)**	3.68 (0.12)	2.64 (0.11)**

Standard errors are shown in parentheses. * Significant at $p < .05$ between arousal levels. ** Significant at $p < .005$ between arousal levels.

valence as predictors. The model for social content was significant [$F(2, 1299) = 121.10$, $p < .001$], and importantly, the effect of cue valence remained ($t = 3.78$, $p < .001$) when memory valence was accounted for, and the latter was also a significant predictor of social content ($t = 10.90$, $p < .001$). The model of energizing ratings was also significant [$F(2, 1299) = 219.40$, $p < .001$], and the effect of cue valence remained ($t = 4.12$, $p < .001$) when memory valence was accounted for, and the latter was also a significant predictor of energizing ratings ($t = 15.37$, $p < .001$).

Finally, we explored the interaction between valence and condition and found significant effects on vividness ratings [$F(1, 44) = 10.827$, $p = .002$, $\eta_p^2 = .197$] and on social content [$F(1, 44) = 5.538$, $p = .023$, $\eta_p^2 = .112$], such that the memories evoked by positively valenced cues were recalled more vividly than those elicited by negatively valenced cues when both were presented in the blocked condition (positive, mean = 4.3, $SE = 0.142$; negative, mean = 4.0, $SE = 0.154$) [$F(1, 23) = 4.504$, $p = .045$, $\eta_p^2 = .164$], but memories evoked by negatively valenced cues were recalled more vividly than those elicited by positively valenced cues when both were presented in the randomized condition (positive, mean = 4.2, $SE = 0.150$; negative, mean = 4.5, $SE = 0.161$) [$F(1, 23) = 6.658$, $p = .014$, $\eta_p^2 = .241$]. Positively valenced cues led to memories that were more social than did negative valenced cues in both conditions, and the interaction effect was driven by a more pronounced effect in the blocked condition [blocked: positive, mean = 4.0, $SE = 0.136$; negative, mean = 2.7, $SE = 0.140$; $F(1, 23) = 64.211$, $p < .001$, $\eta_p^2 = .736$; randomized: positive, mean = 3.7, $SE = 0.177$; negative, mean = 3.0, $SE = 0.140$; $F(1, 23) = 9.429$, $p = .006$, $\eta_p^2 = .310$].

The effect of retrieval characteristic ratings on estimates of vividness

To test our prediction that cue emotion characteristics would influence the experience of remembering, we performed separate linear regressions for each cue condition to determine whether vividness ratings (i.e., a measure of remembering experience) were predicted by the three event quality and the two event emotion ratings. To perform these analyses, we collapsed across conditions, but note that the patterns reported here were the same for each condition. We also treated each trial from each participant as a data point. As is displayed in Table 4, memory intensity (i.e., arousal) was a strong predictor of the likelihood of experiencing a remembered event vividly, irrespective of the cue condition. Interestingly, vivid recollection accessed via highly arousing positive musical cues was also predicted by the energy content of the recalled event and by the uniqueness of the recalled event for the peaceful and scary musical cues.

The effect of cues on memory age

We examined the potential effect of the cues on the age of the retrieved event, although this investigation was not guided by any hypotheses or prediction. A chi-square analysis on the frequency of responses in each of the six date categories was run separately for the blocked and randomized conditions. We found an effect in the blocked condition that approached significance [$\chi^2(1, 15) = 24.659$, $p = .055$] and a significant effect in the randomized condition [$\chi^2(1, 15) = 45.525$, $p < .001$], such that high-arousal positive cues led to more remote memories, and low-arousal negative cues led to more recent memories (Table 5).

Ratings of musical cue enjoyment

We examined whether ratings of how much one enjoyed listening to each clip differed between the musical cues. The only significant effect of clip enjoyment was a main effect of valence, such that negative musical cues (mean = 3.72, $SE = 0.143$) were rated higher than positive cues (mean = 3.44, $SE = 0.116$) [$F(1, 43) = 4.181$, $p = .047$, $\eta_p^2 = .083$].

Table 4 Regression analyses for the predictors of vividness ratings of retrieved memories for each musical cue condition

Cue Condition	*Memory Characteristics*			*Emotional Content*	
	Energy	Social	Unique	Event Valence	Event Arousal
Happy (Positive, High Arousal)	$F(5, 339) = 25.19$, $p < .001$, $R^2 = .27$				
	$b = 0.03$	$b = -0.03$	$b = 0.02$	$b = -0.13$	$b = 1.01$
	$p < .001$	$p = .40$	$p = .67$	$p = .56$	$p < .001$
Peaceful (Positive, Low Arousal)	$F(5, 317) = 34.32$, $p < .001$, $R^2 = .59$				
	$b = -0.05$	$b = -0.004$	$b = 0.17$	$b = -0.04$	$b = 1.43$
	$p = .32$	$p = .93$	$p < .001$	$p = .82$	$p < .001$
Scary (Negative, High Arousal)	$F(5, 313) = 21.30$, $p < .001$, $R^2 = .50$				
	$b = -0.01$	$b = 0.02$	$b = 0.11$	$b = -0.21$	$b = 1.08$
	$p = .80$	$p = .53$	$p = .004$	$p = .09$	$p < .001$
Sad (Negative, Low Arousal)	$F(5, 309) = 25.35$, $p < .001$, $R^2 = .54$				
	$b = -0.36$	$b = -0.42$	$b = 0.05$	$b = -0.93$	$b = 1.39$
	$p = .53$	$p = .38$	$p = .23$	$p = .55$	$p < .001$

Note that the models for all cue conditions are significant. The slopes and associated p values are reported for each of these models. The significant predictors are outlined in this table.

Discussion

In this study, we were interested in determining how emotional characteristics of a retrieval cue impacted the way autobiographical memories were accessed and subsequently experienced. Participants retrieved autobiographical memories to novel musical cues that ranged in valence and arousal and then rated the accessed memory on a series of emotional and retrieval factors. We administered these cues in a blocked fashion to one half of the participants and randomly to the other half of the participants to further examine how cue presentation affected the impact of emotion on autobiographical memory retrieval. Our analyses revealed three main findings. First, both cue valence and arousal levels modulated autobiographical memory retrieval. Specifically, positive and highly arousing musical cues resulted in the quickest access to memories, and we observed a link between the emotional valence, but not the arousal, levels of the cue and the accessed memories. Second, both cue valence and arousal levels determined the type of event that was accessed in terms of its uniqueness, social, and energizing content. Third, cue valence and arousal distinctly altered the factors that affected how an individual experienced a memory (i.e., the vividness of recall). Finally, we found that the effect of these cue emotion characteristics on memory differed depending on the method of cue presentation. These findings all have important methodological and theoretical implications for emotion and memory research, which we discuss below.

Table 5 Counts of memories associated with each date category in the blocked and randomized conditions, as a function of positive or negative cues that are high and low in arousal

Date Category	Positive		Negative	
	High	Low	High	Low
Blocked Condition				
1 *Past week*	18	13	22	9
2 *Last year*	47	56	44	43
3 *1 to 5 years*	47	43	52	64
4 *5 to 10 years*	38	21	29	28
5 *Over 10 years*	24	24	11	16
6 *Don't know*	1	1	2	2
Randomized Condition				
1 *Past week*	8	14	7	17
2 *Last year*	37	39	42	42
3 *1 to 5 years*	43	53	54	62*
4 *5 to 10 years*	32	33	36	19*
5 *Over 10 years*	50*	27	19	13*
6 *Don't know*	0	1	2	1

* Values different from the other column values at $p < .05$.

Emotional cue characteristics and access to autobiographical events

One main finding from our study was that participants were faster to access specific autobiographical memories while listening to high-arousal and positive (happy) cues rather than musical cues of other valence and arousal levels, an indication of more direct retrieval of autobiographical memories (Uzer, Lee, & Brown, 2012). This finding suggests that the reported bias in accessing positive memories (Berntsen et al., 2011; Walker et al., 2003) is also present when accessing memories

to positive cues, but that a cue's arousal level is critical for determining this retrieval-state positivity bias.

One reason that happy musical cues led to the most direct access to past events relates to the proposed function of autobiographical memory to maintain emotional well-being and a positive sense of self (Alea & Bluck, 2003; Conway & Bekerian, 1987). The correspondence between positive and high arousing (happy) cues and the ability to remember personal experiences may reflect our desire to link positive emotions at retrieval with easy access to memory as a means of creating a positive self-identity (see also Conway's self-memory system for a discussion of the function of autobiographical memory in self-identity: Conway et al., 2004).

More generally, the differential effect of the cues on the speed of autobiographical memory recall suggests that emotions influence the way memories are organized on the basis of spreading activation models of organization. This posits that the emotional content of a cue will trigger emotion-congruent memory access if emotional content is an important factor for organization (Buchanan, 2007; Forgas, 1995). We further explored the notion that emotional features of a cue can direct the emotional features of memory access by looking at the link between the emotions of a cue and a retrieved memory. We found a strong and significant link between the cue and memory valence ratings relative to the cue and memory arousal ratings, which fits with findings from a similar study (Schulkind & Woldorf, 2005). Thus, it seems that cue valence facilitates access to similar memories more directly than arousal and this is an important factor for how autobiographical knowledge is organized. Yet, as we discuss in the next section, cue arousal may play a role in the accessibility and organization of autobiographical knowledge when we expand this investigation to other nonemotional factors of a memory. That is, whereas the valence of a retrieval cue may facilitate emotionally congruent memory recall, both emotional valence and arousal levels of a cue impact the processes used to access mnemonic information (Gomes, Brainerd, & Stein, 2013).

Emotional cues and non-emotional aspects of the remembered event

One unique aspect of our study is that we examined the influence of cue emotion on non-emotional characteristics of a remembered event. This latter analysis provides new and noteworthy evidence for how an emotional memory cue—emotion features presented at retrieval—can affect the type and way an encoded event is recovered. Of note, we found that positively valenced cues resulted in the recall of memories that were higher in ratings of social and energizing content than memories recalled to negative cues. Critically, this effect remained when we controlled for the link between cue and memory valence, illustrating that cue valence alone affects the type of memory that is recalled. More specifically, we interpret this finding as support for a social function of autobiographical memory (Alea & Bluck, 2003). In other words, we suggest that positive emotional cues will promote the recall of highly social memories because of a desire to better remember events that highlight appropriate social behaviour.

One finding that was somewhat surprising was that arousing emotional cues, irrespective of valence, led to memories with *lower* ratings of vividness and memory uniqueness and *higher* ratings of social and energizing content. Although previous research has suggested that arousal levels at encoding is a strong predictor of the ability to vividly recall autobiographical memories (e.g., Talarico et al., 2004), other research has found that arousal during an experience can disrupt memory performance or lead to gist-based recall (Adolphs, Tranel, & Buchanan, 2005), fitting with our findings. The discrepancy between our results and some of those reported in the literature may be explained by differences in methodology. First, the link between higher arousal and richer memory recall is typically established in studies that examined the arousal and vividness of an emotional memory and not between the arousal of an emotional cue and the vividness of the recalled memory (e.g., Ford et al., 2012). This is a point of interest because it suggests that emotional arousal at retrieval (i.e., cue) guides the experience of remembering in a manner that is different than emotional arousal at encoding (i.e., the time of the event). Second, many studies that have examined arousal effects on memory have not fully controlled for valence, as we have done in our study (for a discussion on this topic, see Schmidt et al., 2011). Third, we used musical stimuli to cue memories. This is a powerful method to study the emotional effects of a retrieval cue, but often music-evoked remembering is studied using popular or familiar songs (Janata et al., 2007; Krumhansl & Zupnick, 2013). Since song familiarity impacts autobiographical memory retrieval in addition to the emotional content of the cues (Ford, Rubin, & Giovanello, 2016), our choice of novel musical stimuli could have led to different results than those reported in studies using familiar musical stimuli.

For a more theoretical explanation of our results, we turn to the arousal-biased competition theory (Mather & Sutherland, 2011). This theory posits that there is competition among mental representations during retrieval. When one representation (e.g., a memory) is retrieved, other competitors will become suppressed. In our study, participants recovered several memories in each cue condition across the experiment. It could be that upon first hearing an arousing musical cue, a salient and vivid memory was selected for access and this dampened the nearest almost-as-vivid competitors. Thus, when the next arousing cue was heard, those competitors may still have been suppressed, so a less vivid memory was selected for access. This would explain the inverse relationship between cue arousal and vividness ratings, yet it is not clear why it would not also apply to memory valence.

Determinants of memory vividness

In the section above, we suggested that arousal at the time of encoding and retrieval has different effects on remembering because the arousal status of the cue negatively impacted vividness ratings. In fact, in our study a series of regression analyses revealed that the arousal status of the memory (not the cue) could predict vividness irrespective of cue condition. This new finding that cue and memory arousal have opposite effects on retrieval vividness is vital when considering the link between emotion and memory, as it suggests that emotion will differentially modulate encoding and retrieval processes.

Also emerging from the above-noted regression analyses, the likelihood of vivid memory recall was predicted by ratings of memory uniqueness, but only for peaceful (positive, low arousal) and scary (negative, high arousal) cues. This pattern raises interesting new questions about how a memory's valence and arousal interact to affect the likelihood of recalling unique memories, or, put another way, engaging in gist-based recall (Kensinger, 2009). One possibility is that negative memory content leads to the recall of specific and central details of a unique event (Kensinger, Piguet, Krendl, & Corkin, 2005), but this effect is offset when arousal is low (e.g., in the sad cue condition). Similarly, the likelihood to recall more peripheral details of a positively cued memory that led to less unique event recall (Berntsen, 2002; D'Argembeau et al., 2003) may be offset when retrieval arousal is too low (peaceful cues). Yet another possibility is that the link between vividness and memory uniqueness for peaceful and scary musical cues is a result of emotion familiarity. It could be that peaceful and scary emotional cues are simply less familiar or identifiable than happy and sad cues; however, without data to confirm this idea, this remains a suggestion. Even though the interpretations are speculative, both the arousal and valence levels of an emotional cue lead to qualitatively different retrieval experiences.

The impact of emotional cue presentation

Another unique aspect of our study was that we included two forms of emotional cue presentation as a means of investigating how presenting distinct emotional cues under different circumstances influences memory retrieval. First, we found that cues in the randomized condition led to memories that were more quickly accessed than in the blocked condition. A potential explanation for why cues presented randomly led to more direct access (i.e., faster recall) to specific memories is that this is the result of emotional memory interference in the blocked condition. That is, remembering one event via a certain emotional cue blocked or inhibited access to memories of the same emotion on the next trial (Gilet & Jallais, 2011). In line with this explanation, response times to memories slowed across the presentation of the cues within each blocked cue condition.

A more interesting finding is that when cues were presented in a blocked fashion, a greater proportion of specific memories were recalled in response to the highly arousing positive cues. Moreover, in the blocked condition, positive cues were associated with memories rated as more vivid than negative cues, but for the randomized condition, negative cues were associated with memories rated as more vivid than positive cues. It is possible that when cues were presented in a random fashion, the emotional content of the cue directed retrieval to a similar memory via shared emotional information (e.g., Lewis et al., 2005). When memories are presented in a blocked fashion, the participant's own mood or emotional state may have changed to match the cue emotion, allowing this mood to direct autobiographical memory access (Thompson, Schellenberg, & Husain, 2001). If this is the case, then our reported dissociation may indicate, broadly, that mood versus emotional cuing have different effects of memory retrieval and specifically that a positive mood (the blocked condition) enhances the subjective experience of remembering whereas negative memory cues (the randomized condition) serve as a better reminder of a vivid memory. Our hypothesized link between mood and memory fits with some prior work that has indicated that positive mood increases cognitive flexibility and relational elaborative processes (Estrada, Isen, & Young, 1997; Isen, 1993), which are critical for recovering detailed and vivid memories. However, we did not collect measures of mood in our participants, so we cannot verify that the blocked as compared to the randomized condition altered the participants' mood. We bring these ideas forward as fruitful avenues for future research.

Study limitations

In the present study, we focused our efforts on understanding the effect of emotional cues on subjective measures of recollection; therefore, we did not measure the accuracy or details of the memories recalled. Given that subjective remembering and objective measures of memory dissociate, particularly with respect to emotion (Rimmele et al., 2011), this would be an important next step in the line of research. Another limitation of our study was brought to our attention from our finding that negative music was rated with more enjoyment than positive music, which is not an unreported result (Kawakami, Furukawa, Katahira, & Okanoya, 2013). This finding does suggest that the effect of emotion perceived by the participants may be different than the emotion felt while accessing memories (Schubert, 2013). Specifically, the emotion that is induced by musical cues in our study may not necessarily map onto the characteristics of the cue, which would have implications for any mood induction interpretations of our results. A final limitation we note is that we used

musical stimuli. Given that work has suggested that music-evoked autobiographical memories are unique from other cued memories (e.g., Blaney, 1986), it would be wise to determine if our pattern held with other forms of emotional stimuli.

Conclusions

Our findings showcase new evidence for how a retrieval cue's emotional arousal and valence are related to separate but interacting processes of autobiographical memory recall. We note three important implications of our findings. First, we advocate the inclusion of cue valence and arousal, in addition to memory valence and arousal, when interpreting the link between emotion and memory. Second, our results on the effect of emotional memory cues on autobiographical memory recall differ from the results of studies that have examined the impact of recalling emotional memories. This indicates a necessary distinction between how emotion modulates memory at encoding and retrieval. Finally, the differential impacts of cue presentation (i.e., circumstances of retrieval) in our study suggest that the reported emotion effects on autobiographical memory retrieval may partly be determined by whether emotion is induced or cued during retrieval.

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