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Reviews

Emotional cue effects on accessing and elaborating upon autobiographical memories

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ABSTRACT

If remembering the past requires a cue to stimulate mental reactivation of an experience (i.e., a memory), then the nature of the retrieval cue should bias how that experience is recalled. Based on the established link between emotion and memory, we tested how two emotional properties of a cue - valence (positive and negative) and arousal (high and low) - influence different phases of autobiographical memory retrieval: searching/accessing an autobiographical episode, and then elaborating on the associated memory representation. Young, healthy participants completed two experimental sessions that were separated by 24 to 48 h. In session one, participants used musical retrieval cues that varied in emotional valence and arousal to access autobiographical memories. Cue-evoked physiological arousal and valence responses were measured via skin conductance and facial electromyography, respectively, as were the reaction times to access each memory. In session two, participants reactivated and then described (elaborated) the details of the memories that were accessed in session one. The resultant descriptions were scored for the number of specific episodic (internal) and non-episodic (external) details. While arousal and valence levels of the retrieval cues, as well as the evoked physiological responses, significantly predicted the reaction time to access a memory, only cue arousal predicted how detailed the representations were constructed. Memories that were initially accessed to high-arousing cues were later described with more episodic details than memories accessed to low-arousing cues. These data provide new insights into how emotional valence and arousal levels of retrieval cues distinctly bias the accessibility and detailed elaboration of autobiographical memories.

1. Introduction

Autobiographical memories are understood to be dynamic representations that are accessed and reconstructed during retrieval, in response to a cue in the environment (Schacter, 2012; Schacter, Norman, & Koutstaal, 1998; Sheldon, Fenerci, & Gurguryan, 2019; Sheldon & Levine, 2016; Tulving & Thomson, 1973). Under this view, the properties of a retrieval cue can affect how available a memory is at the time of recall as well as the details used to construct a remembered event, referred to here as the access and elaboration phases of memory retrieval, respectively. Given that the emotional properties of a cue can exert a powerful influence on the autobiographical memory (e.g., Simpson & Sheldon, 2019), the current study aimed to examine how certain emotional aspects of a cue—valence and arousal—influence these distinct phases of autobiographical memory retrieval and thus direct the experience of remembering.

Theoretical accounts of autobiographical memory posit that mentally accessing a past episodic event and then elaborating a detailed recollection of that event represent distinct phases of retrieval, and rely upon disparate neurocognitive processing systems (e.g., Addis, Wong, & Schacter, 2007; McCormick, St-Laurent, Ty, Valiante, & McAndrews, 2015). When accessing a memory, search strategies, directed by executive processes, are engaged to locate and extract specific event representations from a person's autobiographical memory knowledge structure (Conway & Pleydell-Pearce, 2000). This structure organizes information hierarchically such that specific episodes from life (e.g., recalling your first date with your current partner that includes associated sensory and perceptual information) are nested within more generalized, abstracted event representations (e.g., outings with a romantic partner). According to this account, there are two routes to access a specific episodic event representation (Haque & Conway, 2001). Specific autobiographical episodes can either be accessed directly and automatically by entering the knowledge structure at the lower 'episodic' level, or effortfully and slowly by first accessing generalized representations, and then searching through the lower level for a more specific event. Studies suggest that whether a more direct or

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more effortful search strategy is used to access a memory will depend on the properties of the cue that stimulate retrieval (Foley, 2018; Uzer & Brown, 2017). Evidence suggests that faster, direct access to a memory is more likely when a retrieval cue is readily represented by information relevant to one's life, including specific events. Effortful generative search, on the other hand, is required when the retrieval cue contains information that is not as representative of one's autobiographical knowledge, thus, requires iterative searches through the knowledge structure for a specific memory (Tulving & Thomson, 1973).

After accessing a memory, different cognitive processes pertaining to episodic and semantic memory are required to construct an elaborated mental recollection of the accessed event. The episodic memory system provides rich, contextualized details of the event, supporting the ability to mentally re-experience the past. The semantic memory system provides general information about the world and oneself associated with the recalled event (Tulving, 2002). Current research indicates that forming an elaborated memory representation is particularly reliant on the episodic memory system to make associations between recovered event details to form a coherent memory trace (Schacter et al., 1998; Sheldon et al., 2019; Sheldon & Levine, 2016), suggesting that any effect of a retrieval cue on this phase of remembering will be on recalling details that rely upon episodic memory.

From the above-reviewed work, we reasoned that the content of a retrieval cue can have effects on both phases of autobiographical retrieval. Since the emotional content of a retrieval cue is known to impact memory processing (for a review, see sections in Holland & Kensinger, 2010), we tested this impact on the initial access phase of retrieval, when an individual access a specific (episodic) memory, and the elaboration phase of retrieval, when an individual constructs a detailed mental representation of a recovered episode. We considered how two key facets of emotion—valence (positive versus negative) and arousal (high versus low emotional intensity; Russell, 1980; for recent evidence, Ford, Addis, & Giovanello, 2012; Russell & Barrett, 1999; Sheldon & Donahue, 2017)—can affect these different phases of remembering.

There are indications that emotional memories are retrieved differently as a function of their valence and arousal levels. First, the valence of a recalled memory determines how well it is accessed, with studies finding that positive autobiographical memories are more accessible than negative autobiographical memories (Berntsen, 2002; Berntsen & Rubin, 2002; Kensinger, 2009; Matlin & Stang, 1978). This is because positive experiences are readily represented as episodic events in an individual's autobiographical knowledge structure, so more direct retrieval strategies are employed during access (Walker, Skowronski, & Thompson, 2003). Negative life events are less readily represented in this knowledge structure, and, accordingly, will require effortful strategies to perform iterative searches to find a suitable specific event to retrieve. Second, work has shown that emotional arousal levels at the time of an event affects how a memory is constructed and subsequently re-experienced during the elaboration phase of retrieval (Fivush, Bohanek, Marin, & Sales, 2009). Highly arousing memories are reported as being recalled more vividly than low arousing memories, regardless of the emotional valence (Ford et al., 2012; Talarico, LaBar, & Rubin, 2004; Talarico & Rubin, 2003), and this has been linked to episodic memory processing (Phelps & Sharot, 2008).

While it is clear that the emotional content of a recovered memory affects retrieval, it is less clear whether the emotional valence and arousal features of a retrieval *cue* also alter autobiographical memory retrieval (Schulkind & Woldorf, 2005; Sheldon & Donahue, 2017; Simpson & Sheldon, 2019). Some studies have reported that emotional cues of different valence (positive, negative, neutral) trigger different retrieval strategies during memory access. Examples of this work come from research on individuals with depression who have a pronounced difficulty retrieving specific memories to emotional cue-words (Williams, 1996; Williams et al., 1996; Williams & Broadbent, 1986), especially when the cue words are positive (Dalgleish et al., 2007). It is proposed that positive episodes are not well-represented in the autobiographical knowledge structure of an individual with depression, thus accessing memories to positive cues require more effortful search processes. In healthy adults, positive emotional memories are presumed to be well-represented within the autobiographical knowledge structure (Prebble, Addis, & Tippett, 2013), leading to the hypothesis that positive cues should allow for direct access to specific autobiographical events in healthy adults. We found support for this hypothesis in one of our previous studies in which young healthy adults accessed specific autobiographical memories faster in response to positive (i.e., happy) retrieval cues than to negative retrieval cues (Sheldon & Donahue, 2017), suggesting that these memories were accessed with a more direct search strategy. This study, however, did not examine the impact of emotional retrieval cues on the second phase of autobiographical memory retrieval, namely, the elaboration phase. The present study addressed this knowledge gap.

There are indications that emotion cues impact autobiographical memory elaboration, and specifically that the arousal level of a cue will enhance the ability to retrieve episodic content of a recalled event. In another one of our previous studies, we found that cue arousal levels affected episodic but not semantic detail production when describing (i.e., elaborating upon) autobiographical events, regardless of the cue valence (Simpson & Sheldon, 2019). Other work had suggested that recollecting an arousing event enhances recall of central and perhaps episodic details of that event (e.g., Burke, Heuer, & Reisberg, 1992; Christianson, Loftus, Hoffman, & Loftus, 1991). Within the brain, this emotional arousal effect on memory has been linked to the influence of the amygdala, a brain region that processes intensity, on the hippocampus (Cahill, Babinsky, Markowitsch, & McGaugh, 1995; McGaugh, 2002, 2004). The hippocampus is a necessary brain structure for the construction, or elaboration, of episodically-rich memory representations (Moscovitch, Nadel, Winocur, Gilboa, & Rosenbaum, 2006; Squire, 1992). Cue arousal is thought to activate the amygdala and this, in turn, affects the functioning of the hippocampus when elaborating upon a memory, likely increasing the production of episodically-specific details. Elaborating on this idea, studies have indicated that memories recalled under high arousal conditions are re-consolidated with more episodic as well as emotional details (Buchanan & Lovallo, 2001; Sheldon, Chu, Nitschke, Pruessner, & Bartz, 2018), which would extend the theorized effect of cue arousal on constructing elaborated memory representations to a later period of remembering.

To follow up on these findings and formulations, we developed an experiment in which we simultaneously tested the effects of valence and arousal levels of a musical retrieval cue on two phases of remembering: autobiographical memory access and elaboration. Although several studies have used music to cue autobiographical memory retrieval (e.g., Belfi, Karlan, & Tranel, 2016; Ford et al., 2012; Janata, 2009; Zator & Katz, 2017), these studies often used familiar songs as stimuli. We chose to use musical excerpts that participants had not heard before and that ranged in emotional content to remove the confounding effect of prior musical exposure on the results.

In session one, participants heard novel musical excerpts that were positive or negative and high or low in arousal, and used these excerpts as cues to access autobiographical memories. To confirm the emotional labels given to the musical cues, we collected psychophysiological measures of emotional arousal (skin conductance) and valence (facial electromyography) as participants listened to these excerpts. We measured memory access by capturing the reaction time to retrieve a memory in response to a cue; and collected subjective ratings about the memory. Session two took place 24 or 48 h later, during which we measured how participants constructed detailed elaborations of the autobiographical memories evoked by the emotional cues in session one (see Fig. 1).

This experimental design permitted us to test two specific hypotheses. First, we tested whether the valence of a retrieval cue would bias the access to autobiographical memories such that positively and

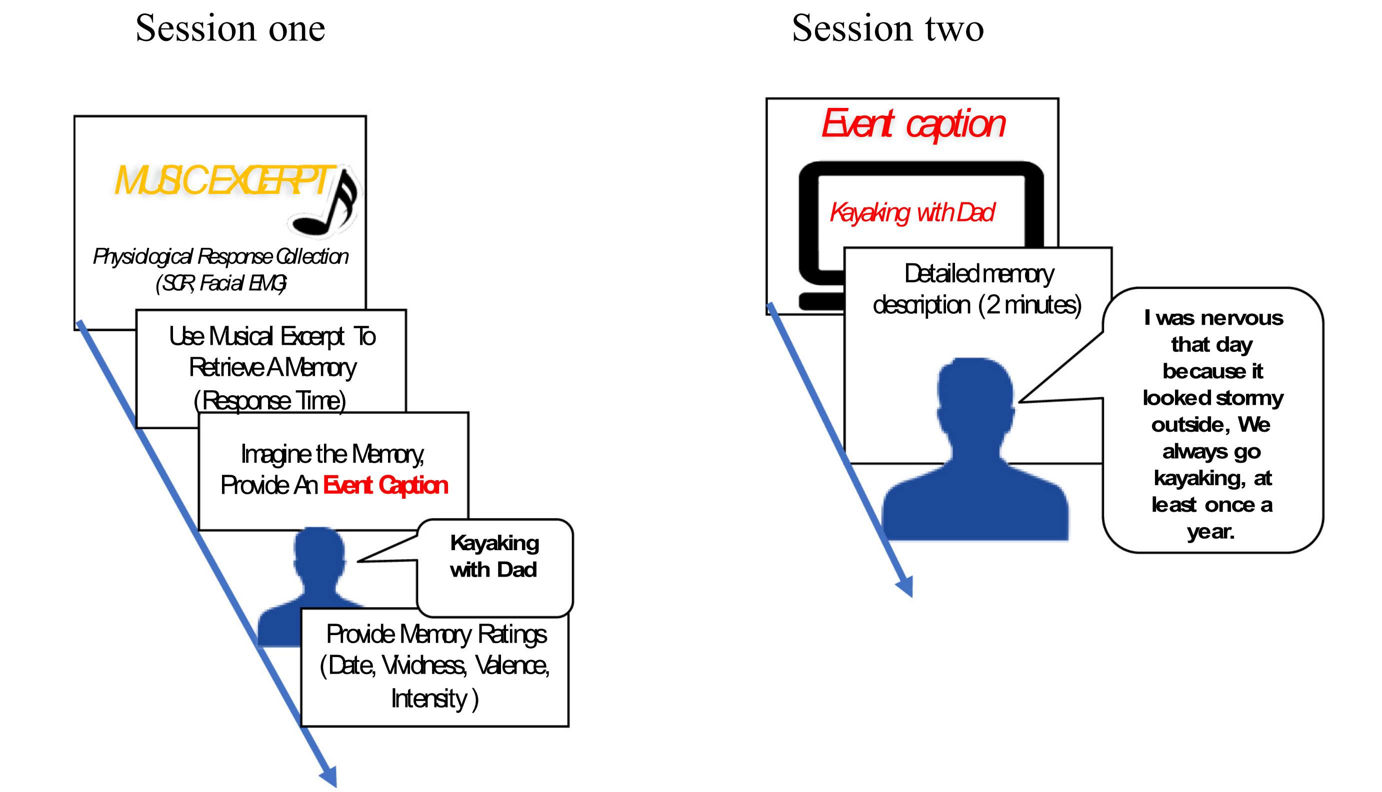

Fig. 1. A schematic of the experimental design. Session one involved participants listening to musical excerpts as physiological measures were collected. Participants used that excerpt as a cue to retrieve an autobiographical memory (memory access) and imagined and rated that memory on a series of scales. Session two took place 24 to 48 h after session one and involved participants describing the memories retrieved in session one in detail (memory elaboration).

negatively valenced cues will primarily activate a direct versus effortful retrieval strategy, respectively. Second, we tested whether the arousal level evoked by a retrieval cue selectively enhances the episodic content of a constructed autobiographical event during memory elaboration. If arousal effect on memory elaboration alters the underlying memory trace, then cue-arousal differences should be present when a memory is elaborated upon at a later time-point.

2. Methods

2.1. Participants

Forty-two healthy adult participants [37 female; mean age = 20 years (SD = 1.4); mean years of education was 14.6 years (SD = 1.1)] were recruited from McGill University's human participant pool hosted by the Department of Psychology. All participants were fluent English speakers, learning English prior to the age of 12, and free of any major neurological or psychiatric disorders. All participants gave informed consent prior to testing and were compensated with course credit.

2.2. Stimuli

Twenty-four musical excerpts were selected from a normed emotional stimulus set of unfamiliar musical pieces (Vieillard et al., 2008). These excerpts were piano MIDI files of classical music designed to vary along two emotional dimensions of interest - valence (positive or negative) and arousal (high or low). Valence was manipulated by composing music in a major or minor key and arousal was manipulated by varying the tempo of the music. Thus, there were four types of excerpts. Happy excerpts were positive valence (written in a major mode) and high arousal (average tempo = 137 BPM, range = 97 to 196 BPM); peaceful excerpts were positive valence (written in a major mode) and low arousal (average tempo = 74 BPM, range = 54 to 100 BPM); scary excerpts were negative valence (written in a minor mode) and high arousal (induced with out-of-key notes; average tempo = 44 to 172 BPM); and sad excerpts were negative valence (written in a minor mode) and low arousal (average tempo = 46 BPM, range = 40 to 60 BPM). We selected six excerpts to use as cues. These cues ranged in length between 11 and 16 s and were matched in length across cue conditions.

2.3. Procedure

The experiment was conducted over two sessions that were separated by one or two days (see Fig. 1 for an overview of the design). During session one, participants completed 24 trials during which they retrieved a specific autobiographical memory following the presentation of a musical excerpt selected at random from the stimuli list, measuring memory access. Prior to testing, participants were told a ‘specific autobiographical memory’ is a recalled event that they personally experienced, that lasted no longer than a day, and that is specific to a time and place. Participants were also told that memories were not required to be congruent with the emotional condition of the musical cue, and to merely report the first memory that comes to mind; however, they were told this memory should be at least 24 h old.

Skin Conductance Responses (SCR) and Facial Electromyography (EMG) measurements were collected as participants heard the musical excerpts (cues) to assess emotional intensity and valence responses, respectively. The primary reason for collecting these measures as participants heard the musical excerpts was to validate the discriminations along these two levels of emotion between the four cue conditions. SCRs were measured via Ag-AgCl electrodes attached to the crease between the distal and middle phalanges of the first and second digits of the left hand and were recorded with a MP160 system (Biopac Systems, Inc., Goleta, CA., USA) at a sample rate of 200 Hz. We employed a

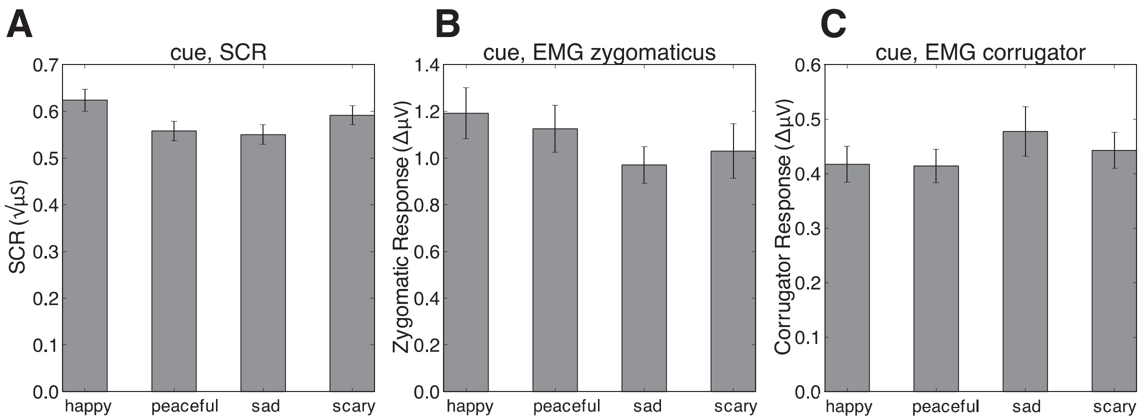

Fig. 2. Average cue-evoked skin conductance response (SCR), zygomatic EMG response, and corrugator EMG response as a function of the four cue conditions during cue presentation: happy (positive valence, high arousal), peaceful (positive valence, low arousal), scary (negative valence, high arousal), and sad (negative valence, low arousal). Error bars denote standard error of the mean.

deconvolution technique, based on a physiological model of the general SCR shape, that allows for separation and quantification of the fast-varying (phasic) and slow-varying (tonic) components of the skin conductance signal (Benedek & Kaernbach, 2010; Otto, Knox, Markman, & Love, 2014). We calculated musical cue-evoked arousal by integrating the phasic driver signal during a period which began 1 s after stimulus onset and ended 10 s after stimulus onset. SCR magnitudes were square-root transformed to remove skew. Facial EMG activity was recorded over the left corrugator and zygomatic sites using cloth-base Ag-AgCl electrodes and a MP160 unit recording at a sample rate of 200 Hz. The corrugator and zygomatic electrode placements followed previously established recommendations (van Boxtel et al., 2010). Signals were high-pass filtered at 20 Hz, rectified, and integrated with a time constant of 500 ms, following Lang, Greenwald, Bradley, and Hamm (1993). Mirroring the SCR measurements, we calculated musical cue-evoked EMG activity at each facial muscle by subtracting the mean activity during the 1 s baseline period preceding cue onset from the maximum response in the cue period beginning 500 ms after stimulus onset and ending 10 s after stimulus onset.

After listening to the full excerpt, participants made a mouse-click response to indicate that a memory has been retrieved, and the reaction time to make this response from the time the excerpt ended was recorded. Participants were asked to imagine the memory in detail for 30 s to promote the reactivation of the associated memory trace. Then, they provided a brief, one sentence description of the memory to the experimenter to be used as a retrieval cue in session two. The trial ended with a series of Likert ratings about the memory date (i.e., when the memory occurred; 1 = Past week, 2 = Within the last year, 3 = Between 1 and 5 years, 4 = Between 5 and 10 years, 5 = Over 10 years, 6 = Don't know), the vividness of the recollection of the event (1 = No images to 6 = Extremely vivid), and the emotional valence (1 = Positive to 6 = Negative) and intensity (1 = Calm to 6 = Arousing) of the memory.

Session two occurred 24 or 48 h after session one. During this session, the event captions that were created during session one were presented to the participants in random order. To each caption, they described in as much detail as possible the associated event, measuring memory elaboration. Participants were given 2 min to describe these events, and one general prompt was given if the participants finished talking before this time-period elapsed.

The descriptions resulting from session two were audio-recorded, transcribed, and then scored according to the protocol outlined by Levine, Svoboda, Hay, Winocur, and Moscovitch (2002). Following this protocol, memory descriptions were segmented into details (i.e., unique pieces of information) and then classified as *internal* or *external*. An *internal* detail provides specific, contextual information about the described event (e.g., *I was wearing a red sweater; I sat in the corner of the dimly lit restaurant*) and is thought to measure episodic memory processing. An *external* detail provides information that is not specific or central to the described event, and includes semantic or factual knowledge (e.g., *I have always enjoyed hiking*). The number of internal and external details provided within a memory was tallied. Three raters scored all the memories and had an acceptable inter-rater reliability score for both internal and external detail counts ($r > 0.80$), established based on a randomly selected subset of descriptions.

2.4. Data analysis

Prior to analysis, we removed any trials in which a specific memory (i.e., an event contained to a single location or time) was not accessed. This removed 17 trials across all participants. To test our specific predictions concerning the relation between cue arousal and cue valence on memory retrieval, we constructed mixed-effects regressions computed using the lme4 package (Bates & Maechler, 2009) with response time, subjective ratings, and detail counts as dependent variables, estimating memory access, experience, and construction, respectively. All regression models included cue valence and arousal (as well as the interaction) as fixed factors and all coefficients taken as random effects over participants. Trial number was included as a nuisance variable (as both a fixed and random effect) to account for potential serial order effects. Significance values and linear contrasts were computed using the ‘car’ (Fox & Weisberg, 2011) and ‘doBy’ packages (Højsgaard & Halekoh, 2009) respectively.

3. Results

3.1. Session one

We verified the cues' assigned valence and arousal categorization by constructing mixed-effects regressions that tested if these assignments could predict the collected physiological responses of arousal (SCR) and valence (Facial EMG). The average of these responses per cue condition is plotted in Fig. 2. The regression predicting SCR revealed a positive significant main effect of cue arousal, where high arousal cues were associated with a greater response (M = 0.607, SD = 0.339) than low arousal cues (M = 0.553, SD = 0.318), [$\beta = 0.030$, SE = 0.025, $p = .002$]. There were no significant effects of cue valence ($\beta = -0.0002$, SE = 0.0233, $p = .636$) nor an interaction between cue valence and arousal ($\beta = 0.036$, SE = 0.032, $p = .586$). The regression predicting zygomatic EMG response revealed a significant effect of cue valence, such that positive cues were associated with a stronger response (M = 1.162, SD = 1.612) than negative cues (M = 1.032,

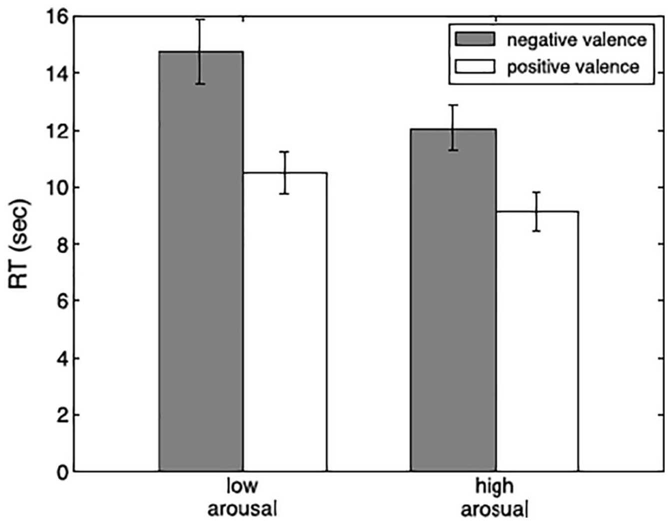

Fig. 3. The average reaction time (RT) to access an autobiographical memory as a function of cue arousal and valence. Error bars denote standard error of the mean.

SD = 1.560) [β = 0.041, SE = 0.042, $p = .023$]. There was no significant effect of cue arousal level (β = −0.016, SE = 0.0376, $p = .674$) nor an interaction between cue arousal and valence level (β = 0.049, SE = 0.053, $p = .352$). Similarly, the regression model predicting the corrugator EMG response revealed the same sensitivity to cue valence but in the opposite direction (positive valence M = 0.412, SD = 0.488; negative valence M = 0.467, SD = 0.610; main effect β = −0.036, SE = 0.020, $p = .0456$) and no significant effects of cue arousal (β = −0.017, SE = 0.02, $p = .573$) or interaction between cue valence and arousal (β = 0.016, SE = 0.030, $p = .59$). Together, these patterns of evoked physiological responses validate the cue categorization in terms of arousal and valence level.

3.1.1. Response times

The regression model to predict autobiographical memory response times (RTs) revealed that both cue valence (β = 2.914, SE = 0.804, $p < .0001$) and cue arousal (β = −1.443, SE = 0.832, $p = .016$) exerted significant negative effects on RT, with valence effects being numerically but not significantly larger than those of arousal (linear contrast, $p = .113$). We observed no significant interaction between cue valence and arousal (β = 0.600, SE = 1.274, $p = .637$). Fig. 3 depicts RTs across the four cue conditions as a function of cue valence and cue arousal and shows that positively valenced cues and high-arousing cues resulted in faster autobiographical memory access.

We further investigated if RTs could be predicted by the cue-evoked physiological responses of valence and arousal by estimating a regression which predicted RT as a function of cue-evoked zygomatic EMG response, corrugator EMG response, and SCR. Mirroring the above analysis of ‘ground-truth’ cue valence, we found that cue-evoked zygomatic EMG response negatively and significantly predicted RT (β = −1.970, SE = 0.948, $p = .015$), but neither corrugator EMG response (β = 2.357, SE = 1.528, $p = .123$) nor SCR (β = 0.094, SE = 1.264, $p = .940$) had significant effects upon RT.

3.1.2. Subjective ratings

Separate regressions were created for the subjective ratings. For memory date ratings, there was an effect of cue arousal (β = −0.244, SE = 0.088, $p = .015$), but no effect of cue valence (β = 0.022, SE = 0.097, $p = .201$), and no interaction (β = 0.189, SE = 0.133580, $p = .160$). The effect of arousal was because memories cued to high arousal cues were classified as older (M = 2.834, SD = 1.167) than those to low arousal cues (M = 2.726, SD =1.039), but the averages both fell within the same categorical date bin (Within the last year). For memory vividness ratings, we did not observe significant effects of cue valence (β = −0.104, SE = 0.098, $p = .841$) or cue arousal (β = 0.0216, SE = 0.104, $p = .130$), or a significant interaction (β = 0.233, SE = 0.134, $p = .081$). For memory intensity ratings, there were no significant effects of cue arousal (β = −0.056, SE 0.121, $p = .088$), cue valence (β = −0.258, SE = 0.138, $p = .587$), nor an interaction between these factors (β = 0.356, SE = 0.182, $p = .057$). For memory valence ratings, we observed significant main effects of cue valence (β = 2.344, SE = 0.174, $p < .0001$) and arousal (β = 2.557, SE = 0.235, $p < .0001$), but no interaction (β = 0.321, SE = 0.2577, $p = .258$). The main effect of cue valence was larger than that of cue arousal (linear contrast, $p < .0001$), suggesting that cue valence played a stronger role in guiding the valence of the recollected memory. To follow upon this finding, we then examined the proportion of memories recalled with an emotional valence that matched the cue valence for each cue condition. We categorized the emotional valence ratings of the memory as positive (response of 5,6), neutral (response of 3,4) or negative (response of 1,2), and then estimated a logistic regression to examine how the match between these binned responses and the cue valence (a binary outcome variable) were predicted by the cue conditions. Here, we found effects of cue arousal (β = −0.156, SE = 0.074, $p = .00014$) and cue valence (β = 0.514, SE = 0.074, $p < .0001$) upon valence match, and notably a significant interaction between cue valence and arousal (β = −0.497, SE = 0.074, $p < .0001$). This interaction effect was driven by a higher proportion of memories matching cue valence to the high arousal positive cue (happy, M = 0.868, SD = 0.337) than any other cue condition (all others M = 0.5964, SD = 0.491; Fig. 4).

Finally, as an exploratory analysis, we examined the extent to which physiological responses to the cues, irrespective of emotional cue category, predicted these subjective ratings. We found that reported-memory valence was significantly and positively predicted by cue-evoked zygomatic EMG response and significantly and negatively predicted by cue-evoked corrugator EMG response, but not by cue-evoked SCR (see Table 1). Reported memory vividness was not significantly predicted by any of the three cue-evoked physiological responses nor was self-reported memory intensity.

3.2. Session two

We analyzed the number of details provided in the descriptions as a function of cue condition separately for internal and external details,

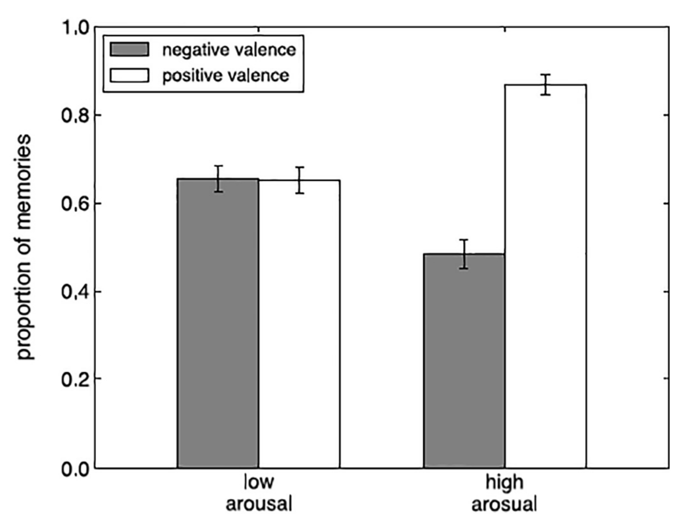

Fig. 4. The average proportion of memories recalled with the same valence as the cue, plotted separately for the four cue conditions. Error bars denote standard error of the mean.

Table 1
Regression results for the prediction of the subjective ratings (Italicized) of the retrieved memory by the physiological response measures taken during cue exposure. Ratings were all captured via Likert scales between 1 and 6 with the following anchors: Memory Vividness (1 = no images to 6 = extremely vivid); memory valence (1 = positive to 6 = negative); memory intensity (1 = calm to 6 = arousing).

Predicted variable and fixed effect estimates	β	SE	p
Vividness			
Cue zygomatic EMG response	−0.077	0.113	0.496
Cue corrugator EMG response	0.196	0.194	0.312
Cue SCR	−0.009	0.145	0.953
Memory valence			
Cue zygomatic EMG response	0.333	0.169	0.049
Cue corrugator EMG response	−0.723	0.315	0.022
Cue SCR	0.433	0.264	0.101
Memory intensity			
Cue zygomatic EMG response	−0.062	0.097	0.518
Cue corrugator EMG response	0.114	0.191	0.552
Cue SCR	0.11	0.142	0.435

following the detail scoring technique described by Levine et al. (2002). A regression model predicting the number of internal details recalled revealed that memories initially cued by high arousal cues were constructed with more internal details than those initially cued to low arousal cues (low arousal M = 15.489, SD = 9.195; high arousal M = 16.688, SD = 9.355; see Fig. 5A), as evidenced by a main effect of cue arousal [β = 1.58, SE = 0.710, p = .014]. In this model, neither cue valence (β = 0.002, SE = 0.631, p = .631) nor the interaction between valence and arousal (β = −0.804, SE = 1.011, p = .426) had significant predictive effects on the number of internal details. The regression model to predict the number of external details recalled as a function of the same cue properties did not include any significant predictors (ps > 0.445 for main effect, p = .139 for the interaction effect; see Fig. 5B).

4. Discussion

The aim of this study was to examine how the emotion of a retrieval cue affected phases of the autobiographical memory retrieval process. Using a within-subjects design, we manipulated the emotion of musical retrieval cues along two dimensions, valence and arousal, and tested how this manipulation affected autobiographical memory access (the speed at which a past event was accessed) and elaboration (the level of detail with which a memory was constructed). The main finding was that the emotional valence of the musical retrieval cue was linked to autobiographical memory access and cue arousal was linked to autobiographical memory elaboration. These data suggest that the arousal level and emotional valence of a retrieval cue exerts separable effects on these two phases of autobiographical memory retrieval, which we elaborate on in the sections below.

4.1. Emotional cue effects on memory access

While cue valence and arousal both impacted the response time to retrieve a memory, a metric of memory access, cue valence conferred a numerically larger effect than cue arousal. The more robust effect of cue valence than arousal on response time was driven by positive cues leading to quicker access of autobiographical memories than negative cues. One explanation for this effect is that the emotional valence of the cue impacted the approach taken to search and retrieve memories. Prior work has indicated that positive emotion leads to a broadening of cognitive function, or scope, and negative emotion narrows cognitive focus (e.g., Easterbrook, 1959; Fredrickson, 2001). This would translate to the positive cues leading to a global or holistic approach to memory search, inviting more memories to be potentially accessed, and negative cues leading to narrowing of this search, which could slow the search and access of a memory. This result could also indicate that memories of different valence are represented differently within one's autobiographical knowledge structure and, more specifically, that positive memories are better represented and more available for retrieval than negative memories, which we found that the greatest number of memories that were matched in valence to the given cues were for happy cues (positive and high arousal; Fig. 4). These data indicate that there are more - or at least more accessible - memories that are highly positive, and thus more quickly accessed, than negative within one's autobiographical memories organizational structure. Since fewer memories are represented by a negative retrieval cue, memory retrieval requires more effortful generative search strategy to find a congruent event. This account compliments the adaptive function of being able to directly recall positive (happy) events, which is to maintain a healthy personal narrative (Neisser et al., 1996) and an optimistic sense of self

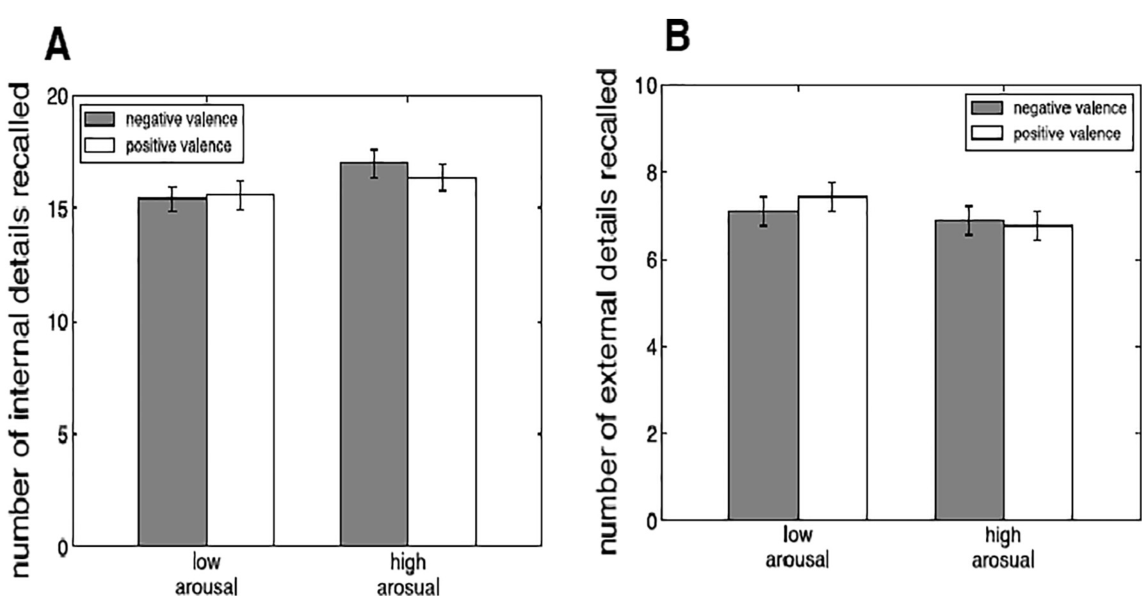

Fig. 5. The average number of internal (A) and external (B) details used to describe the autobiographical memories as a function of cue valence and arousal. Error bars denote standard error of the mean.

(Erskine, Kvavilashvili, Conway, & Myers, 2007; Prebble et al., 2013; Rasmussen & Berntsen, 2009).

The effect of emotional retrieval cues on memory access mirrors what we reported in a previous study (Sheldon & Donahue, 2017), however the present results provided new evidence that the musical retrieval cues represented different emotional content by illustrating distinct physiological responses to the cues of different valence and arousal categories. Although we collected facial EMG and SCR as participants listened to the musical cues, rather than when they retrieved the memories, the possibility remains that the reported cue-evoked physiological responses are capturing distinctions in initial memory retrieval and not in how the cues are being evaluated, which could also explain the link between cue-evoked physiological responses of valence (EMG responses) and the subjective reports of memory valence (Table 1).

4.2. Cue arousal effects on memory elaboration

While exposure to positive or negative emotion via retrieval cues altered memory accessibility, only emotional arousal of a cue impacted the elaboration upon a recalled event. Memories initially cued to high arousing excerpts were constructed with more episodic content—as measured by the number of internal details recalled (Levine et al., 2002)—than those initially cued to low arousing excerpts. This effect was found when participants described cued memories after a 24-hour delay, a design choice we made so that we could examine the effects of the emotion of the cue on the reconsolidation and subsequent elaboration of an autobiographical memory trace. Following contemporary memory models that view retrieval as a dynamic phenomenon that updates accessed and elaborated-upon memory representations (Hupbach, Gomez, Hardt, & Nadel, 2007; Lee, Nader, & Schiller, 2017; Nader, 2015), we interpret our findings in the following way. During session one, cue arousal activated episodic memory processes when imagining a recalled event, that then enhanced the episodic content (internal details) reconsolidated into the underlying memory trace which was available to be reactivated during the later retrieval session (session two). However, a reconsolidation-based interpretation of our results is not the only explanation for the reported arousal effects seen during session two. Another explanation is that high-arousing cues led to different memories being accessed than low-arousing cues. Some studies suggest that when we are aroused, we tend to recall memories that are personally important (Clore & Schnall, 2005), and these types of memories are recalled with more episodic details (Neisser et al., 1996). Collecting ratings of personal relevance or importance of the memories could speak to this explanation, however these were not measured in our current study. The memory ratings we did collect suggest that the arousal cues did not affect the subjective experience of the accessed events. With that said, we were surprised to find that the cue arousal levels – and valence – did not affect the reported vividness of memory recall. This diverges from prior research that has shown that arousing memories are recalled with more vivid recollection than low arousing memories (Ford et al., 2012; LaBar & Cabeza, 2006; Talarico et al., 2004), and departs from theories of emotional arousal effects on memory (Phelps & Sharot, 2008). We suspect that this indicates that arousal at encoding and retrieval alter different aspects of remembering. During encoding, arousal enhances the later subjective or qualitative experience of an event, yet during retrieval, arousal enhances the objective or amount of detail when elaborating on a memory (for a related idea in older adults, see Crumley, Stetler, & Horhota, 2014).

Further to the point that emotion can target the types of memories are that are recalled, we did not fully consider the types of events accessed in response to the cues. One noteworthy study found that positive events tended to be more culturally scripted events (e.g., weddings), whereas negative events tended to be more distressing, non-scripted events (e.g., loss of a pet; Berntsen, Rubin, & Siegler, 2011). It would be interesting to more directly test if there are content differences in the memories cued to cues of different arousal as well as valence, and whether these differences reflect different functions or uses of memory. This research endeavor could help uncover how emotional cues direct memory search to specific types of memories.

4.3. The link between musical cues and memory

Given that we used music as a memory cue, an important discussion point is whether music confers a special relationship to memory. We used musical excerpts as a means to manipulate emotion, yet there is a field of research that investigates the characteristics of musically-cued autobiographical memories (Janata, Tomic, & Rakowski, 2007). This work has attempted to understand why music is particularly good at cuing past memories. Musical cues evoke more vivid recollections of past events than other types of cues (Belfi et al., 2016) and accessing events to music are more specific and positive than when cued in other ways (see El Haj, Fasotti, & Allain, 2012, for a study involving dementia population). Yet there is also evidence that memories containing musically-related autobiographical memories are not different than non-musical autobiographical memories (Halpern, Talarico, Gouda, & Williamson, 2018). What is important to note is the research examining music-evoked autobiographical memories often will use popular musical clips as retrieval cues, (e.g., Belfi et al., 2016; Ford et al., 2012; Janata, 2009; Zator & Katz, 2017), which means that both familiarity with the musical piece as well as the specific musical characteristics - such as those related to emotion - are influencing autobiographical memory retrieval. Since we wanted to focus only on the emotional characteristics of the musical cue, we used unfamiliar musical pieces as cues. Even without any familiarity with a musical piece, the emotional content of a heard piece will determine the access *and* construction of autobiographical memories. Whether the effect of cue emotion we report here is specific to musical cues – and holds for familiar musical pieces - are open research questions.

5. Limitations, conclusions and future directions

The present results corroborate the idea that valence and arousal are separable features of emotion (Russell, 1980) and, moreover, that these features can determine what is mentally accessible in memory, supporting an affect-as-information view of emotion (Clore, Schiller, & Shaked, 2018). More specifically, our data support that exposure to emotions of different valence determines how an individual will search for specific events stored within their organizational structure, whereas exposure to different levels of arousal has a more powerful effect on remembering, particularly in relation to the amount of detail included in the elaboration of the accessed events (Simpson & Sheldon, 2019). We argue that these effects arise from the emotional responses induced by a retrieval cue, which tap into different underlying mnemonic processes (but see alternative interpretations in the above section). Arousal stimulates relational processing of the episodic memory system to help construct elaborated memory representations, whereas valence instigates certain executive processes, and thus, affects the search for autobiographical memory. While we designed our experiment to test how emotional cues affect these aspects of autobiographical memory retrieval, there are other possible sources for the results. One possibility is that the reported cue effects on autobiographical memory retrieval are due to changes in mood. There is a large body of work studying the mood-congruent memory effect, an effect that states that the emotion of an individual's current mood will be same as the emotion of a retrieved memory (Blaney, 1986; Bower, 1981; Eich, Macaulay, & Ryan, 1994; Lewis, Critchley, Smith, & Dolan, 2005; Matt, Vazquez, & Campbell, 1992; Rusting, 1998). It is worth noting that the reliability of the mood-congruent memory effect is contested (Blaney, 1986; Holland & Kensinger, 2010). Some research has reported no effect of mood on autobiographical memory retrieval (McBride & Cappeliez, 2004) and others have found evidence for a mood-incongruency effect, such that positive memories are more likely to be recalled when in a negative mood to regulate emotion (Rusting & DeHart, 2000). Thus, we think it is unlikely that the results we report are due to mood alone.

There are methodological limitations that could have influenced our results. One limitation is that our sample was predominantly female, raising questions as to whether the reported effects would generalize to other individuals. Another limitation is in how to interpret the effects of cue on memory elaboration as we measured the details used to build a memory representation after a 24-hour delay. While we reasoned this design would allow us to test the effects of emotional cue characteristics on elaborating upon reconsolidated memory traces, in hindsight it may have been more effective to understand what the memory representation was prior to evoking these processes by testing memory elaboration without such a delay.

Future studies could examine how the reported emotional cue distinctions during the two phases of autobiographical memory are represented in the brain. To date, work has indicated that different brain regions are involved during memory access and elaboration. Whereas memory search or access is related to widespread cortical activity, notably in regions like the hippocampus and ventromedial prefrontal cortex, autobiographical memory elaboration has been associated with activity in posterior regions (visual cortex, precuneus) and the ventral PFC (Daselaar et al., 2008; Addis et al., 2007; Holland & Kensinger, 2010). Research has examined the effect of emotion on these neural activations, reporting that this effect is most present during search phase of memory retrieval (Ford, Rubin, & Giovanello, 2016), however it remains unclear whether this effect is due to valence versus arousal and is an important next step in this line of research.

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Data availability statement

All raw data pertaining to this study can be accessed via the Open Science Framework at http://doi.org/10.17605/OSF.IO/SUZAT.

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