Exploring the generalisation of affect across related experiences:

A study of affective bleed and memory precision

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ABSTRACT

When positive or negative events occur in a context, memory can be reflected in how positively or negatively we judge that context, and also by whether, upon later remembering that emotional event, we can bring to mind the specific context in which it occurred. We examined each of these forms of associative memory, comparing performance when positive, negative, or neutral stimuli were paired with a context. By doing so, we could contribute to debates about how emotion affects associative binding. Participants intentionally formed associations between famous places and positive, negative, or neutral pictures. In Experiment 1, we observed shifts in judgments for places as a function of associated valence; effects summated over accumulated experiences. In Experiment 2, memory precision was examined by manipulating whether lures on a five-alternative forced-choice recognition, included different places or alternate views of the target. Results revealed emotional impairments in associative memory and a selective decrease in precision for negative pairs. Eye-tracking showed more saccades between pictures for remembered pairs, but less of these inter-item saccades when pictures were emotional. Overall findings suggest that positive and negative affect are transferred similarly through episodic associations, although the specificity of context transfer may be lessened for negative content.

Keywords: emotion; associative memory; eyetracking; mnemonic similarity; affective priming

INTRODUCTION

How do positive and negative events influence later memory for associated information? Although it is well-established that emotional stimuli are better remembered than neutral stimuli, there is also evidence that negative emotion can impair intentional association learning when the to-be-associated stimuli are unrelated (Touryan et al., 2007; Zimmerman & Kelley, 2010; Madan et al., 2012, 2017a; Bisby & Burgess, 2014; Bisby et al., 2018; Caplan et al., 2019; Palombo et al., 2021). Notably, this occurs even when items are presented relatively slowly and sequentially (Madan et al., 2012) and when there is sufficient evidence of item-memory but impaired association-memory (Madan et al. 2017).

We have recently shown that this same associative binding deficit may not arise with positive content; and in fact, associative memory may be enhanced when stimuli contain positive content (Madan et al., 2019). Here, we broadened the way in which we measured associative learning, examining whether there would still be diverging effects of negative and positive emotion on associative memory performance. In the present study, we examined associative learning in two different ways. First, we measured the ability for some of the affective qualities of the positive or negative associate to ‘bleed’ across the episodic association and become imbued into the associated, previously-neutral, context. This was examined in Experiment 1, and is more closely tied to the affective priming literature (Fazio, 2001). Second, positive and negative events may influence the precision with which the context is remembered. That is, an emotional event may blind people to the specifics of the surrounding context—which we tested in Experiment 2.

Affective bleed

A number of studies have examined how previous association with an emotional item or context can influence the dynamics of memory retrieval (e.g., Maratos & Rugg, 2001; Smith

et al., 2004; Riggs et al., 2014; Ventura-Bort et al., 2016, 2020; Liu et al., 2017). However, these studies have not examined how prior association with emotional stimuli may change the perceived affect of the associated item. For instance, if you know that someone was mugged near a specific building, you may now view that location more negatively than before you had known of this incident. Few of these studies directly tested for memory of the valenced associate. Studies of affective priming and conditioning may be more relevant to this question than the extant episodic memory research. Briefly, affective priming studies have shown that processing of the affective attributes of an initial stimulus can automatically influence the processing of a following stimulus (e.g., Klauer, 1997; Fazio, 2001). Conditioning studies have presented neutral pictures with aversive outcomes, particularly sounds or electric shocks, and tested for subsequent changes in memory due to these associations (Mather & Knight, 2008; Sakaki et al., 2014; Dunsmoor et al., 2015). Convergently, studies of reward-memory effects that have used procedures where rewards are conditioned to be associated with reward values have found reward-related subsequent memory effects (Estes, 1966; Allen & Estes, 1972; Madan & Spetch, 2012; Chakravarty et al., 2019).

The prior literature has not allowed for any direct contrast of the ability for positive versus negative emotions to lead to affective transfer. Yet, there is growing evidence that positive emotion has different effects on memory, rather than a more general effect of emotional arousal (e.g., Zimmerman & Kelley, 2010; Madan et al., 2019). Here, we designed an experiment to directly compare the affective bleed from positive versus negative content.

Moreover, although these studies suggest that affective bleed will arise, it is possible that with intentional associations and less salient affective stimuli (than used in conditioning studies), participants will process the associative learning more deliberately and cognitively, rather than affectively, and *not* produce any affective bleed effect.

Here, we could adjudicate between multiple possible alternate outcomes. We predicted a greater shift in affect, either positive or negative, when multiple unique pictures of the same famous place were paired with multiple pictures of the same valence (either positive or negative), representing a generalisation or integration of these distinct episodes. However, it was also possible—based on prior literature suggesting that negative affect may reduce affective binding more than positive affect—that affective bleed would arise predominantly for positive stimuli and that the associative learning would not arise with negative stimuli. And, it was even possible that, when testing for how affective judgments may generalise to previously unseen pictures of famous places, as a proxy for generalisation of previous emotional episodes to *new* experiences, that no affective transfer would occur.

Memory precision

The second major topic in the present work is how emotional items modulate how people attend to details of associated information. While previous studies have assessed the influence of emotion on associative memory using cued recall or associative recognition (e.g., Zimmerman & Kelley, 2010; Madan et al., 2012, 2017; Bisby et al. 2014), none have examined how memory may influence the *memory precision* for the associate. Yet in the broader literature, there has been extensive discussion about whether emotional valence affects the specificity of memory representations, with positive emotion perhaps leading to more general memory representations than negative emotion (Gasper & Clore, 2002; Kensinger & Schacter, 2016). To assess this facet of emotional associative memory, we manipulated the recognition lure similarity to be either different places (‘gist’) or different pictures of the same famous place (‘specific’).

We additionally collected eye-tracking data during encoding to see how gaze patterns may be relate to emotion and predict subsequent memory. Saccades between the two to-be-

remembered pictures, or ‘inter-item saccades’, may be particularly important for remembering associations between pictures. And one reason why negative emotion may impair associative memory may be because individuals make fewer such inter-item saccades. Indeed, Madan et al. (2017a) found that negative emotion led to reduced inter-item saccades between to-be-associated pictures, but that subsequent associative memory was related to more inter-item saccades during encoding; both effects were recently replicated by Fujiwara et al. (2021). These results suggest that negative emotional pictures capture people’s attention and result in worse associative learning, though it is unclear if this effect would generalise to positive emotion as well, or if emotion may instead broaden people’s attentional resources (e.g., see Gasper & Clore, 2002).

Together these two studies allow us to examine how emotion—both negative and positive—can modulate different aspects of associative memory. The first experiment explores affective judgments as an indirect test of associative memory and integration across related experiences, whereas the second experiment assessed memory precision for items associated with emotional information along with data of gaze behaviour during encoding.

EXPERIMENT 1

Methods

Participants

A total of 38 young adults (28 females), ranging from 18 to 23 years old ($M=19.2$), pre-screened to exclude individuals with a history of psychiatric or neurological disorders participated either for partial course credit or payment (\$10/hour). Informed written consent was obtained from all participants prior to beginning the study, which was approved by the

Boston College Institutional Review Board. No individuals participated in more than one experiment.

A post-hoc power-analysis determined that with this sample size and ANOVA design, we had 80% power to detect effects (η_p^2) of .052 or larger.

Stimuli

Famous place pictures. A subset of pictures of 72 famous places, 5 unique pictures of each place, were selected from the stimuli set developed in the norming study (see Appendix for details; initially based on Niazi et al., 2014).

IAPS pictures. Emotionally positive, negative, and neutral pictures—63 of each—were selected from the International Affective Picture System (IAPS; Lang et al., 2008) based on normative ratings. Pictures were selected such that positive and negative pictures were equal in arousal and absolute valence [arousal: $t(124)=1.64$, $p=.10$; absolute valence: $t(124)=0.08$, $p=.94$], but differed from the neutral pictures in both dimensions [arousal: $t(124)=17.8$, $p<.001$; absolute valence: $t(124)=12.9$, $p<.001$]. All three sets of pictures were also similar in objective measures of visual complexity: edge density, feature congestion, and subband entropy [all p 's $>.2$] (see Madan et al., 2018, for further details).

Procedure

The task consisted of five phases and took approximately 1 hour to complete. Famous place picture assignment (e.g., which were shown in repeatedly vs. only in Phase 3, which were associated with a given valence) was randomised across participants. In all phases, trials across all conditions were intermixed and presented in a randomised order. Figure 1 shows an illustration of the task sequence and each phase. The associative learning, associative

recognition, and famous place recognition phases each began with four practice trials that were not included in the analyses.

Experiment 1

Experiment 2

Figure 1. Task design for Experiments 1 and 2. (A) Task sequence for Experiment 1. (B-F) Illustration of task for the five phases comprising Experiment 1. (G) Task sequence for Experiment 2, noting that eye-tracking data was collected during the association-learning phase. (H) Illustration of the modified associative recognition task used in Experiment 2. Alternative pictures are shown instead of the IAPS pictures, due to restrictions on reproducing pictures from the original database.

(1) Initial affective judgment. Participants were shown pictures of famous places and instructed to make an affective judgment. Below each picture was a 9-point Self-Assessment Manikin (SAM; Bradley & Lang, 1994; Lang, 1980) scale, with 9 corresponding to very

positive. A portrait version of the SAM scale was used, showing an enlarged view of the face of the manikin (Suk, 2006; also see Madan et al., 2017b). Pictures were shown until a judgment was made. A 500-ms intertrial interval occurred between trials. Four unique pictures of each of the 72 famous places were shown, comprising 288 trials (i.e., 72 places $\times$ 4 unique pictures).

(2) Associative learning go/no-go. A picture of a famous place was shown simultaneously with another picture for 4 seconds. If the other picture was a (non-scrambled) IAPS picture, participants were instructed to remember the pair of pictures ('no-go'); if the other picture was scrambled, participants were asked to press the "S" key ('go' response). IAPS pictures were either emotionally positive, negative, or neutral (one-third each). This presentation was then followed by a 500-ms intertrial interval.

For the famous place pictures, each picture from Phase 1 was shown again; for half of the places, one of the pictures was shown alongside an IAPS picture, the remaining three pictures of that place were shown alongside a scrambled picture. For the other half of the places, all four unique pictures for each famous place were shown alongside an IAPS picture, with a unique picture for each. For these famous places associated with four unique IAPS pictures, all four pictures were valence consistent (e.g., all four negatively valenced). This phase was also comprised of 288 trials (i.e., 108 of which included a scrambled picture).

(3) Subsequent affective judgment. This second judgment task followed the same format as in Phase 1, however, only two pictures of each famous place were shown. One of the famous place pictures was previously shown in Phase 2 alongside an IAPS picture (and thus also in Phase 1, 'repeated') and the other was a previously unseen ('new') picture. This phase was comprised of 144 trials (i.e., 72 places $\times$ 2 unique pictures). Pictures were shown until a judgment was made.

(4) Associative recognition. Memory for associations was tested using a five alternative forced choice (5-AFC) associative recognition test, based on the procedure from Madan et al. (2017a). IAPS pictures were always used as the retrieval cue and presented in the center of the screen. Surrounding the cue, an array of five pictures (one target, four lures) were shown in fixed screen positions—as shown in Figure 1E. All lures were pictures of famous places previously shown in the experiment; all were presented equally often as lures. Participants had to choose the target picture from the array using the computer mouse; the cue and options were shown until an option was selected. This was then followed by a 500-ms intertrial interval. This phase was comprised of 180 trials (i.e., $[36 \text{ places} \times 4 \text{ pictures}] + [36 \text{ places} \times 1 \text{ picture}]$).

(5) Famous place recognition. To test participants' knowledge of the famous places, a name recognition test was included based on the design of the associative recognition test. Here specific famous place pictures used in Phases 1-4 was shown centrally on the screen and surrounded by five names of famous places used in the study, in the same array of screen locations as the choices in Phase 4. Participants had to choose the correct name from the array using the computer mouse; the cue and options were shown until an option was selected. This was then followed by a 500-ms intertrial interval. This phase was comprised of 72 trials.

Data analysis

Data from 4 participants were excluded from all analyses due to below chance performance on the associative recognition test ($N=3$; i.e., mean accuracy less than 20%) or a low hit rate on responding to the scrambled pictures in the associative learning go/no-go phase ($N=1$; i.e., hit rate below .60), resulting in a final sample of 34 participants.

All post-hoc comparisons were Holm-Bonferroni corrected for multiple comparisons.

Results & Discussion

Manipulation checks

During the associative learning go/no-go phase, hit and false alarm rates to the scrambled pictures was near-perfect: .979 hits, .002 false alarms (of 108 ‘go’ scrambled pictures and 180 ‘no-go’ IAPS pictures). Performance in the famous place recognition phase was relatively high, with 79.1% correct [range: 57.9—92.1%].

Affective judgments

Judgments in the initial task were slightly positive, consistent with the norming study, and did not differ for the pictures that were included in the subsequent judgments vs. the other three pictures [$t(33)=0.31$, $p=.76$, Cohen’s $d=0.01$; $M=6.57$]. On average, affective judgments slightly decreased in the subsequent judgments relative to the initial judgments [$t(33)=4.24$, $p<.001$, $d=0.41$; $M=-0.36$].

The critical comparison was the change in affective judgment between the initial and subsequent judgments in relation to the valence of the associated IAPS picture and the summation condition when presented with the same picture and with regards to the pictures that were shown again or previously unseen. These comparisons were tested using a $3 \times 2 \times 2$ repeated- measures ANOVA of Valence (positive, negative, and neutral), Summation (1 and 4), and Generalisation (repeated and new). The main effects of Valence [$F(2,66)=5.40$, $p=.007$, $\eta_p^2=.14$] and Generalisation [$F(1,33)=7.42$, $p=.010$, $\eta_p^2=.18$] were statistically significant. The main effect of Summation was not significant [$F(1,33)=0.20$, $p=.66$, $\eta_p^2=.006$]. The interaction of Valence $\times$ Summation was also statistically significant [$F(2,66)=4.31$, $p=.017$, $\eta_p^2=.12$]; none of the other interactions were statistically significant.

Post-hoc comparisons for the Valence main effect demonstrated that affective judgments for famous places that were associated with negative pictures were lower than those for famous places that were associated with positive pictures [$t(33)=3.24$, $p=.006$, $d=0.56$]. The comparisons relative to neutral pictures were both not statistically significant [positive: $t(33)=1.12$, $p=.27$, $d=0.19$; negative: $t(33)=2.11$, $p=.077$, $d=0.36$]. Follow-up tests to the Generalisation main effect revealed that affective judgments were more positive for the previously unseen pictures than those that were repeated from the initial judgments [$t(33)=2.72$, $p=.010$, $d=0.47$].

With respect to the Valence $\times$ Summation interaction, simple main effects analyses indicated that differences in judgments for the famous places were significantly different for the those that were presented as part of four unique associations [$F(2,66)=6.62$, $p=.002$, $\eta_p^2=.17$], but not for those only involved in one association [$F(2,66)=0.79$, $p=.61$, $\eta_p^2=.018$], as shown in Figure 2A.

Figure 2. Results of Experiment 1. (A) Change in affective judgment between initial and subsequent judgments and (B) associative recognition performance. Pairs involving famous places pictures associated with positive, negative, or neutral IAPS pictures are shown in red, blue, or grey, respectively. If one picture of the famous place was associated with an IAPS picture, these are denoted as “1 pres.” and unfilled markers or bars; if there were four pictures shown, this is denoted as “4 pres.” and a filled marker or bar. Chance performance in the associative memory test was 50% and is denoted with a dashed line. Error bars are 95% confidence intervals corrected for inter-individual differences.

Associative recognition

Associative memory was examined with a 3×2 repeated-measures ANOVA of Valence (positive, negative, and neutral) and Summation (1 and 4). Neither of the main effects [Valence: $F(2,66)=2.04$, $p=.14$, $\eta_p^2=.058$; Summation: $F(1,33)=2.18$, $p=.15$, $\eta_p^2=.062$] nor the interaction were significant [$F(2,66)=1.93$, $p=.15$, $\eta_p^2=.055$], as shown in Figure 2B. Mean accuracy was relatively low (with the 5-AFC procedure, chance is 20%, and mean accuracy was 35.3%); near-floor performance likely attenuated sensitivity to compare the conditions.

EXPERIMENT 2

Here we used the same overall procedure, but asked participants to learn fewer associations (78 pairs, compared to 180 pairs in Experiment 1) so as to reduce memory demands to avoid the poor memory performance revealed in the prior experiment. We only presented famous places with single associated pictures (positive, negative, or neutral), which was shown in the prior experiment to minimize most of the affective bleed effects. This design choice allowed us to hone in on the memory precision for details of the associated pictures: We pseudorandomly tested half of the associations with recognition lures of different famous places ('gist' trials) and on other trials presented four previously unseen pictures of the target famous place as the lures ('specific' trials). This manipulation of lure similarity is inspired by previous studies of memory precision in item recognition (Friedman, 1979; Tulving, 1981; Huffman & Stark, 2017; Stark et al., 2019; Fandakova et al., 2021). As we did not observe any change in affective judgments with just 1-presentation in Experiment 1, we also removed the affective judgment phases when designing Experiment 2.

Methods

Participants

A total of 50 young adults (34 females), ranging from 17 to 29 years old ($M=20.6$) participated in this experiment.

Data from 9 participants were excluded from all analyses due to below chance performance on the associative recognition test ($N=0$; i.e., mean accuracy less than 20%), near-ceiling performance ($N=2$; i.e., mean accuracy above 85%), or unusable eye-tracking data ($N=7$; i.e., insufficient gaze position calibration after several attempts).

A post-hoc power-analysis determined that with this sample size and ANOVA design, we had 80% power to detect effects (η_p^2) of .053 or larger.

316

317 *Apparatus*

318 Eye-tracking data was collected during the associative learning phase using SMI RED remote
319 eye-tracker integrated in a 22" monitor (SensoMotoric Instruments Inc., Boston, MA),
320 sampling the participants' left eye gaze at 120 Hz. Participants were seated at eye level with
321 the monitor, approximately 70 cm away, though chair position was adjusted for each
322 participant. The experimenter observed eye-tracking data acquisition and if the participant
323 had shifted to a position where the sensor could no longer detect their eyes (e.g., leaning
324 forward with chin resting on hands), participants adjusted their posture and seat as necessary.
325 Gaze position was calibrated with a 9-point calibration to have precision under 1.25° of
326 visual angle.

327

328 *Procedure*

329 The task consisted of three phases. The entire task took approximately 35 minutes to
330 complete. Procedures were the same as in Experiment 1 unless otherwise described, including
331 the presence of practice trials. Each phase was comprised of 78 trials. See Figure 1G for an
332 illustration of the task sequence.

333

334 **(1) Associative learning.** Each famous place was shown only *once*, alongside an IAPS
335 picture, presented for 2 seconds. Each of the pictures were squares, subtending 10.3° of
336 visual angle; horizontally separated by 2.3° . Participants were instructed to do their best to
337 remember the paired pictures. In between presentation of the pairs, a control set of pictures
338 (of the same average luminance and was colours, generated by averaging the original
339 pictures) was presented for 6 seconds. No scrambled pictures were used in this experiment.

Eye-tracking data was collected only during this phase, which lasted approximately 12 minutes.

(2) Associative recognition. For half of the trials, all four lure pictures were *other* famous place pictures that were previously shown in Phase 1 (as in Experiment 1), referred to as Gist trials. For the remaining half of the trials, the lure pictures were other pictures of the *same* famous place, not previously presented within the experiment, referred to as Specific trials.

(3) Famous place recognition. No changes in procedure relative to Experiment 1.

Results & Discussion

Manipulation checks

Performance in the famous place recognition phase was relatively high, with 78.6% correct [range: 58.5—91.5%].

Associative recognition

Associative memory was examined with a 3×2 repeated-measures ANOVA of Valence (positive, negative, and neutral) and Precision (Gist and Specific). While we did not observe a significant main effect of Precision [$F(1,40)=0.76$, $p=.39$, $\eta_p^2=.019$], we did find a significant main effect of Valence [$F(2,80)=10.90$, $p<.001$, $\eta_p^2=.21$] as well as interaction [$F(2,80)=3.52$, $p=.034$, $\eta_p^2=.081$]. As shown in Figure 3A, association memory accuracy was significantly worse for both emotional pair types as compared to neural pairs [positive: $t(40)=2.91$, $p=.009$, $d=0.46$; negative: $t(40)=4.62$, $p<.001$, $d=0.72$]; the two emotional pairs did not differ in accuracy from each other [$t(40)=1.70$, $p=.093$, $d=0.27$]. Simple main effect analyses indicated that accuracy related to detail only differed for negative pairs, with association-memory significantly poorer for negative pairs tested in the Specific relative to the Gist condition [$F(1,40)=7.52$, $p=.009$; $\eta_p^2=.16$].

365

366

367 **Figure 3. Results of Experiment 2.** (A) Associative recognition and (B) inter-item saccades
 368 during encoding. Pairs involving famous places pictures associated with positive, negative, or
 369 neutral IAPS pictures are shown in red, blue, or grey, respectively. Chance performance in
 370 the associative memory test was 50% and is denoted with a dashed line. In the gaze
 371 behaviour panel, filled markers represented pairs that were subsequently correctly
 372 remembered; unfilled markers represent those that were incorrectly remembered. Note that
 373 for each Valence×Precision condition, filled markers are all above the unfilled markers—
 374 corresponding to the main effect of Subsequent Memory. Error bars are 95% confidence
 375 intervals corrected for inter-individual differences.

376

377 *Gaze behaviour*

378 Eye-tracking data was quantified as the number of inter-item saccades between the to-be-
 379 associated pictures during encoding. These values were then examined with a 3×2×2
 380 repeated-measures ANOVA of Valence (positive, negative, and neutral), Precision (Gist and
 381 Specific), and Subsequent Memory (Correct and Incorrect). Consistent with prior findings,
 382 we observed a significant main effect of Subsequent Memory [$F(1,35)=5.59, p=.024,$
 383 $\eta_p^2=.14$], with more saccades between items for later remembered associations, as shown in
 384 Figure 3B. Valence was also a significant main effect [$F(2,70)=8.90, p<.001, \eta_p^2=.20$]. Post-
 385 hoc comparisons indicated that there were fewer inter-item saccades for the pairs including

an emotional picture as compared to neutral picture [positive: $t(40)=2.91, p=.010, d=0.48$; negative: $t(40)=4.10, p<.001, d=0.68$]. The difference between positive and negative was not significant [$t(40)=1.20, p=.24, d=0.20$]. No other effects were significant [all η_p^2 's<.06].

GENERAL DISCUSSION

While it was clear from prior research that emotion influences associative memory, here we further asked about how emotional valence influences *aspects* of associative memory. Experiment 1 demonstrated that representations of places associated with emotional experiences are themselves changed by the associative binding, becoming imbued with some of the valence of the associated experiences. Affective judgements of these famous places were shifted, and the extent of this shift summated across distinct experiences. This finding bridges the realms of affective priming and episodic memory, showing that this type of affective bleed can arise even when people are intentionally binding events to their places. Experiment 2 showed some similar effects of positive and negative emotion on association memory, with either emotional association leading to reduced saccades between the to-be-associated pictures, and successful associative memory (i.e., a subsequent memory effect) was present when more of these inter-item saccades were made. There was some evidence that memory precision for contexts associated with negative experiences were impaired relative to a more gist-based test, as well as replicating the previously well-established impairment of associative memory.

We were successful in shifting the affective judgment of the famous places due to accumulated episodic associations with emotional pictures, moreover, this occurred despite using unique pictures of the famous places on each trial. Famous places provided a strong test of affective bleed, as they are already associated with previous experiences, as well as being readily identifiable as a singular place represented by distinct pictures. The use of famous

places was particularly relevant in testing for summation of affect across multiple experiences and how malleable and adaptive these judgements are to accumulated experiences. While we were successful in having participants integrate these associations and did observe stronger shifts in affective judgments with more associations, e.g., “several negative events happened here” (rather than the unique pictures being treated as independent), it is possible that the pre-existing familiarity of the famous places also led to some resilience to shifting the affective judgment of the places due to their long-standing prior history. It is plausible that with locations for which people have no pre-existing knowledge, both the slope of summation over time, and the repetitions required to reach significant affective bleed, may be different. Overall, the design of Experiment 1 demonstrates a novel approach for assessing associative memory through an indirect test, despite marked differences relative to other studies that assessed valence transfer through more conditioning-like methods (e.g., Mather & Knight, 2008; Weinreich & Gollwitzer, 2016). It also aligns well with studies of belief updating (e.g., Sharot et al., 2012; Coutts, 2019) and the notion of micro-valences (Lebrecht et al., 2012).

A limitation of Experiment 1 was the poor associative memory performance. We did not observe any differences between conditions, but this was likely due to the task being too difficult because of the sheer number of associates learned within the same study set. Experiment 1 involved learning 180 associations and had relatively low mean accuracy [$M=35.4\%$], but Experiment 2 had only 78 associations to learn and memory accuracy was sufficiently higher [$M=60.8\%$]. Here, we did observe a relative impairment for associative memory for negative emotion (as compared to neutral), replicating numerous prior findings using unrelated pairs (Touryan et al., 2007; Zimmerman & Kelley, 2010; Madan et al., 2012, 2017; Bisby & Burgess, 2014). It is worth noting, however, that some emotional associative memory studies have instead found enhancements due to emotion (e.g., Mickley Steinmetz et

al., 2016; Madan et al., 2020). So far, the critical factor appears to be the presence of pre-existing conceptual or semantic relationships (Madan et al., 2020; Barnacle et al., 2021).

While much of the relevant literature has previously singularly focused on negative emotion, previous findings have suggested that positive emotional valence can have distinct effects on attention (Fredrickson, 1998, 2001; Gasper & Clore, 2002) and more general memory representations (Kensinger & Schacter, 2016). These findings suggest that emotion effects on memory are not only influenced by arousal, but that there is also a role of valence. We, however, did not observe an enhancement of associative memory due to positive emotion. This perhaps is not surprising as Zimmerman and Kelley (2010) and Madan et al. (2019) only observed this enhancement when *both* constituent items were positive.

The current study represents a shift in how we study emotion influences on associative memory. Rather than examining recognition or recall accuracy, here we examined aspects of memory—through both affective bleed and memory precision. Using these novel designs, we revealed that when positive or negative events occurred in a context, effects of emotion on memory were reflected in how positively or negatively we judge that context, and also by whether, upon later remembering that emotional event, we can bring to mind the specific context in which it occurred.

453

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APPENDIX: NORMING STUDY

An initial norming study was conducted to aid in the selection of famous place pictures to be used in the primary studies.

Methods

Participants

A total of 12 young adults (7 females), ranging from 19 to 27 years old ($M=22.2$) participated for payment (\$10/hour).

Stimuli

The stimuli set of famous places was initially based on Niazi et al. (2014), which included 69 distinct places with between 1 and 8 unique pictures of each place ($M=5.1$), providing a total of 339 pictures. Of the 69 places, 51 places had five or more unique pictures. Four places were of the Radboud University campus and were excluded.

Several websites listing famous landmarks around the world were used to increase the number of included famous places to 100. Examples of places added include the Arc de Triomphe, Atomium, Lotus Temple, Petra, and Statue of Liberty. Pictures were then collected from the internet such that the norming study included 100 distinct places with between 5 and 11 unique pictures of each place ($M=5.6$), providing a total of 556 pictures. In this set, all 100 places had five or more unique pictures.

Procedure

The norming task consisted of two phases and took approximately 30 minutes to complete.

(1) Affective judgment. Each of the 556 pictures was judged for affect using the portrait version of the SAM scale, using the same trial procedure as in Experiment 1 (see Figure 1B).

(2) Place consistency and familiarity. A random subset of five unique pictures for each famous place was presented and participants were asked to judge if the pictures were easy to identify as the same place, providing a ‘yes’ or ‘no’ response by clicking on an on-screen button with the computer mouse. After 500 ms, this was immediately followed by a second screen that maintained the presentation of the same five pictures but then asked if the participants knew the place and again prompted for a response with the computer mouse (‘no’, ‘know place but not name’, ‘know place and name’). This was then followed by a 500-ms intertrial interval. This was repeated for all 100 famous places in a randomised order.

Results

The set of famous places was reduced to a smaller subset based on the mean affective judgment, collapsing across unique pictures, and the consistency judgments of if it was easy to identify the set of pictures as representing the same place.

For most places, participants had responded ‘yes’ in the consistency judgment. The mean ‘yes’ response across places was 87.6%, but ranged from 18.0% to 100%. All participants had responded ‘yes’ (i.e., 100%) for 50 of the famous places. Six places had averages below 50% and were not used in the primary experiments.

Average affective judgments for the famous places ranged from neutral (4.52) to positive (7.43, on a 9-point scale). Picture sets were reduced to 72 (Experiment 1) or 78 (Experiment 2) famous places by removing the most positive places; some of these places included Edinburgh Castle, Mont Saint-Michel, Eiffel Tower, Niagara Falls, and Christ the Redeemer.