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Distinct Signatures of Social and Emotional Cues in Memory and Eye Movements

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Negative emotional stimuli are associated with increased recognition accuracy but decreased memory for the associative context, an effect coined as "tunnel memory" (Steinmetz & Kensinger, 2013). Recently, Stewardson et al. (2023) found that social cues enhance both recognition and associative memory and weaken the effects of negative emotion on memory, suggesting potentially distinct mechanisms underlying how adaptively relevant information is processed and retained when social cues are present. In this study (conducted in 2023–2024), we sought to replicate these findings and use eye tracking to explore attention as a mechanism underlying this divergence. As predicted, both negative images and social cues enhanced recognition memory, with differential effects on associative memory (diminishing for negative, enhancing for social). Negative pictures with few social cues were associated with a "tunneling" of both memory and attention, that is, better recognition but poorer associative memory alongside more frequent, longer fixations on the picture and reduced picture–object saccades. By contrast, social cues led to a partial tunneling of attention—that is, more frequent but shorter fixations and fewer linking saccades—and yet enhanced both picture recognition and associative memory. Perhaps most striking, negative emotion's effects on memory and attention were significantly attenuated when social cues were present. These findings suggest that differences in how negative versus neutral content is processed and retained depend on the social context.

Keywords: emotion, social cues, memory, negative, eye tracking

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Of the countless experiences we have, only some are remembered. Understanding why some experiences stick in our memories while others are forgotten may reveal how the brain prioritizes, processes, and stores information. For instance, pictures that elicit strong emotional reactions are remembered more accurately than pictures that are emotionally neutral (for review, see Kensinger, 2009). Yet emotion does not boost memory for everything that we see. Heightened emotions can reduce memory for the details surrounding the target of the emotions (Bisby & Burgess, 2014; Cox et al., 2023; Fujiwara et al., 2021; Kensinger et al., 2007; Kim et al., 2013; for review, see Bisby & Burgess, 2017; but see Bogdan, Dolcos, Katsumi, et al., 2024; Madan et al., 2020).[1] One explanation for this finding—observed most robustly for negative stimuli—is

[1] Notably, some studies find improved memory for context surrounding emotional content or associative processes (e.g., Bogdan, Dolcos, Katsumi, et al., 2024; Madan et al., 2020; Ventura-Bort et al., 2016, 2020; see Talmi & Palombo, 2025).

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that there may be a trade-off between memory accuracy for a key emotionally evocative target event and its surrounding context, a tunneling effect (Safer et al., 1998). Here, we investigate boundary conditions of this effect when social cues are present and use eye tracking to elucidate the extent to which attentional differences may underlie these effects.

An intuitive explanation for why negative cues enhance recognition memory but diminishes associative memory is offered by the Arousal-Biased Competition theory (ABC; e.g., Mather & Sutherland, 2011; also see the Attention Mediation Hypothesis by Anderson, 2005; Talmi et al., 2008; for discussion of related theories see Talmi & Palombo, 2025). The ABC theory suggests that emotionally arousing information has greater goal relevance than the surrounding neutral context, allowing it to win the "tug of war for attentional resources," with downstream consequences for later remembering (Reisberg & Heuer, 2004; Talmi, 2013; Williams et al., 2022). Indeed, eye-tracking studies demonstrate that negative emotional information attracts fixations of longer duration (a proxy for complexity of processing; Fujiwara et al., 2021) and more numerous fixations (a proxy for selective attention; Brooks et al., 2024; Fujiwara et al., 2021; Loftus et al., 1987; Monkman et al., 2025; Steinmetz & Kensinger, 2013). The contextual objects associated with negative pictures receive proportionately fewer fixations (Bogdan, Dolcos, Katsumi, et al., 2024; Riggs et al., 2011). These eye-tracking signatures of emotional valence at encoding are robust enough to replicate in online studies with crude, webcam-based eye tracking (Bogdan, Dolcos, Buetti, et al., 2024).

However, not all eye-tracking evidence is consistent with this account. Madan et al. (2017; Fujiwara et al., 2021) reported that although negative scenes attracted longer and more numerous fixations, neither fixation duration nor frequency was associated with memory accuracy for a target scene or an associated context scene. Rather, the number of saccades linking the two scenes was predictive of associative memory performance. Several other studies have found that fixation frequency on the target and context items only partially mediate memory performance (Riggs et al., 2011; Steinmetz & Kensinger, 2013). For example, Riggs et al. (2011) found more fixations and better memory for the central negative item relative to its context (for which fixations were fewer and memory poorer), yet this did not fully explain the observed memory tunneling effect. Other studies have observed a correlation between the number of fixations and associative memory only for neutral but not negative stimuli (Kim et al., 2013; Subramanian et al., 2014; interestingly, both studied stories-in-pictures or movies, respectively, rather than single images). More recently, Bogdan, Dolcos, Katsumi, et al. (2024) revealed a more complex pattern. In their data, associative memory did not differ between negative and neutral items, yet the context received fewer fixations when the target item was negative versus neutral, and this, in turn, had a negative effect on associative memory. Interestingly, once this attentionally mediated cost of negative content was taken into account, there emerged a positive direct effect of emotion on memory (Bogdan, Dolcos, Katsumi, et al., 2024), suggesting that when selective looking at the context is kept constant, negativity of the information enhances associative memory. Together, the findings by Bogdan, Dolcos, Katsumi, et al. suggest that negative information tends to attract more selective looking, in which case the context is remembered less, yet compared to a stimulus that likewise attracts selective fixations, negative stimuli produce better memory for the context. In light of these varied findings, more research is needed to elucidate the relationship between the content of the information to be remembered, attention, and memory.

Apart from the complex relationships between eye movements and memory, not all emotional information results in memory tunneling. A salient example can be found in pictures of people interacting with one another or their environments. Stewardson et al. (2023) studied recognition memory for pictures varying in their emotional and nonverbal social cues (i.e., facial expressions and gestures or body language). The pattern of recognition accuracy was strikingly different, depending on the social cues. Although the typical tunnel memory effect was observed when comparing negative and neutral emotional pictures with fewer social cues, pictures with greater social cues were recognized more accurately overall, and the objects associated with them were recognized more accurately as well. The presence of social cues weakened the effects of negative emotion on memory.

One way to understand the memory boost associated with pictures high in social cues is their influence on selective attention. Past work shows that people's eyes (Althoff & Cohen, 1999; Birmingham et al., 2008a), faces (Langton et al., 2008; Vuilleumier, 2000), human bodies (Downing et al., 2004), and interacting people (Birmingham et al., 2008b; Papeo, 2020; Parish-Morris et al., 2019; Villani et al., 2015) all attract attention at a heightened level. Attention to social content is also very sensitive to the context in which it occurs, namely, the task being performed (Birmingham et al., 2008a; Pereira et al., 2020; Yarbus, 1965), and whether the observed person is on video or live (Foulsham et al., 2011; Gregory & Antolin, 2019; Mayrand et al., 2023). People can also serve as attention-directing cues. We tend to follow the gaze of people in a picture, looking in the direction they are looking (Capozzi & Ristic, 2020; Fernandes et al., 2021; Mayrand et al., 2023; Ristic et al., 2002) and looking at the objects they are manipulating (Birmingham et al., 2008b). All this suggests that pictures high in social cues might also nudge observers to explore the context surrounding the picture. Indeed, Stewardson et al. (2023) may have found improved associative memory for pictures high in social cues exactly because selective looking was more evenly distributed between target pictures and context objects—a hypothesis that could not be tested in their online study.

The Present Study

The extant literature suggests that emotional memory effects may differ when tested with pictures that are low versus high in social cues. Furthermore, the memory accuracy effects in these two contexts may be associated with unique patterns of selective looking. The present study, therefore, had a twofold aim. First, we sought to replicate the item and associative memory results of Stewardson et al. (2023), a prior study from our laboratories (authors CMK, DJP), with a large and independent set of observers. Our second aim was to investigate the selective looking patterns associated with these findings. Following Stewardson et al., participants in the present study viewed pairs of images on the first day of testing: a naturalistic photo positioned beside an everyday object. They were asked to rate how easy it was to link the two. The next day, they were presented with a surprise memory test in which they were first asked to recognize pictures seen on the previous day (new/old response) and then to select one object (from among four) that had been paired with the picture.

We tested two preregistered hypotheses for recognition accuracy measures (https://osf.io/e53tg). First, we expected emotion to have a main effect on both item and associative memory, such that negative emotional pictures enhance item memory over neutral pictures while reducing associative memory (typical tunnel memory). Second, we expected social cues to have a main effect on both item and associative memory, such that pictures high in social cues enhance both item and associative memory, as reported in Stewardson et al. (2023). As per our preregistration, we did not provide specific predictions about interactions between social cues and emotion on either item or associative memory. Interactions observed in Stewardson et al. suggest attenuated tunneling for stimuli rich in social cues; however, this pattern was somewhat inconsistent across discovery and replication samples.

Our preregistered hypotheses for eye-tracking measures were that negative pictures would attract more selective looking than neutral pictures and that pictures high in social cues would attract more selective looking than pictures low in social cues (preregistered H3). Following the findings of Fujiwara et al. (2021) and Madan et al. (2017) noted above, we expected to find enhanced exploration of the context objects (assessed as gaze binding) when pictures were high in social cues (preregistered H4). Crucially, we expected the difference between negative and neutral images to be less for all eye-tracking measures for pictures high in social cues (preregistered H4); that is, we predicted that simple effects of emotion would be different for social and nonsocial pictures.

In addition, we sought to explore the relationships between memory performance and looking behavior on a trial-by-trial basis. As reviewed above, various relationships have been found in different studies. To give a very high-level summary, most studies show that while people usually remember what they looked at better than what they did not fixate on, there is more to memory performance than what looking patterns suggest. Introducing the social dimension into the stimuli to be remembered allows a new way to interrogate the associations between looking behavior and memory performance. Hence, we pursued two exploratory hypotheses that were not preregistered. First, following the findings summarized above (Bogdan, Dolcos, Katsumi, et al., 2024; Riggs et al., 2011; Steinmetz & Kensinger, 2013), we hypothesized that recognition accuracy would be positively correlated with selective looking at a picture, regardless of its social cues or negativity. This finding would be an important anchor for establishing credibility in theoretically linking looking at the time of encoding to subsequent memory accuracy. Second, we expected that the magnitude of these eye tracking-accuracy associations would be different for pictures low and high in social cues, because, as reviewed above, social pictures are expected to produce a different scanning pattern altogether.

Method

Participants

A total of 114 young adults participated in the study. Although this study is part of a larger, ongoing project that includes participants with a diagnosis of autism spectrum disorder (hereon referred to as autism), the present article focuses on participants without this diagnosis. To achieve 80% power to detect medium effects ($\eta_p^2 \geq .08$) for a main effect or an interaction in a 2×2 within-participant design, we aimed for 100 nonautistic young adults (per our preregistration) after exclusions and continued to recruit for the present study until we reached this target. With multiple participants completing the study per day, we ended up with slight oversampling ($N = 103$; see below). Power was estimated using a simulation approach proposed by Lakens and Caldwell (2021) and its implementation in a web app from the same authors.

Eligibility criteria as per preregistration (see https://osf.io/e53tg) were as follows: age between 18 and 30 years, fluent English, no eye abnormalities, no color blindness as per the Ishihara test (Clark, 1924), no history of a head injury in the past 6 months, no history of seizures or psychosis, and no current substance use disorder. Of those who completed the study, we excluded participants whose scores on the Social Responsiveness Scale–Second Edition (Constantino & Gruber, 2012) were in the "severe" range (T score > 74, $n = 3$) given prior work suggesting elevated autistic traits are associated with a distinct social and emotional attention and memory performance (Wardell et al., 2024). In addition, we used the following preregistered exclusionary criteria: failure to complete the memory paradigm by midnight on the day of the test (excluded, $n = 0$); technical difficulties during the online sections of the study (by self-report, $n = 0$); repetition of any trials of the memory paradigm (which could happen if the browser was refreshed during the test, $n = 0$); completion of less than 60% of the encoding task and less than 80% of the memory test ($n = 0$); median reaction times significantly shorter or longer (i.e., z score > ±3) than the mean of the entire sample on the memory test (both item and associative memory, $n = 4$); below-chance performance on item memory (d' score of 0 or below, $n = 4$); failure on two or more attention checks out of the three implemented in the online image rating task (one participant with d' at or below zero also failed the attention check; no additional participants were excluded for this criterion).[2] In total, these requirements resulted in exclusion of 11 participants. In addition, two participants' eye movements were not recorded because of equipment malfunction. Data from these two participants were used in the memory analyses but not in any analyses involving eye movements. All in all, our sample includes 103 participants for memory analyses and 101 for eye movement analyses. The study procedures were reviewed and approved by the Behavioural Research Ethics Board at the University of British Columbia (BREB No. H23-00378), and all participants provided informed consent prior to participation.

Participants were recruited from the University of British Columbia's human subject pool ($n = 48$) and from the broader community ($n = 55$) between June 2023 and November 2024. Community participants were recruited through printed flyers distributed in Vancouver and Greater Vancouver area, as well as online advertisements on social media. Of the 103 participants (after exclusions), 52 (50.5%) self-identified as cisgender women, 47 (45.6%) as cisgender men, two (1.9%) as transmen, and three (2.9%) as nonbinary. The average age was 21.68 (18–30 years). Thirty-seven percent of the participants self-identified as White, 2% as Black, 66% as Asian, 6% as Middle Eastern, and 2% as "other" (note that multiethnic self-identification was permitted, so the numbers do not add up to 100%). The study took 2.5 hr in total, for which

[2] We also preregistered excluding participants by attention checks during the online memory test ($n = 2$); however, these attention checks were converted into attention enhancers, and no data were recorded for any of the participants.

participants received either course credit or \$37.50 CAD in the form of an electronic gift card for their participation.

Stimuli

The stimuli included a set of 128 naturalistic scenes (hereinafter referred to as target pictures) stratified by emotional content (negative, neutral) and the presence of social cues (social, nonsocial; see below), along with 64 images featuring neutral everyday objects (hereinafter referred to as objects).

Target Pictures

Target pictures were sourced from several standardized image sets: the Nencki Affective Picture System database (Marchewka et al., 2014), the International Affective Picture System (Lang et al., 1999), the Open Affective Standardized Image Set (Kurdi et al., 2017), the Geneva Affective Picture Database (Dan-Glauser & Scherer, 2011), the Socio-Moral Image Database (Crone et al., 2018), and a set of images used in Leal et al. (2017).

We categorized the target pictures into four conditions: negative social (e.g., a person with a distressed face), negative nonsocial (e.g., a car crash), neutral social (e.g., two people casually talking), and neutral nonsocial (e.g., parked cars). The presence of social cues was classified by two independent coders based on whether images contained social cues (social) or not (nonsocial). In line with our previous work, social cues were defined as the presence of what was determined to be nonverbal social communication (i.e., gestures, body language, or facial expression) or other behaviors that were directed to the viewer or another person in the image (e.g., a person walking to join a group or reaching out; see Stewardson et al., 2023; Wardell et al., 2024). Accordingly, nonsocial images could include people as long as they lacked nonverbal communication (e.g., a picture of hands or feet in a neutral posture). Images with companion animals were excluded due to the propensity to personify such animals.

The emotional content of images was estimated in two rounds of norming studies, in which 698 participants rated 320 images on arousal and valence using an 11-point Likert scale (0–10; for details, see Dudarev et al., 2024). Note that new norming was done after the publication of Stewardson et al. (2023) in order to increase the number of stimuli per condition. To ensure that emotional ratings were truly neutral and negative and to adhere to conventions in the field, we implemented rating cutoffs for each condition: Negative images were restricted to those rated 3.5 or lower on valence (on the scale from 0 = *negative* to 10 = *positive*) and greater than 4 on arousal (on the scale from 0 = *not arousing at all* to 10 = *very arousing*), and neutral images were restricted to those rated between 4 and 6.5 on valence and less than 4 on arousal. Then, we randomly selected 32 images for each condition (neutral nonsocial, neutral social, negative nonsocial, negative social) while balancing them on content (whether the image mainly featured people, faces, animals, or objects; Marchewka et al., 2014), orientation (vertical or horizontal), and low-level properties (e.g., luminance, contrast, $L \times a \times b$ color space, entropy, and jpeg size) across conditions. Furthermore, the negative conditions (negative social and negative nonsocial) were matched on arousal and valence ratings, as were the neutral conditions (neutral social and neutral nonsocial). Additionally, social characteristics—such as the presence of social interactions, the number of people, and the nature of eye contact (direct vs. indirect)—were balanced within social conditions (neutral social and negative social) and within nonsocial conditions (neutral nonsocial and negative nonsocial) given research suggesting differences in attentional effects of these types of images (for review, see Hamner & Vivanti, 2019). Finally, a qualitative inspection was conducted to ensure that the set did not include images that were conceptually similar to each other (e.g., of several images picturing cows in a field, only one was included).

Objects

Our set of objects consisted of 64 ordinary, neutral objects (e.g., a coffee cup), randomly selected from the Bank of Standardized Stimuli (Brodeur et al., 2010). We excluded objects that were difficult to recognize, could elicit positive (e.g., birthday cake) or negative emotion (e.g., shark), were of a particularly narrow shape (e.g., hairpin), or represented animals. The objects were balanced on low-level properties, including luminance, contrast, $L \times a \times b$ color space, entropy, jpeg file size, and white space. We created two random sets of pairs of the target pictures with objects, so that objects paired with negative pictures in one set were paired with neutral pictures in the other set, and an object paired with a social picture in one set was paired with a nonsocial one in the other set.

Procedure

The study was conducted in three sessions: two online and one in-lab. First, participants filled out a battery of online questionnaires (see Supplemental Table S1). Two to 5 days after, they arrived at the lab to complete the encoding phase, which was eye-tracked, as well as cognitive testing (see Supplemental Table S1). On the next day (14.5–35.4 hr later), memory testing was completed online. In that session, participants were also asked to rate the images on valence, arousal, and social relevance. The whole procedure took about 2.5 hr (40 min online, 1 hr in-lab, 40 min online). Only memory and eye-tracking data are reported in this article.

Encoding

Participants viewed 64 side-by-side image pairs, with each target and object pair displayed on a white background for 6 s. The positions of the target and object pairs were randomly assigned to either the left or right side of the screen. In order to promote engagement and prompt relational processing,[3] following each pair, participants were asked to rate the difficulty of imagining a connection between the two images on a scale from 1 (*very easy*) to 7 (*very difficult*). The rating scale was shown for 5 s before automatically advancing to the next pair, regardless of whether a rating was given. The paradigm was programmed in PsychoPy (Version 2022.2.4).

[3] We used this particular task during the encoding phase—asking participants to imagine a connection between the two images—following the practice of many studies reporting memory tunneling for negative information (Bisby & Burgess, 2014; Palombo et al., 2021; Stewardson et al., 2023). This task likely supports the establishment of a memory association and thus creates the best possible conditions for retaining it successfully while still being a surprise memory task. These data were not analyzed.

Eye Tracking

Participants' gaze was tracked during encoding via a Tobii Pro Spectrum 600 Hz eye-tracker placed under a computer screen (52.8 × 29.7 cm, resolution 1,920 × 1,080 pixels). Participants sat at a distance of about 60 cm from the screen and positioned themselves so that their eyes were in the center of the headbox of the Tobii Eye-Tracker Manager's Position Finder. Before any images were presented, a 5-point calibration and validation were performed, with a trained research assistant assessing the calibration quality and repeating the calibration if needed.

Participants' eye movements were then classified into fixations and saccades by defining saccades as velocity of eye gaze being at least 30° per second. The analyses were based on regions of interest, which were defined as the outlines of the images (for the context object, a virtual square that fitted the object) extended by 5% of the image height and length.

Memory Test

The next day, participants were presented with a surprise memory task, which they did online via https://Pavlovia.org and PsychoPy3. The 24-hr delay was incorporated to allow for consolidation, which enhances the emotional impact on memory over time (Sharot & Yonelinas, 2008). The recognition test was followed by the associative memory test.

In the *item memory test*, participants viewed 128 target scenes comprised of 64 previously shown and 64 new scenes. Images were shown in a random order, one at a time, with two response options: "OLD" and "NEW" presented on the screen (see Figure 1). Participants were instructed to make their choice by clicking on the relevant word on the screen, at their own pace. Trial duration was not restricted. A blank screen was shown for 1 s after the response, followed by the next trial. After the item memory test, participants were offered a self-paced break.

In the *associative memory test*, participants were shown, in a random order, each of the old scenes, one by one, accompanied by four objects (see Figure 1), and their task was to select the object that had been paired with the scene during encoding. All objects used in this test had been presented during the encoding phase. Trial duration was not restricted. The intertrial interval was 1 s.

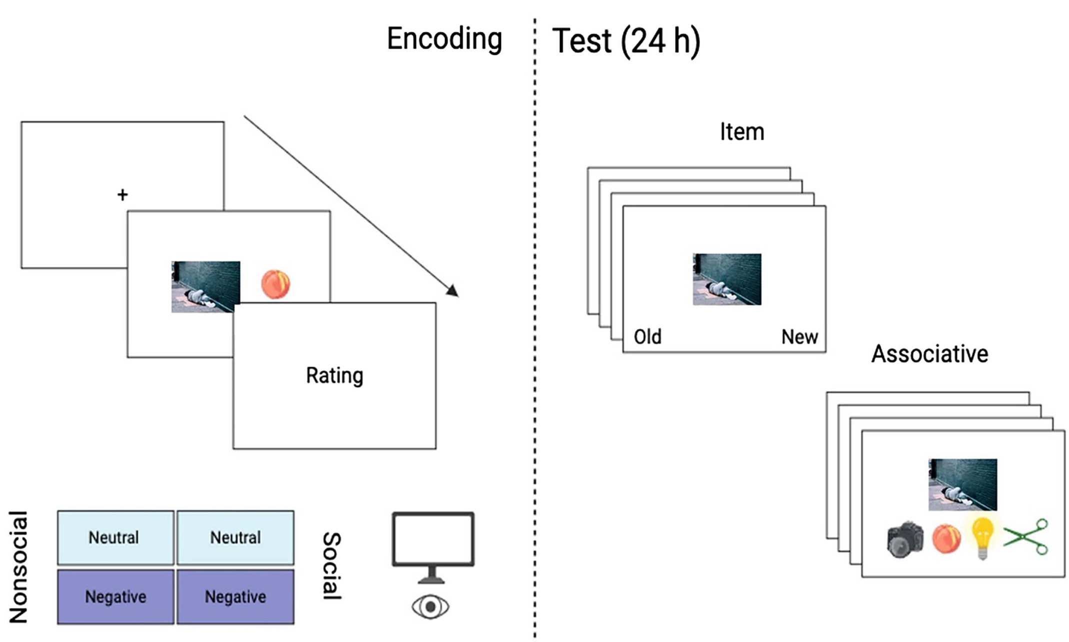
Analytic Plan

We had a number of memory and eye-tracking outcomes, listed and explained in Table 1. We first submitted each of our dependent variables to a two-way analysis of variance with emotion (negative, neutral) and social cues (social, nonsocial) as the two factors to investigate how the content of the scenes affected memory and eye movements. Post hoc analyses, which involved paired *t* tests, were performed when necessary with a Bonferroni correction (adjusted: $\alpha = .0125$). Note that because the data approximated a normal distribution, we did not perform any transformations, per our preregistration.

To explore the association between eye movements and memory performance (not preregistered), we used a logistic mixed-model regression approach. Logistic regression allows for testing binary outcomes (Breslow & Clayton, 1993), such as, in our case, item/association being remembered versus forgotten. The mixed-model

Figure 1

Procedure of the Memory Encoding and Test (See the Main Text for Details)



Note. The photo by Jon Tyson on Unsplash is presented for illustrative purposes only as the stimuli used in the study cannot be published for copyright reasons. The figure is created in BioRender with permission. See the online article for the color version of this figure.

Table 1
Operationalizations

Concept	Operationalization (DV)
Item memory	d', computed as the normalized proportion of hits (correctly recognized old items) minus the normalized proportion of false alarms (new items reported as old; Stanislaw & Todorov, 1999). The R package "psycho" was used to compute d' scores (Makowski, 2018), with Hautus adjustment for extreme values (Hautus, 1995).
Associative memory	The proportion of correct responses when choosing the object that had been paired with the picture during encoding. Because there were four response options, the a priori chance level for this test is 0.25.
Selective looking	The proportion of fixations on the scene, out of all fixations on a given trial. Proportion of fixations on the object was also examined (not preregistered).
Gaze binding	The proportion of saccades from the scene to the object or from the object to the scene, out of the total number of saccades on a given trial (Madan et al., 2017). Note that a lot of saccades are made within the picture or within an object, which makes this measure not trivially dependent on the number of fixations. Also, transitions between picture and object that "passed" through the white space (i.e., fixation on the picture followed by fixation on white space followed by fixation on the object) were not included in the count of picture-to-object saccades.
Complexity of processing	The average duration of fixation on the picture (longer corresponding to more complex processing; Enns & Watson, 2017; Madan et al., 2017; Rahal & Fiedler, 2019). In other words, when fixation on the picture was made, its duration, in milliseconds, was taken and then averaged across all fixations on a given trial. We also examined the complexity of object processing as the average duration of fixation on the object (not preregistered).

Note. DV = dependent variable.

variant (also known as multilevel regression) enables the modeling of effects of variables that are manipulated on a within-participant level while accounting for between-participant variability (Laird & Ware, 1982). That is, manipulated variables are entered as fixed factors to test their effect on the outcome, just like regular predictors in linear regression. In addition, factors such as participant ID or image ID can be used as random effects to remove unique variance associated with participant/image idiosyncrasies from error variance, allowing for more precise estimation of the fixed effects (Brauer & Curtin, 2018; Meteyard & Davies, 2020).

We conducted logistic mixed-model regressions predicting trial-by-trial item and associative memory (in two separate sets of models) from participant-centered measures of selective looking, gaze binding, and complexity of processing, with items and participants as crossed random factors (intercepts) and a random slope for the effect of emotion, using *lmerTest* (Kuznetsova et al., 2017) and *effectsize* (Ben-Shachar et al., 2020) packages in R.

Transparency and Openness

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study. All data are available at https://osf.io/ftxvc/ (Dudarev, 2025). Research materials cannot be shared due to copyright restrictions, yet identifiers of picture stimuli used in this study are available in the data that are shared. Data were analyzed using R, Version 4.0.0 (R Core Team, 2020), and the packages *lmerTest* (Kuznetsova et al., 2017) and *ggplot2*, Version 3.2.1 (Wickham, 2016). This study's design and its analysis were preregistered.

Results

In describing the results, we take the approach of presenting the findings in the order that corresponds to our preregistered hypotheses. That is, behavioral (memory) results are presented in the standard order: main effects, followed by interaction, followed by simple effects. For eye-tracking results, we present simple effects first. We believe this ordering of the results will make it easier for readers to align the current findings with past outcomes and our preregistered hypotheses.

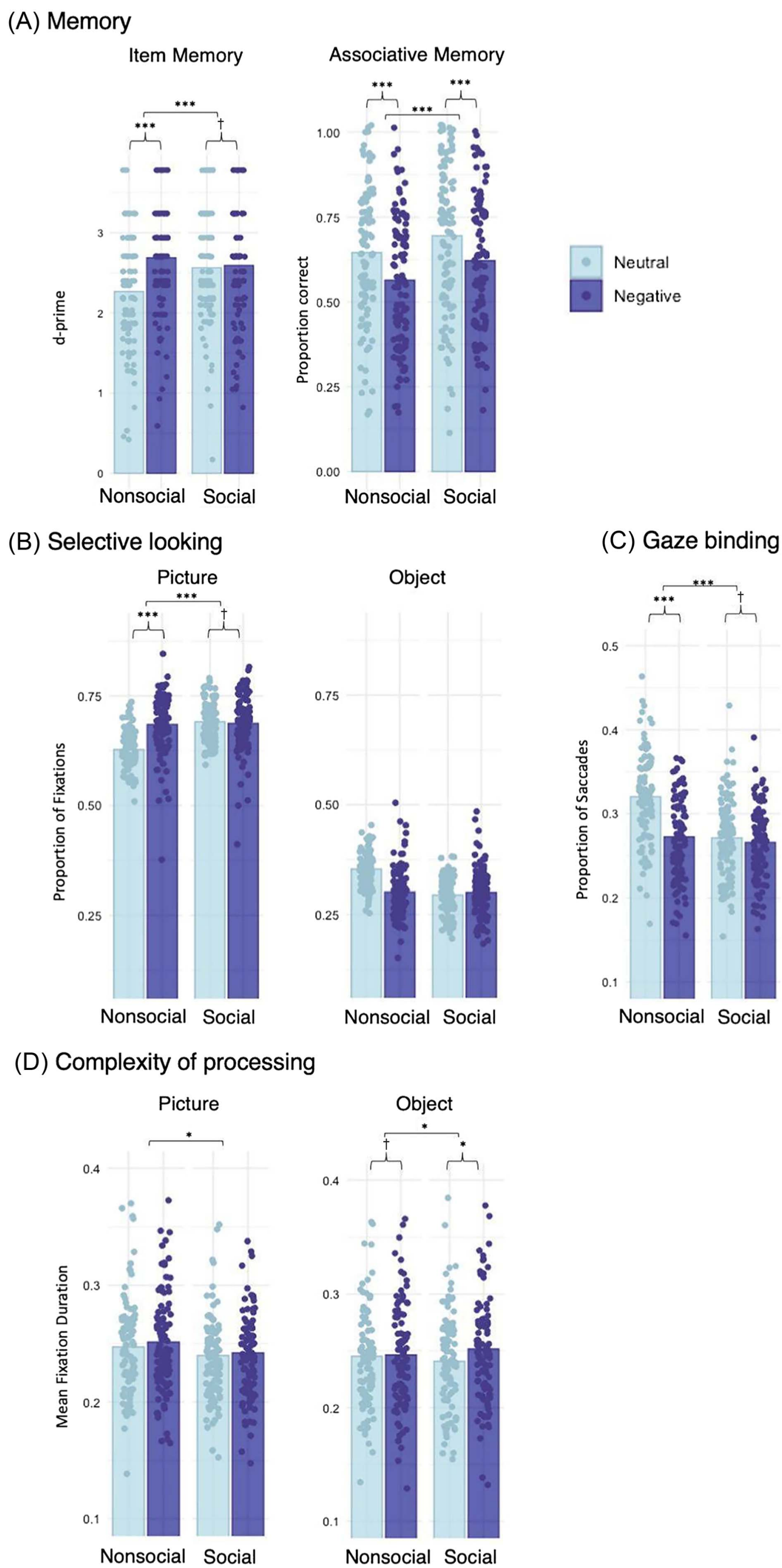
Memory Performance

Item Memory

Participants recognized the target pictures with a high level of accuracy (d' = 2.70, SD = 0.71, minimum = 0.77, maximum = 4.42), well positioned between floor (d' = 0) and ceiling levels (maximal d' = 4.85). Negative pictures were recognized better than neutral pictures, $F(1, 102) = 20.84$, $p < .001$, $\eta_p^2 = .17$, and pictures high in social cues were recognized better than those low on social cues, $F(1, 102) = 4.00$, $p = .048$, $\eta_p^2 = .038$. These main effects were qualified by an interaction, $F(1, 102) = 17.23$, $p < .001$, $\eta_p^2 = .15$, such that when target pictures had no social cues, negative pictures were remembered better than neutral ones, $t(102) = 6.06$, $p < .001$, Cohen's $d = 0.60$, whereas target pictures with social cues were recognized similarly regardless of their emotional valence, $t(102) = .43$, $p > .6$, Cohen's $d = 0.04$ (see Figure 2A). The main effects of emotion and social cues align with Stewardson et al. (2023). Note that Stewardson et al. also reported a significant social by emotional interaction, as we do here, in their replication, but not their discovery sample.[4] The overall pattern of results on item memory aligns with our preregistered hypotheses.

[4] To investigate how much of the above pattern was driven by new images (false alarms) versus old images (hits), we looked separately at hits (proportion out of all old images) and false alarms (proportion out of all new images). This analysis was not preregistered but reported for completeness. The proportion of hits showed the same general pattern as d': for the interaction, $F(1, 102) = 18.27$, $p < .001$, $\eta_p^2 = .152$; main effect of negative emotion, $F(1, 102) = 51.84$, $p < .001$, $\eta_p^2 = .34$; main effect of social cues, $F(1, 102) = 18.16$, $p < .001$, $\eta_p^2 = .15$. The fact that the pattern on hits and overall recognition performance were so similar allows us to do the eye-tracking analyses further on, as eye tracking was only done during encoding (i.e., only for old images). For new images, participants false-alarmed the most for social negative images, interaction between social and emotion $F(1, 102) = 5.64$, $p = .019$, $\eta_p^2 = .052$. False alarms were also higher for negative than neutral images, $F(1, 102) = 7.73$, $p = .006$, $\eta_p^2 = .070$, and for social than nonsocial images, $F(1, 102) = 2.23$, $p = .14$, $\eta_p^2 = .021$.

Figure 2
Overview of the Results



(*figure continues*)

Associative Memory

Participants recognized the context object associated with each picture with a mean accuracy of 63.17% ($SD = 17.33\%$), which was well above the chance guessing level of 25% and below the ceiling of 100%. Associative recognition was higher for neutral than for negative scenes, $F(1, 102) = 38.59$, $p < .001$, $\eta_p^2 = .27$, consistent with our preregistered hypothesis, and higher for social than non-social scenes, $F(1, 102) = 24.09$, $p < .001$, $\eta_p^2 = .19$, also as hypothesized. There was no interaction between social and emotional factors, $F(1, 102) = .15$, $p = .70$, $\eta_p^2 = .001$, while Stewardson et al. (2023) reported a significant social by emotional interaction in their discovery, but not in their replication sample.

In summary, item memory was enhanced for both negative over neutral scenes and for social over nonsocial images, with only the nonsocial condition providing a recognition benefit for emotionally negative pictures over neutral pictures. In contrast to this pattern, associative memory was reduced for negative over neutral pictures, whereas it was enhanced for social over nonsocial images. Taken together, this pattern is consistent with emotional pictures leading to the typical memory tunnel effect in the nonsocial condition (Stewardson et al., 2023). However, in a social condition, negative and neutral pictures were remembered equally well, while associative memory was still lower for the negative than for neutral pictures. These results support Stewardson et al. (2023) in demonstrating an attenuated memory tunneling effect for social pictures and their associated contexts.

Eye Tracking

In the following analyses, we first examine the eye-tracking data to test whether the memory tunneling effect can be linked to participants looking more often and longer at negative images, at the expense of looking at the surrounding context. Second, we test whether pictures containing social information promote a greater degree of looking in the surrounding context. Figure 2B–2D shows the results for selective looking, gaze binding, and complexity of processing, respectively.

Selective Looking

Figure 2B shows that for nonsocial pictures, negative information was fixated more often than neutral information,[5] $t(100) = 9.71$, $p < .001$, Cohen's $d = 0.97$. In contrast, social pictures attracted a similarly large proportion of fixations to both negative and neutral emotional content, $t(100) = 0.68$, $p > .4$, Cohen's $d = 0.068$. This was supported by a significant interaction between emotion and social cues, $F(1, 100) = 91.11$, $p < .001$, $\eta_p^2 = .48$, and the two main effects, emotion: $F(1, 100) = 31.53$, $p < .001$, $\eta_p^2 = .24$, and social cues: $F(1, 100) = 71.16$, $p < .001$, $\eta_p^2 = .42$. This pattern of finding is consistent with our preregistered hypothesis.

Notice that these findings mirror the pattern that was observed for item recognition, together suggesting that target pictures that were fixated on least (neutral nonsocial) were also recognized with the lowest level of accuracy. When comparing the proportion of fixations on target pictures versus associated context objects, it is important to note that there is an inherent trade-off. An increased proportion of fixations on the picture necessarily implies a decreased proportion of fixations on the object. And indeed, this trade-off was supported by a very strong negative correlation overall between proportions of fixations on the picture versus object, at $r = -.95$. Notice, however, that the proportion of fixation measure is constrained in a way that the behavioral measure of memory accuracy is not. Namely, while selective looking at the picture versus the object (Figure 2B) was mirrored closely by recognition accuracy for both pictures and objects in the nonsocial condition (Figure 2A), for the social condition, this linkage was less strong. When pictures were rich in social cues, participants looked less at the object associated with the picture, and yet they were able to bind them more accurately. That is, in the social condition, accuracy for objects was significantly higher than would be predicted by a selective looking model of memory accuracy (Bogdan, Dolcos, Katsumi, et al., 2024).

Gaze Binding

Our preregistered prediction was that negative images would induce fewer saccades between the picture and the object, while social images would induce more exploration, manifested in a higher proportion of gaze binding. The data supported the first but not the second hypothesis. Figure 2C shows the proportion of saccades that involve successive looks made between pictures and objects. Participants made the greatest number of picture–object saccades when the pictures were emotionally neutral and there was no social information, relative to all other conditions. Indeed, the

[5] Two participants' eye movements were not recorded because of equipment malfunction, bringing the sample size for all analyses including eye movements to $N = 101$.

Figure 2 Note. (A) Memory performance: item (left panel) and associative memory (right panel) for nonsocial and social images (horizontal axis). Emotional valence is shown in color (light blue = neutral, dark blue = negative). (B) Selective looking is shown as the proportion of fixations on the picture and on the context object (the proportion of fixations on the object was not analyzed). (C) Gaze binding is shown as the proportion of saccades between the picture and the object. (D) Complexity of processing is shown as the mean duration of fixations on the picture and the context object. Long square brackets below curved brackets denote the main effect of social cues, and long square brackets above the curved brackets show interaction effects. p values for the contrasts are Bonferroni-corrected. One participant was making uncommonly long fixations across the trials ($M > .4$), and their data are not shown in the two-dimensional plot. All reported results include this participant; excluding them from the complexity of processing analysis only makes the results stronger. See the online article for the color version of this figure.
$^{\dagger}p > .05$. $^{*}p < .05$. $^{***}p < .001$.

picture–object saccades were most frequent for neutral nonsocial pictures, as again emotion modulated saccading for the pictures without social cues, $t(100) = 10.94$, $p < .001$, Cohen's $d = 1.10$, but not for pictures with social cues, $t(100) = 1.41$, $p = .16$, Cohen's $d = 0.14$. This observation was supported by a significant interaction, $F(1, 100) = 62.82$, $p < .001$, $\eta_p^2 = .39$; main effect of emotion, $F(1, 100) = 88.51$, $p < .001$, $\eta_p^2 = .47$; and main effect of social cues, $F(1, 100) = 84.89$, $p < .001$, $\eta_p^2 = .46$. In short, our preregistered hypothesis that social pictures encourage an increase in the number of successive looks between pictures and objects was not supported.

Complexity of Processing

Average fixation duration (Figure 2D) was on average 4 ms longer for negative than neutral target pictures, and this difference was reliable, $F(1, 100) = 6.14$, $p = .015$, $\eta_p^2 = .058$. This supports our preregistered hypothesis. For the social pictures, we did not have a specific prediction. The data showed that fixations on social target pictures were 8 ms shorter than on nonsocial target pictures, $F(1, 100) = 5.74$, $p = .018$, $\eta_p^2 = .054$, with no interaction, $F(1, 100) = .70$, $p = .41$, $\eta_p^2 = .007$. The emotional effect suggests that participants engaged with the negative target pictures at a greater level of cognitive complexity (sometimes called "depth" of processing) than with the neutral target pictures, a pattern that is consistent with a previous study by Fujiwara et al. (2021). The social effect was opposite in its direction; average fixation duration was shorter for social than nonsocial pictures, implying that they were processed with reduced cognitive complexity. This finding is consistent with social scenes being processed more fluently than nonsocial scenes (Reber & Norenzayan, 2018).

We also examined fixation durations on the context objects in the four conditions (not preregistered) to determine whether the pattern of their complexity of processing was consistent with their recognition accuracy. Mean fixation duration was longest for objects paired with negative social pictures, which was supported by an emotion by social interaction, $F(1, 100) = 4.23$, $p = .042$, $\eta_p^2 = .041$. The main effect of emotion was significant, $F(1, 100) = 5.19$, $p = .025$, $\eta_p^2 = .049$, but not the main effect of social, $F(1, 100) = .018$, $p = .89$, $\eta_p^2 < 001$. Inspection of the overall pattern for target pictures and objects showed that in the nonsocial condition, the pattern for fixation duration fits that of selective looking; participants fixated marginally longer on the *pictures* that were negative, $t(100) = 2.18$, $p = .032$, Cohen's $d = 0.22$, and not on the *objects* paired with them, $t(100) = 0.32$, $p > .7$, Cohen's $d = 0.03$. However, in the social condition, participants made longer fixations on *objects* paired with negative pictures, $t(100) = 2.98$, $p = .004$, Cohen's $d = 0.30$, as if they were avoiding looking directly at the negative information.

Interim Discussion

Theoretical accounts of the memory tunneling effect (e.g., ABC; Mather & Sutherland, 2011) propose that heightened physiological arousal results in longer looking at high-priority content (in this case, negative images), to the detriment of the memory traces associated with contextual objects. The eye-tracking results we have reported are generally consistent with this view. Negative pictures were looked at more often and retained better, while the context objects associated with negative pictures were remembered less often. Pictures with social content moderated this effect, such that the difference between negative and neutral pictures was less pronounced in both memory and gaze behavior. Yet the relationships between memory accuracy and eye measures gleaned from these analyses are indirect.

In the exploratory simultaneous regression analyses that follow, we evaluated whether gaze behavior directly predicted item and associative memory on a trial-by-trial level and quantified these relationships separately for pictures first with and then without social cues. We also were interested in testing which eye-tracking measures—selective looking, gaze binding, or complexity of processing—have closer relationships to memory for the picture and the context object. While most previous studies have focused exclusively on selective looking (proportion of fixations), some studies suggest gaze binding is predictive of associative memory but not of item memory (Fujiwara et al., 2021; Madan et al., 2017).

Does Gaze Behavior Predict Memory Performance?

Item Memory

We first examined item memory for nonsocial images from participant-centered selective looking (proportion of fixations on the picture), gaze binding (proportion of picture–object saccades), and complexity of target picture processing (average fixation duration) while controlling for emotional valence and the two-way interactions between emotional valence and each eye-tracking measure. We then reran these analyses but for social images. Full regression reports are presented in the Supplemental Material.

For nonsocial images, recognition was higher for images on which participants made more fixations, $\beta = .14$, 95% CI [.02, .25], $z = 2.27$, $p = .023$, and for images participants did not look away from as indicated by binding saccades, $\beta = -.18$, 95% CI [−.29, −.07], $z = -3.13$, $p = .002$. In other words, pictures more selectively looked at, as indicated by both fixations and saccades, were remembered better as an item. An additional outcome of this analysis was that the recognition of nonsocial pictures was predicted by their valence, $\beta = -.58$, 95% CI [−.83, −.32], $z = -4.41$, $p < .001$, affirming that negative pictures were remembered better than neutral ones, as reported earlier.

By contrast, in social pictures, item memory accuracy was negatively correlated with gaze binding, $\beta = -.14$, 95% CI [−.26, −.02], $z = -2.33$, $p = .020$, but not with any other eye-tracking measure, $ps > .06$. The fewer saccades were made from the picture to the context object, the better the target picture was retained in memory. The effect of emotional valence did not reach significance, $\beta = -.20$, 95% CI [−.41, .01], $z = -1.91$, $p = .056$; numerically negative pictures were remembered better as an item compared to neutral pictures. Recall that this difference was not significant in the contrast analyses described above, and the effect size is much reduced compared to nonsocial images, supporting our conclusion that the difference between negative and neutral images was attenuated in the presence of social cues.

To summarize, gaze binding was negatively related to item memory for both social and nonsocial images once emotional valence was controlled. In addition, social images were remembered better as an item when they were gazed at more often (selective looking).

Associative Memory

For associative memory, we tested four eye-tracking predictors: selective looking at the picture, gaze binding, complexity of picture processing, and complexity of object processing.[6] Emotional valence and the interactions between emotion and each of the eye-tracking measures were also included as covariates. Again, full regression models are reported in the Supplemental Material.

For nonsocial images, associative memory correlated negatively with complexity of processing, $\beta = -.09$, 95% CI [−.17, .0], $z = -2.03$, $p = .043$. That is, context objects next to nonsocial images were remembered better when those images were processed more fluently (i.e., shorter fixations). Associative memory for nonsocial pictures was also higher for neutral than negative pictures, $\beta = 0.19$, 95% CI [.04, .33], $z = 2.47$, $p = .014$, corresponding to the analyses already reported.

For social images, associative memory was higher on trials with a greater number of binding saccades, $\beta = .12$, 95% CI [.03, .21], $z = 2.62$, $p = .009$. In addition, and as shown earlier, objects paired with neutral pictures were remembered better than those paired with negative pictures, $\beta = 0.24$, 95% CI [.09, .39], $z = 3.11$, $p = .002$, all other ps > .08.

In sum, nonsocial images were remembered better when the complexity of picture processing was lower, while for social images, associative memory was predicted by gaze binding.

Discussion

This preregistered study set out to investigate the potentially moderating effect of social cues (e.g., gestures, facial expressions) on the well-replicated finding that negative information often enhances memory for a focal stimulus while impairing memory for its associated context (i.e., a "tunneling" effect). It did so by examining selective attention as a potential explanatory mechanism for both the tunneling effect of negative emotion and its amelioration by social cues (e.g., Bisby & Burgess, 2014; Kensinger, 2009; Madan et al., 2017; Monkman et al., 2025; Palombo et al., 2021; Steinmetz & Kensinger, 2013). As hypothesized, the behavioral results showed that negative emotion heightened item memory and diminished associative memory in images with minimal social content. However, this pattern was attenuated for images containing social cues. Social cues enhanced recognition of neutral images, such that memory for neutral social images was as strong as for negative social or nonsocial ones. Social cues also enhanced associative memory across neutral and negative conditions.

The analyses of gaze behavior pointed to divergent mechanisms underlying memory for social versus nonsocial images, particularly for the effects on associative memory. For nonsocial negative images, the classical memory tunneling pattern was accompanied by greater selective looking (fixation frequency), increased processing complexity (i.e., longer fixation duration), and reduced gaze binding (linking saccades). In the context of social cues, this pattern of selective attention for negative images was different. Although social cues were also linked to greater selective looking and reduced gaze binding, these images were processed more efficiently: They were better remembered and had shorter average fixation durations than comparable images with no social cues. We discuss these findings in turn below.

As reviewed in the introduction, memory tunneling for negative images has been observed in many prior studies (Bisby & Burgess, 2014; Kensinger, 2009; Madan et al., 2017; Palombo et al., 2021). One proposed explanation for memory tunneling is the ABC model, which posits that negative emotion narrows attention toward salient stimuli, enhancing item memory and detracting from memory for associated context (Mather & Sutherland, 2011; Talmi & Palombo, 2025). Our results partially support this framework: For nonsocial images, participants looked more selectively at negative than neutral images, and regression results indicated that item memory was stronger when gaze stayed on the target (i.e., high selective looking and low gaze binding). Yet, in contrast to ABC predictions, while selective looking was enhanced and gaze binding diminished for negative versus neutral nonsocial images, these patterns were not predictive of associative memory performance, echoing prior findings that attention only weakly correlates with associative memory (Steinmetz & Kensinger, 2013). This is consistent with other studies reporting that selective looking at negative images does not consistently predict lower associative memory for them (Bogdan, Dolcos, Buetti, et al., 2024; Bogdan, Dolcos, Katsumi, et al., 2024; Fujiwara et al., 2021; Madan et al., 2017; Riggs et al., 2011). Interestingly, in our results, it was ultimately more complex processing (i.e., longer fixation duration) of the focal image (whether neutral or negative) that predicted poorer associative memory in the nonsocial condition, and negative images elicited longer fixations. These findings are consistent with some prior studies (Fujiwara et al., 2021; Madan et al., 2017) and the theoretical idea that people may dwell on negative images, which in turn reduces their ability to remember the associated context.

Perhaps the most important finding of the present study, however, is that social cues altered this negative tunneling pattern. As hypothesized, we observed a mutual enhancement of item and associative memory for social images, rather than a trade-off or tunneling. This finding is consistent with some earlier studies, which suggest that social information is prioritized in episodic memory (Ghouse & Kaplan, 2024; Stewardson et al., 2023). Yet we found that social cues did not amplify the effects of negative emotion beyond that observed in the nonsocial condition (i.e., item memory for negative images was similar in the social and nonsocial conditions). A similar nonadditive pattern of effects was described by Gutchess and Kensinger (2018), who varied the presence of self-referencing and emotional information in the context of autobiographical memory. These authors reported that differences between emotional and neutral information disappeared within the self-referencing condition. Following the interpretation provided by Gutchess and Kensinger for their results, it may be that the social cues trigger the same encoding-enhancing mechanisms (i.e., selective looking) as negative content, which is further supported by our eye-tracking findings, and thus produce analogous rather than magnified effects on item memory. By contrast, the additive nature of emotional and social cues on associative memory suggests the involvement of distinct mechanisms, and we turn to the gaze behavior data to elucidate them.

We have noted that social images attracted more selective looking and were less complex to process (shorter fixations) compared to

[6] We did not include selective looking at the object because, as reported above, it correlated with selective looking at picture at $r = -.95$. Replacing one variable for the other did not change the pattern of the results we report.

nonsocial images. The observed boost for selective looking at social content is in line with a large body of evidence (Althoff & Cohen, 1999; Birmingham et al., 2008a, 2008b; Downing et al., 2004; Langton et al., 2008; Villani et al., 2015; Vuilleumier, 2000), and it would be intuitive to think this prioritization might also result in memory tunneling around social images. Yet the data showed evidence for social binding, that is, an enhancement of item and associative memory, rather than tunneling. One potential explanation for this pattern in the memory and eye-tracking data is that social information is processed more efficiently. A number of studies show that working memory capacity is enhanced for social versus nonsocial stimuli (Thornton & Conway, 2013), as are attentional orienting and executive control performance (Federico et al., 2013; Passarello et al., 2023). This efficiency of processing for social stimuli can therefore plausibly lead to both enhanced item memory and a boost in associative memory. Relatedly, Stewardson et al. (2023) hypothesized that while social and negative content may both attract attention due to their adaptive and biological significance, the tendency to visually dwell on an image may be greater for negative but not social content, to the detriment of associative memory in negative but not social conditions. In keeping with this interpretation and the notion of efficient social processing, we found that (a) fixation duration was lower for social than nonsocial images (but still yielded better item memory for social images) and that (b) gaze binding, though lower overall for social images, was nonetheless still predictive of enhanced associative memory for those images. That is, the more participants looked back and forth between social images and objects, the more accurately they could link them. These findings may also support the notion that interpretation of social cues is inherently contextualized and communicative—that is, contextual details are often necessary to interpret the meaning of social cues (e.g., to understand the source of a distressed facial expression), and vice versa, social cues are often utilized to communicate that a context or object may be threatening or neutral (e.g., a coffee cup that is scalding hot vs. ready to drink; see Aviezer et al., 2017). Such processes may lead to enhanced associative memory despite reduced (but still predictive) gaze binding.

An extension of this argument is that social cues more readily lend themselves to the construction of stories or narratives. These narratives could provide a structured attentional scaffold that guides viewers' gaze and attention and thereby shapes memory encoding, consistent with studies suggesting that pictures of human or humanlike agents elicit automatic inference of mental states (Cohen & German, 2009; Samson et al., 2010; Schneider et al., 2012), including their goals and intentions (Hassin et al., 2005), and that interactions between people are extracted rapidly and prioritized for attention (Papeo, 2020; see Black et al., 2021, for a review). This interpretation also aligns with the finding that gaze binding predicted associative memory for social but not nonsocial images. It may be that nonsocial images lack such structured guidance and are processed in a more idiosyncratic manner, resulting in less consistent scanning patterns and weaker associative memory across participants. Viewed in this light, the success of associative memory depends less on the allocation of selective attention than on the nature of the relational binding that is possible between image and context, as proposed by Palombo and Cocquyt (2020).

Constraints on Generality

Several limitations should be considered. First, our findings may be specific to the particular set of naturalistic scenes we selected for the study. These images included those used in Stewardson et al. (2023) along with a number of additional images. The memory patterns we observed with this enlarged set of images closely resembled that reported in Stewardson et al., increasing our confidence that the findings will generalize to other stimuli. Yet there are some nuances that are not fully resolved. For example, the interaction in the present study between emotion and social cues on item and associative memory was more consistent with the replication sample from Stewardson et al., though not with their discovery sample. Second, only negative and neutral images were included in the present study, which may involve unique attentional effects, ones that do not apply to positive pictures (e.g., Brooks et al., 2024; Madan et al., 2020). Third, here we focused on attentional mechanisms of associative memory while leaving other factors, such as consolidation (Jimenez & Meyer, 2024), for future investigation. Last, our design and interpretation of the results were based on the assumption that social cues and emotional valence are free to vary independently, though there is evidence that these dimensions are interdependent (Dudarev et al., 2024). The data, namely, the attenuation of memory tunneling for social images, support this treatment, but future work would benefit from a more dedicated consideration of the relationship between emotional value and social relevance.

Future Directions

Our findings underscore the importance of integrating social dimensions into emotional memory research. The attenuation of memory tunneling by social cues challenges prevailing theories, which often overlook the interplay between emotional and social factors (see Dolcos et al., 2017, for discussion). Neglecting social content risks incomplete understanding of how emotion shapes memory, particularly in real-world scenarios.

In addition to manipulating the content of information to be remembered, as we did here by manipulating the amount of social cues, future research could examine individual differences in social processing to further elucidate the mechanisms of social modulation in emotional memory. For instance, autistic children seem to show less prioritization for social cues (e.g., they look less at depicted people's eyes and faces; Riddiford et al., 2022). This gaze behavior may contribute to variations in how social and emotional cues are processed and remembered. In studying gaze behavior and memory in autistic individuals, it will be useful to look at eye-tracking measures beyond the number and total duration of fixations. The present data and previous studies (Fujiwara et al., 2021; Madan et al., 2017) suggest that gaze binding and complexity of processing are useful for characterizing cognitive processing beyond mere selective looking and have distinct relationships with subsequent memory performance.

Similarly, social anxiety, characterized by heightened sensitivity to social evaluation, may be associated with distinct patterns of attention allocation, such as prolonged gaze toward threatening social stimuli (e.g., angry faces) and avoidance of direct eye contact (for review, see Günther et al., 2021). Such gaze behavior, too, may be relevant for subsequent memory. For instance, heightened attention to social threat could enhance memory for emotionally charged parts of the social scene, amplifying memory tunneling, and thus making processing of social images more akin to that of images without social cues.

Neural investigations could further illuminate the interconnected processing of emotional and social information, offering a more mechanistic understanding of these phenomena (Barrett & Satpute, 2013; Gilam & Hendler, 2016; Satpute & Lindquist, 2019; Smallwood et al., 2021). For example, a recent study suggests that stimuli with social content are prioritized for replay during rest (Jimenez & Meyer, 2024). Adding an emotional manipulation to this study would allow testing how social and emotional cues interplay during consolidation.

In conclusion, the present study highlights the deep connection between emotional and social memory processes. By integrating intricate stimuli with behavioral and eye-tracking measures, our results offer a more comprehensive understanding of how humans prioritize and retain information in complex, real-world scenarios. These findings pave the way for future investigations into the dynamic interplay of emotion, social context, and memory.

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