The Effect of State Anxiety on Emotional Associative Binding

Nishi Mehta

Tufts University

Author Note

Nishi Mehta, Department of Psychology, Tufts University.

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Correspondence concerning this article should be addressed to Nishi Mehta, Department of Psychology, Tufts University, 490 Boston Avenue, Medford, Massachusetts 02155. Email: nishi.mehta@tufts.edu

Abstract

Research has consistently demonstrated a memorial advantage for emotionally-salient information. It has been suggested that this enhanced recollection of emotional items leads to disruptions in the binding of peripheral information. Little is known however about how emotional states like anxiety may impact binding of emotional material, despite its practically important relevance to our understanding of binding disruptions in areas including flashbulb memory, eye witness testimony, and anxiety and mood disorders. We hypothesized that a state of anxiety would magnify the extent to which negative stimuli impact recognition of items (cues) and recollection of their context (targets). One hundred and three participants (18-26 years old, 52% female) were exposed to a psychosocial stressor (Trier Social Stress Test) or a control version, after which they performed an associative binding memory task. This included an old/new recognition test of emotional cues and a cued recall test of their neutral counterparts. Heart rate, skin conductance level, and self-report data were additionally collected to index anxiety levels. Participants displayed enhanced recognition of negative cues, as well as disruptions in binding these cues with their neutral counterparts. However, results yielded no significant group difference of anxiety to have persisted during the memory task, indicating that the experimental manipulation did not have the desired effect. Future directions are discussed to elucidate causes of underlying memory performance.

The Effect of State Anxiety on Emotional Associative Binding

It is intuitive that we are more apt to remember the moments in our lives which are colored by emotion as they become distinguished from the mundane by the feelings they draw forth. However, accurately remembering an event requires more than correct memory for items, and must instead include the binding together of the various elements of the event (Mather, 2007). The process of remembering an emotional stimulus and its context is additionally modulated by the emotional state of the individual. It is important that this complex interaction be better delineated as it forms a basis for more fully understanding mechanisms underlying binding disruptions in areas including flashbulb memory, eye witness testimony, and anxiety and mood disorders.

One's emotional, or affective, state is expressed and motivated by a complex interplay of cognitive and biological processes. Core affect, its most primitive form, is said to be made up of the combination of two components, pleasure-displeasure and arousal, which exist orthogonally in a spectrum and together create the most primitive emotions. These are then brought together with additional cognitive components, which include the identification of an object, the attribution of core affect to the object, and the meta-experience, or one's self-perception or subjective categorization of their feelings (Russell 2003). Emotion is additionally associated with a myriad of physiological changes. This may include increases in sweat gland activity, heart rate, and hormones such as adrenocorticotropin (ACTH) and cortisol (e.g. Dawson, Schell, & Filion, 2007; Berntson, Quigley, & Lozano, 2007; Kirschbaum, Pirke, & Hellhammer, 1993). Neurobiological models of anxiety have emphasized the reciprocal nature of these processes, recognizing that emotion can be primed by either physiological responses or cognition (Cacioppo, Berntson, Larsen, Poehlmann, & Ito, 2000). It is also important to note that there are

gender differences in emotion, for example, with men having higher cortisol responses to psychological stressors than women (e.g. Kudielka & Kirschbaum, 2005).

In causing a change in one's internal, affective state, a stimulus signals that the information may be personally significant or relevant and thus important to be remembered (Kensinger & Schacter, 2010). Research has consistently demonstrated that emotionally-salient material is recognized or recalled better than non-emotional, or neutral, material. This has been replicated across studies presenting various modalities of emotional stimuli, including words, pictures, sentences, or narrated slideshows (Kensinger & Corkin, 2003). It is unclear whether this advantage is comparable for positive and negative information. Studies conducted in the laboratory measuring response to verbal or visual stimuli have generally found memory for aversive items to be superior (e.g. Charles, Mather, & Carstensen, 2003; Ortony, Turner, & Antos, 1983). In contrast, studies examining autobiographical memory or information that in some way is made personally significant have found positive items to be recalled better than negative ones (e.g. Linton, 1975; Matt, Vazquez, & Campbell, 1992; White, 2002). More broadly, there is also reason to believe that this memorial advantage for emotionally-salient information does not operate in the same way in younger and older adults. A "positivity shift" with aging has been shown, with older adults being significantly more prone to remember positive information as opposed to neutral or negative information (Kensinger & Schater, 2008).

In addition, there is evidence that emotional information is processed through a fundamentally different pathway than non-emotional information, such that this boost in its recollection is more than simply the result of an enhancement of processes usually employed in memory: attention, rehearsal, or elaboration (Hamann, 2001). The amygdala appears to play a critical role in this memory enhancement by modulating the function of sensory cortices and

enhancing consolation processes in the hippocampus (Dolan & Vuilleumier, 2003; McGaugh, 2004). Neuropsychological studies show that patients with damage to the amygdala do not show enhanced memory for positive or negative items as opposed to neutral items (e.g. Adolphs et al., 1997; Abrisqueta-Gomez et al., 2002, Brierley et al., 2005; Markowitsch et al., 1994). In addition, healthy patients with the greatest activation of the amygdala while viewing a set of emotional stimuli had the greatest enhancements in emotional memory (Cahill et al., 1996). This was also true on an item-by-item basis, with the emotional items that garnered the biggest response in amgydala activity having an increased likelihood of being remembered (Phelps, 2004). However, a review by Hamann points out that the fact that this memorial enhancement is limited to stimuli that elicited a high level of activity in the amygdala may indicate that there might be a threshold of emotional arousal that is required for superior recollection of the emotional information (Hamann, 2001).

While memory for emotional stimuli is superior to memory for neutral stimuli, this memory enhancement seems to come at a cost. In studies in which participants study cue – target word pairs, pairs that included one emotional and one neutral element (e.g., murder–table) result in poorer memory for targets than pairs that consist of two neutral elements (e.g., envelope–table). For example, Murray and Kensinger (2012) presented participants with a series of neutral–neutral word pairs as well as a series of emotional–neutral word pairs to study. At test, participants were provided with the first word of the pair (cue) and were prompted to produce the second word (target). They found that participants were less likely to correctly produce the target if the cue was a positive or negative word. These results suggest that emotional information may hinder binding of that information with its associated details.

In the laboratory setting, this associative trade-off has been studied through the use of slide shows which depict an event through semantically connected images. One or more pictures in the middle of the slideshow are altered between groups to create emotional and neutral versions of the slideshow. For example, an emotionally-arousing version shows a boy being hit by a car on the way to school, whereas in the neutral version the boy continues past the car on his way to school (Christianson, 1984). The research is consistent in its finding that participants are better able to remember central details of the emotional version. However, whether peripheral details are recalled less well by participants viewing the emotional slideshow or whether there is no difference in memory for peripheral details between the emotional and neutral groups is still unclear (Burke, Heurer, & Reisberg, 1992; Christianson, 1984; Christianson & Loftus, 1987; Heurer & Reisberg, 1990; Kebeck & Lohaus, 1986). However largely evidence seems to support the Easterbrook hypothesis, which posits that emotional arousal leads to a narrowing of focus, such that low arousal would cause more information to be taken in, regardless of relevance (for a review, see Christianson, 1984). In contrast, higher arousal would lead to increased attention and superior memory performance for central features, but perhaps peripheral information being remembered less well.

Individuals diagnosed with anxiety disorders such as Post-Traumatic Stress Disorder and mood disorders like Major Depressive Disorder show disruptions in associative binding (Ehlers et al. 2006; Golinkoff & Sweeney 1989). This suggests the possibility that mood states such as sadness and anxiety might impact associative binding. However, the presence of diagnosed psychopathology makes it difficult to know if mood state is specifically responsible for this effect. Waring, Payne, Schater, and Kensinger (2008) attempted to investigate how individual differences in anxiety, working memory capacity, and executive function ability may modulate

this emotion-induced memory trade-off between an item and its associated details. In this study, they placed a negative or neutral item against a neutral background, and then after a delay asked participants to recognize whether items and backgrounds were the same or similar to the ones presented to them. They assessed trait anxiety through a questionnaire taken prior to the study, and state anxiety through self-reported anxiety during the study. They found higher levels of trait and state anxiety to be related to better specific memory for features at the expense of memory for backgrounds. However, they found no correlation between a more general recognition memory trade-off and anxiety. This study was limited in that it was correlational in nature, and did not experimentally manipulate state anxiety, instead simply defining it through the emotional influence of valenced stimuli on participants. It therefore did not allow causal inferences about the effect of state anxiety on associative binding involving emotional stimuli.

The present study sought to determine whether an anxious mood state has a detrimental effect on associative memory for emotional words. In a meta-analysis of 208 studies of acute laboratory-based stressors, Dickerson and Kemeny (2004) found that tasks that combined uncontrollability and threat to social self (i.e. others could negatively judge performance) resulted in the greatest change in cortisol levels, and had the longest times needed for recovery. We therefore elected to use a modified version of the Trier Social Stress Test as a means of inducing an anxious mood state in some participants, as it includes these stressor characteristics and format (Kirschbaum, Pirke, & Helhammer, 1993). After inducing an anxious mood state, participants were asked to perform an associative memory task similar to that employed by Murray and Kensinger (2012). Participants studied cue-target words pairs consisting of emotional or neutral cue words paired with a neutral target word. They then completed an old/new memory task in which participants are presented with cues identical to those studied as

well as false lures in order to test item recognition for valenced cues. Following this, they were asked to recall the neutral target each cue was presented with. In order to ensure that participants were not simply responding to demand characteristics when asked periodically to report on their levels of somatic and cognitive anxiety, we collected recordings of electrocardiography (ECG) and electrodermal activity (EDA). Additionally, because gender has been hypothesized to influence stress responses, we also sought to discover whether gender would moderate our results.

We predicted that there would be enhanced recognition of emotional cues relative to neutral cues in both groups. Furthermore, we anticipated that the presence of a high level of state anxiety as elicited by the TSST would potentiate the tendency to better recognize negatively-valenced cues, as compared to positively-valenced cues. Regarding recollection of word pairs, we predicted that the anxious group (AG) would display increased disruptions in binding of negative pairs, as evidenced by poorer recall for their neutral targets than the control group (CG).

Method

Participants

One hundred and three students from Tufts University (54 females; M_{age} = 19.08 years, SD_{age} = 1.23 years) participated, and were compensated through course credit or cash payment. Participants were 72.1% White, 21.2% Asian, and 6.7% and African-American or Black, with 1% choosing not to provide this information. The Institutional Review Board at Tufts University approved all study procedures and participants gave informed consent prior to participating in the study.

Materials

Resting State Task (RS).

This task was a shortened version of one used by previous researchers to assess baseline physiological activity (e.g., Schoenberg, Sierra, & David, 2012). Participants were instructed: "During this task you will simply relax with your eyes open for two minutes. Please simply look at the fixation cross in the center of the screen during this time." This task was added to the present study after collecting data from 17 participants in order to ensure that any differences found between groups in peripheral physiology were not a result of individual differences that existed at the onset of the study.

Anxious Mood Induction (TSST).

A variant of the Trier Social Stress Test (Kirschbaum, Pirke, & Hellhammer, 1993) was used to induce anxiety in participants. First there was a prep period (P), in which participants were given three minutes to make notes on their "organization skills and ability to meet deadlines under pressure." This piece of paper was taken away before the participants delivered a five minute speech (TS) on the given topic. Participants then were instructed to perform mental arithmetic (TM) aloud for five minutes without the help of a pen and paper, counting backwards from 2,223 in increments of 17. The experimenter informed the participant every time they made error and instructed them to start again from 2,223. Deception was involved in that the participants were told that the math task was "quite easy and most people don't have a problem with it" in order to increase social stress.

The TSST was modified slightly from the original version in order to accommodate the constraints of the experimental space. Rather than two researchers being present as evaluators in the room with the participant, there was a single experimenter who communicated with the participant through an intercom system. To maintain consistency with the traditional TSST, the

experimenter informed the participant before they began the TSST that "The speech will be filmed and voice recorded. Additionally, two of the research affiliates are trained in verbal and nonverbal communication. They will review the video recording together and will take notes regarding the manner and content of your speech, including notes about body language and the persuasiveness of your argument." Given that this change could have reduced the level of induced anxiety, an additional element was introduced to the task to augment this (Birk et al., 2014). As they performed the speech and math portions, the lab projected a live stream of the participant's face to the screen in front of them so that they were watching themselves as they performed the tasks.

The current study used a control version of the TSST that was developed by Het and colleagues (Het, Rehleder, Schoofs, Kirschbaum, & Wolf, 2008). Following a three-minute prep period, participants were asked to make a speech on a novel, movie, or recent holiday. They were told the intercom system would be turned off in the room, so they would not be heard or recorded. Following this, participants completed a much easier version of the math task. They counted down from 3000 in increments of ten.

Associative binding task (ABT).

During the study phase, participants viewed 36 cue-target pairs for four seconds each. These pairs were made up of common English words, and ratings of stimulus valence and arousal for young adults were taken from Warriner, Kuperman, and Brysbaert (2013). These cues included 12 negative words ($M_{\text{valenceYA}} = 2.45$, $M_{\text{arousalYA}} = 5.10$), 12 neutral words ($M_{\text{valenceYA}} = 5.19$, $M_{\text{arousalYA}} = 4.50$), and 12 positive words ($M_{\text{valenceYA}} = 7.36$, $M_{\text{arousalYA}} = 5.47$). During the study phase (SP) these words were each presented along with a neutral target in random order. Following this, there was a three minute retention interval (RI) during which the participant

performed number-based puzzles. Finally, during the test phase (TP), participants were presented with all 36 cues, as well as 36 additional false lures matched as closely as possible for valence and arousal. For each word, they were first asked to make an old/new judgment. They were then asked to produce the target if they indicated the cue had been previously presented.

Peripheral Physiology.

Physiological data were collected using a MP150 system and AcqKnowledge 3.8.2 software (Biopac, Goleta, CA) throughout the TSST and Associative Binding Task.

***Electrocardiography*.** Electrocardiography was used to measure heart rate (HR), which is innervated by the sympathetic and parasympathetic system of the autonomic nervous system. When viewing unpleasant pictures, HR is known to slow down due the parasympathetic system. After wiping the left and right collarbones on the chest with electrode preparation pad, two disposable Ag/AgCl electrodes pre-gelled with 7% chloride (1 cm circular contact area) were placed on the same location. ECG was collected continuously at 1,000 Hz.

Offline, the ECG signal was downsampled to 400 Hz and bandpass-filtered from 0.5 to 40 Hz. Interbeat interval series were created by identifying the R-spikes using automated ANSLAB algorithms. R-spikes that were incorrectly identified or were missed were manually changed or selected, respectively. After such artifact correction, the interbeat interval series was converted to HR in beats per minute. HR data was decimated to 10 Hz and then smoothed with a 1-s prior moving average filter.

Electrodermal Activity. Electrodermal activity (EDA) was used to measure sympathetic activation through skin conductance level. Two disposable Ag/AgCl electrodes pre-gelled with 0.5% chloride isotonic gel (1 cm circular contact area) were attached to the distal phalanges of the index and middle fingers of the subject's non-dominant hand. One additional ground

electrode for all physiological channels was placed on the back of the neck. EDA level was recorded with DC coupling and constant voltage electrode excitation at 31.25 (sensitivity = 0.7 nS). Offline, EDA was smoothed with a 1 Hz low-pass filter and decimated to 10 Hz.

Primary Self Report Measure.

State-Trait Inventory for Cognitive and Somatic Anxiety (STICSA).State anxiety was assessed using the state version of the STICSA (M. J. Ree, C. MacLeod, D. French, & V. Locke, 2000). This is a 21-item measure of cognitive and somatic anxiety that was used in order to assess anxiety induced by the TSST. Participants were asked to respond based on what was true right then, in that moment *(*e.g., *My muscles are tense; I think that the worst will happen).*

Secondary Self Report Measures.

An additional set of questionnaire measures were administered as part of the study. Analyses will focus on testing the primary hypotheses of the study thus data from the following questionnaires will not be reported:

Mood Ratings. The Mood Ratings questionnaire is an 11-item self-report measure that aims to assess a range of positive and negative mood states. This scale was adapted from previous work by Tamir, John, Srivastava, and Gross (2007). Participants rate the extent to which they feel the three mood states listed in each item (e.g. *"anxious, worried, fearful", "judged, scrutinized, evaluated"*). The measure is designed to evaluate multiple aspects of mood, including anxiety.

Affective Style Questionnaire (ASQ). The ASQ is a 20-item measure that aims to assess general strategies used to handle emotion reactions (Hofmann & Kashdan, 2010). This includes subscales for concealing, adjusting, and tolerating emotional reactions. Participants were asked

to respond based on what they usually did, rather than what they wish they did or should do (e.g., *People usually can't tell how I am feeling inside; It's ok to feel negative emotions at times).*

Emotion Regulation Strategies Questionnaire (ERS). The ERS is a 21-item measure assessing the strategies people use to regulate emotions. Participants were asked to rate the extent to which they used these strategies to deal with the anxious mood induction (e.g., *I averted my gaze from the screen, I decreased my rate of breathing*).

State-Trait Anxiety Inventory (STAI). The trait version (Y-2) of the STAI is a 20-item measure of trait anxiety (Spielberger, 1983). This scale has excellent internal consistency reliability (Cronbach's $\alpha = .92$) and asks participants to rate how they generally feel about statements that are either anxiety-present or anxiety-absent (e.g., *I wish I could be as happy as others seem to be; I am a steady person).*

Difficulty, Success, and Effort scale (DSE). DSE is a 9-item measure evaluating the participant's perception of the task and their performance (e.g., *the speech was difficult; I tried to do well on the speech; I succeeded on doing well on the speech*)

Sleep Assessment. The sleep assessment is a 10-item questionnaire that asks participants about aspects of their sleep the night before coming in to take part in the experiment (e.g. *How many times did you wake up, not including your final awakening? How would you rate the quality of your sleep?).*

Menstrual Cycle Assessment. The menstrual cycle assessment is an 8-item self-report measure that asks female participants about their menstrual history (e.g. *When was your last period? Have you ever experienced amenorrhea?)*

Demographic information was collected, including age, sex, race, ethnicity, level of education, marital status, number of children, and number of people in household. Participants

were also asked for ratings of valence and arousal for their speech topic, as well as the topic of their speech and a verbatim report of the last sentence they spoke to ensure task compliance in the control condition.

Procedure

Upon arriving into the laboratory, participants provided informed consent. The experimenter then attached the EMG and EDA sensors, which was followed by the two-minute resting state task. Participants then completed baseline STICSA and mood ratings. After this, the stressful or control TSST was administered, followed by another set of mood ratings, the Associative Binding task, and the final set of ratings. After the experiment was over, participants were asked to complete a set of questionnaires and were then debriefed, thanked, and credited or compensated for taking part in the study. See Figure 1 for an outline of the procedure.

Data Retention

As resting state data was not collected from the first 17 participants, their data was excluded from analyses in order to ensure differences found were not a result of individual differences between groups at the onset. Exclusion of these participants did not result in any material change in findings. In addition, some participants did not contribute data to all peripheral physiology measures due to equipment failures or artifact; only participants who contributed data across all time points were included in analyses for a given measure. Multivariate outliers were excluded based on Mahalanobis Distance using average values across each measure ($p < .001$). Accounting for these factors, the subsample sizes for HR and SCL were 78 (38 female) and 73 (40 female) participants, respectively. All participants contributed data to self-report and memory analyses.

Results

Manipulation check

Was the TSST successful in inducing a state of anxiety?

Our assumption in utilizing the TSST was that it would produce a strong anxious response relative to the control version that had the potential to persist through the associative binding task. GLM analyses were conducted assessing the effects of task (resting state baseline, speech, math) and group (anxious, control). As expected, these showed that the TSST increased HR and SCL significantly above baseline, as evidenced by a main effect of task in both measures, $F(2, 75) = 105.534$, $p = .000$ and $F(2,66) = 33.520$, $p = .000$, respectively. These effects are depicted in Figures 2 and 3.

However, only with HR was there an interaction between task and group, $F(2,75) = 14.556$; $p = .000$. Specifically, the anxious group had higher HR than the control group during the speech task, $F(1,76) = 8.472$, $p = .005$. As you can see in Figure 2, moving from the speech ($M = 91.54$, $SD = 12.38$) to the math task ($M = 86.25$, $SD = 11.32$), the anxious group experienced a significant drop in HR, $p = .000$. This was such that there was no longer a significant difference in HR between the control ($M = 83.36$, $SD = 12.39$) and anxious group ($M = 86.26$, $SD = 11.32$) by the end of the math task, $p = .333$. GLM analyses of skin conductance level found no significant interaction between group and task during the TSST, $F(2,66) = 1.657$, $p = .198$ (see Figure 3).

Finally, we conducted a repeated measures GLM with two factors, STICA somatic scores (post-RS, post-TSST) and group (anxious, control). This analysis of self-reported STICSA somatic scores showed significant increases from post resting state to after the TSST for both the anxious group and the control group, as found in the main effect of valence, $F(1,101) = 11.46$, $p = .001$ (see Figure 4). This was not the case for STICSA cognitive scores from post resting state

to post TSST tasks; both groups showed an insignificant drop in cognitive anxiety. Overall, these results suggest the TSST produced the expected anxious response in participants.

Did this anxious mood persist through the associative binding task?

To facilitate determining whether the anxious response produced in participants persisted through the associative binding task (ABT), HR and SCL data was averaged into 30-second periods. We conducted GLM analyses of HR within the study phase of the ABT using two factors, time (five 30-second periods) and group (anxious, control). Contrary to what we expected, these revealed that there was no main effect of group, $F(1,80) = 1.543$, $p = .218$, and there were no interactive effects between group and time, $F(4,77) = .832$, $p = .509$.This pattern was also apparent as the result of a similar GLM analysis of HR across all ten 30-second periods of the test phase. For HR, there was no main effect of group, $F(1,80) = .854$, $p = .358$, and no interaction between time and group, $F(9,72) = 1.216$, $p = .299$.

Parallel GLM analyses of SCL during the study and test phases also showed no main effects of group, $F(1,69) = .155$, $p = .695$ and $F(1,69) = .098$, $p = .755$, respectively, nor interactions between group and time, $F(4,66) = .882$, $p = .480$ and $F(9,61) = 1.059$, $p = .406$, respectively. Additionally, a repeated measures GLM examining STICSA somatic scores with two factors, time (post-TSST, post-ABT) and group (anxious, control), revealed no main effect of group, $F(1,100) = .001$, $p = .982$, but there was a significant group by time interaction, $F(1, 101) = 5.608$, $p = .02$. There was a significant drop in self-reported somatic anxiety from post-TSST to post-ABT for the anxious group. This was not the case for control group; in fact there was a slight, non-significant increase from post-TSST anxiety levels to post-ABT levels (see Figure 4). Because of this, there was no longer a significant difference in somatic anxiety between groups immediately following the associative binding task, $p = .292$.

Finally, a repeated measures GLM examining STICSA cognitive anxiety scores with two factors, time (post-TSST, post-ABT) and group (anxious, control), revealed no main effect of group, $F(1,101) = .098$, $p = .755$, and no time by group interaction, $F(2,100) = .562$, $p = .572$. Overall, these results indicate that the state anxious effect did not persist, rendering it unlikely that the experimental manipulation would impact associative binding.

Hypothesis Testing

Did the presence of anxious mood enhance recognition of emotional cues?

Table 1 summarizes the descriptive statistics for cue recognition performance during the associative binding task. In addition to presenting hits and false alarms, we also present d' (Z hits – Z false alarms). This statistic corrects for response biases in categorizing cues as "old" or "new". Means, standard deviations, and standard errors are provided separately for men and women in the anxious and control groups.

GLM analyses with two factors, valence (negative, neutral, positive) and group (anxious, control) were conducted separately for hits and false alarm data. In both, there were significant main effects of valence, $F(2,94) = 18.97$, $p = .000$ and $F(2.94) = 8.842$, $p = .000$, respectively. For hits, this effect resulted from hit rates for positive cues ($M = .536$) which were significantly lower than those for negative ($M = .624$, $p = .000$) and neutral cues ($M = .649$, $p = .000$). With FAs, a different pattern emerged; there was a significantly higher false alarm rate for neutral cues ($M = .097$) than for negative ($M = .054$, p = .000) or positive cues ($M = .063$, p = .002).

GLM analyses of d' assessing effects of valence (negative, neutral, positive), group (anxious, control) and gender (female, male) were conducted. These showed a main effect of valence for d' scores of recognition, $F(2,94) = 6.280$, $p = .003$. Pairwise comparisons of valence conducted after collapsing across groups show that negative words ($M = 2.374$) were recognized

significantly better than neutral, (M = 2.068, p = .006), or positive words, (M = 2.054, p = .002). There was no significant difference in how neutral and positive words were remembered, p = .894.

In addition, while there was no interaction between valence and group, $F(2,94) = .543$, p =.583, there was a significant interaction between valence and gender, $F(2,94) = 5.029$, p = .008. This was driven by women demonstrating significantly better memory for positive cues than men, p = .000, M = 2.423 and M = 1.685, respectively (see Figure 5). The interaction between group and gender was marginally significant, $F(1,95) = 3.268$, p = .074, with females in the control group (M = 2.449) performing significantly better than males in the control group (M = 1.787), p =.002. This difference did not exist between females (M = 2.275) and males (M = 2.151) in the anxious group, p = .561. Because the experimental manipulation did not produce the desired effect in anxiety, it is not surprising that significant group differences in recognition performance for emotional cues did not emerge. Although no specific hypotheses were formed surrounding gender, it is clear that there were gender differences in performance.

Did the stress group display impaired binding of emotional cues with their neutral targets?

We performed a GLM of cued recall data with three factors, valence (negative, neutral, positive), group (anxious, control), and gender (female, male). This showed a main effect of valence, $F(2,94) = 7.149$, p = .001. Pairwise analyses of valence conducted after collapsing across groups found impaired binding for pairs with positive or negative cues, with participants demonstrating better recall for targets presented with neutral cues. In addition, the three-way interaction between valence, group, and gender was marginally significant, $F(2,9) = 2.369$, p =. 099. As seen in Figure 7, women performed better overall on the cued recall test, $F(1,95)$ =

6.229, $p = .014$). As there was no significant difference in cued recall performance between the genders in the anxious group ($p = .265$), this was driven by women performing better than men in the control group ($p = .018$). In addition, women better recalled neutral targets of positive ($p = .005$) and negative ($p = .011$) cues than men. However, there was no difference in their memory for neutral-neutral pairs (p = .173)

Discussion

Summary and Explanation of Results

The aim of this study was to determine whether a state of anxiety would magnify the extent to which emotional information impacts recognition of items (cues) and their context (targets). To this end, state anxiety was experimentally manipulated through the use of a potent stressor prior to participants studying cue-target words pairs. Participants were then tested for recognition of the emotional cues and recall of the neutral target counterparts. Consistent with previous findings, participants in both groups displayed enhanced recognition of negative cues as well as disruptions in binding of these cues with their neutral targets. In addition, there were some unanticipated effects of gender. Women performed significantly better than men on recognition of positive cues. In addition, there was a marginally significant group by gender by valence interaction for recall of targets.

We hypothesized that the presence of a high level of state anxiety, as elicited by the TSST, would potentiate the tendency to better recognize negatively-valenced cues, as compared to positively-valenced cues. Regarding recollection of word pairs, we predicted that the anxious group would display increased disruptions in binding of negative pairs, as evidenced by poorer recall for their neutral targets than the control group. However, integral to these predictions was

the underlying assumption that any behavioral differences found in memory performance would be caused by heightened anxious mood in the anxious group as compared to the control group. Both the Trier Social Stress Test and its control form caused a significant heightening of autonomic arousal in participants during the speech task, as evidenced by increases in heart rate from baseline. Although this increase was initially more substantial in the anxious group, by the math period their heart rate had decreased such that there was no statistical difference in HR between groups. The self-report assessment for somatic anxiety mirrored this pattern. Therefore, although it is clear that anxiety levels were heightened, they were not substantially differentiated based on group during the associative binding task. This is additionally supported by skin conductance data and self-report of cognitive anxiety, for which during no phase was there a significant group difference.

There was no interaction between group and valence of cues in either recognition or cued recall performance; thus, the effects of valence only clearly emerged after collapsing across groups. Doing this was in some way intuitive, as both physiological and self-report data had converged to show that the groups were not statistically distinct in anxiety levels. There, interestingly, was then much of what we predicted at the onset of the study for performance of the anxious group. Recognition of negative words was significantly better than that of neutral words and positive words. The cued recall data showed significantly impaired binding of neutral targets with negative and positive cues. These findings are largely consistent with previous studies on binding of emotional stimuli (Murray & Kensinger, 2012). It is interesting to note that that it is only for negative cues that participants displayed a recognition advantage. Positive cues were recognized no better than neutral cues. Following with this, neutral targets were bound significantly less well with negative cues as compared to neutral cues, while this effect was

marginal in positive cue-neutral target pairs. However, this favoring of negative information in recognition and subsequent disruption to their neutral targets did not depend on a heightened anxious mood. This may be because the impact of the stressor, as evidenced by a difference between the anxious and control groups, did not persist into the associative binding task. It is important therefore to further consider reasons which may explain the failure of the experimental manipulation to produce a difference in anxiety levels.

Although HR and self-reported somatic anxiety had a greater increase in the speech task in the stress group, it is also not surprising that they began to gradually decline after that most potent point of the stressor. That the levels of all physiological and self-report measures from the math task and through the study and test phases of the ABT were undifferentiated between groups rather suggests that it could be that the control group was simply unduly anxious relative to our intended aim. The control TSST was designed by Het and colleagues to parallel the format of the stressor while eliminating the presence of the uncontrollable and social-evaluative elements, which were found to be the most efficacious in eliciting stress responses (Dickerson & Kemeny, 2004). They conducted a neuroendocrine and psychometric evaluation and found that this form of TSST to be in successful as a non-stressor (Het et al.2008). However, it possible that the changes made to tailor this task to the constraints of the laboratory space in some way made it more anxiety provoking. More specifically, by having participants give their speech while facing a blank computer screen rather than in an empty room, perhaps participants did not fully believe that they were not being evaluated, or if they did, perhaps it simply felt unnatural.

It is difficult to interpret the results relating to gender without a clear understanding of the outcome of our experimental manipulation of anxiety, and also without previously formed hypotheses. In addition, researchers are only beginning to better understand the relationship

between gender and stress, as well as the way this may relate to memory. Epidemiological studies points to a significantly higher prevalence of anxiety and mood disorders in women (e.g. McLean & Anderson, 2009). However, a study by Wolf and colleagues (2001) that showed that increased levels of cortisol strongly impaired memory performance in men, but not in women, which may point to perhaps greater stress reactivity in men. Women have consistently been found to perform better on verbal memory tasks (e.g. Herlitz, Nilsson, & Backman, 1997; Kimura & Clarke, 2002). The current study presents an interesting framework for parsing out the manner in which these gender, stress, and memory interact.

Theoretical and Practical Implications

The behavioral effects on memory provide additional support to the Easterbrook hypothesis, which posits that emotional arousal leads to a narrowing of focus (Christianson, 1984). This leads to enhanced memory for central or highly relevant features, perhaps though at the expense of accurate memory for peripheral information. A case of this seen in daily life is flashbulb memory, in which individuals report having an extremely vivid and detailed memory for an emotional event. For example, people often can give evocative accounts of where they were or what they were doing when significant events such as the assassination of President Kennedy or the attacks on the World Trade Towers occurred (e.g. Brown & Kulik, 1977; Hirst et al. 2009; Christianson, 1989; Smith et al. 2003). Brown & Kulik (1977) state that the key determinants of flashbulb memory are high levels of surprise, consequentiality, and emotional arousal. However, despite the sense of increased vividness of these memories, the recollection of peripheral details may not necessarily be accurate. This parallels certain findings in studies of eyewitness testimony.

During eyewitness testimony, memory demands are placed on an individual who often was under a high level of stress during the encoding of an emotionally charged event. "Weapon-focus" is the anecdotal descriptions for the phenomenon where the salience of a weapon (e.g. the barrel of gun) draws attention such that one experiences a reduced ability to remember details of other items (Loftus, Loftus, & Messo, 1987). Better delineating the manner in which state anxiety interacts with the memory for emotional items, and understanding disruptions this may cause to memory for contextual information, is therefore vital.

Strengths, Limitations and Directions for Future Research

The present study had several notable strengths. Our approach to the questions of interest in the current study has the benefit of using both self-report and physiological indicators of anxiety. Given that emotion includes both physiological and subjective components, it is important that anxiety be assessed through autonomic arousal and subjective perception of stress. This also allowed us to uncover responses to the anxious mood induction that might otherwise have gone undetected. An additional strength of the present study was the focus on state anxiety. In order to understand how state anxiety may impact emotional associative binding, it is important that we do not rely solely on correlational studies detecting group differences in memory performance by people with high or low levels of anxiety. In order to induce anxiety, we used an ecologically valid social stress mechanism, allowing for better generalizability of results. Another strength of our design was the assessment of both cue recognition and target recall. This enabled us to detect the interesting associative trade-off in memory for emotional information. Finally, our large sample size renders it unlikely that null effects are the result of insufficient statistical power.

Despite these notable strengths, the present study had several key shortcomings. As already discussed, the manipulation of anxiety was unsuccessful in persisting through the memory task and it is possible that the control TSST may have elicited some anxious response. This made it difficult to detect differences between groups and assess the casual relationship between variables. Therefore, future directions include the inclusion of a control task which omits some of the possibly anxiety-provoking components of our control version of the TSST. This could take the form of a task in which participants are instructed to simply sit for a duration of time equal to the length of the stressful TSST to assess whether the control task used in the present study was autonomically arousing. In addition, use of an alternative stressor that may lead to a more persistent effect of anxiety (i.e. threats of electrical shock) should be explored.

Another significant limitation is the use of a rather homogeneous sample. Having primarily consisted of undergraduates at Tufts, it's not clear that the effects we found in our sample would generalize to other populations. For instance, it is clear that there are memory differences with age, with older adults being more likely to remember positive information than negative information (Mather, 2006; Kensinger & Schacter, 2008). This may be in part because older adults put more emphasis on deriving emotional meaning from life, emotion regulation, and maintaining positive affect (e.g. Mather & Carstensen, 2005). As aging brings significant stressors, future studies might usefully explore the effect of state anxiety on emotional memory.

Concluding Comment

In sum, the present study set out to determine the effect that state anxiety has on binding emotional and neutral information. Better understanding the mechanism by which these elements interact is practically important given the potential relevance of associative binding disruptions to flashbulb memory, eye witness testimony, and other such phenomenon. To accomplish this

goal, we used the Trier Social Stress Test to induce a high level of anxiety in subjects, after which they participated in an emotional binding task. Although behavioral effects emerged which replicated prior work on associative trade-offs, the effect of state anxiety on this was inconclusive as state anxiety did not persist through the memory task. Future work in this domain will be important in clarifying causality underlying some the results found in this study. Overall, this study provides an experimental framework through which to study this open question.

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Table 1

Descriptive Statistics for Recognition Data

		Anxious			Control		
		n	*M (SD)*	*SE*	*n*	*M(SD)*	*SE*
Male	hit_neg	23	.59 (.19)	.04	23	.59 (.21)	.04
	hit_neut	23	.65 (.18)	.04	23	.56 (.24)	.05
	hit_pos	23	.44 (.22)	.05	23	.50 (.23)	.05
	fa_neg	23	.03 (.08)	.02	23	.07 (.10)	.02
	fa_neut	23	.08 (.06)	.01	23	.11 (.12)	.02
	fa_pos	23	.05 (.09)	.02	23	.12 (.12)	.02
	d'_neg	23	2.56 (.82)	.17	23	2.07 (1.0)	.21
	d'_neut	23	2.05 (.90)	.19	23	1.76 (1.23)	.26
	d'_pos	23	1.84 (1.03)	.22	23	1.53 (1.27)	.26
Female	hit_neg	26	.64 (.16)	.03	27	.68 (.15)	.03
	hit_neut	26	.69 (.20)	.04	27	.70 (.17)	.03
	hit_pos	26	.59 (.19)	.04	27	.61 (.20)	.04
	fa_neg	26	.06 (.09)	.02	27	.06 (.08)	.02
	fa_neut	26	.11 (.10)	.02	27	.08 (.08)	.02
	fa_pos	26	.04 (.06)	.01	27	.04 (.08)	.02
	d'_neg	26	2.41 (.71)	.14	27	2.46 (.81)	.16
	d'_neut	26	2.08 (1.05)	.21	27	2.38 (.99)	.19
	d'_pos	26	2.34 (.84)	.16	27	2.51 (.71)	.14

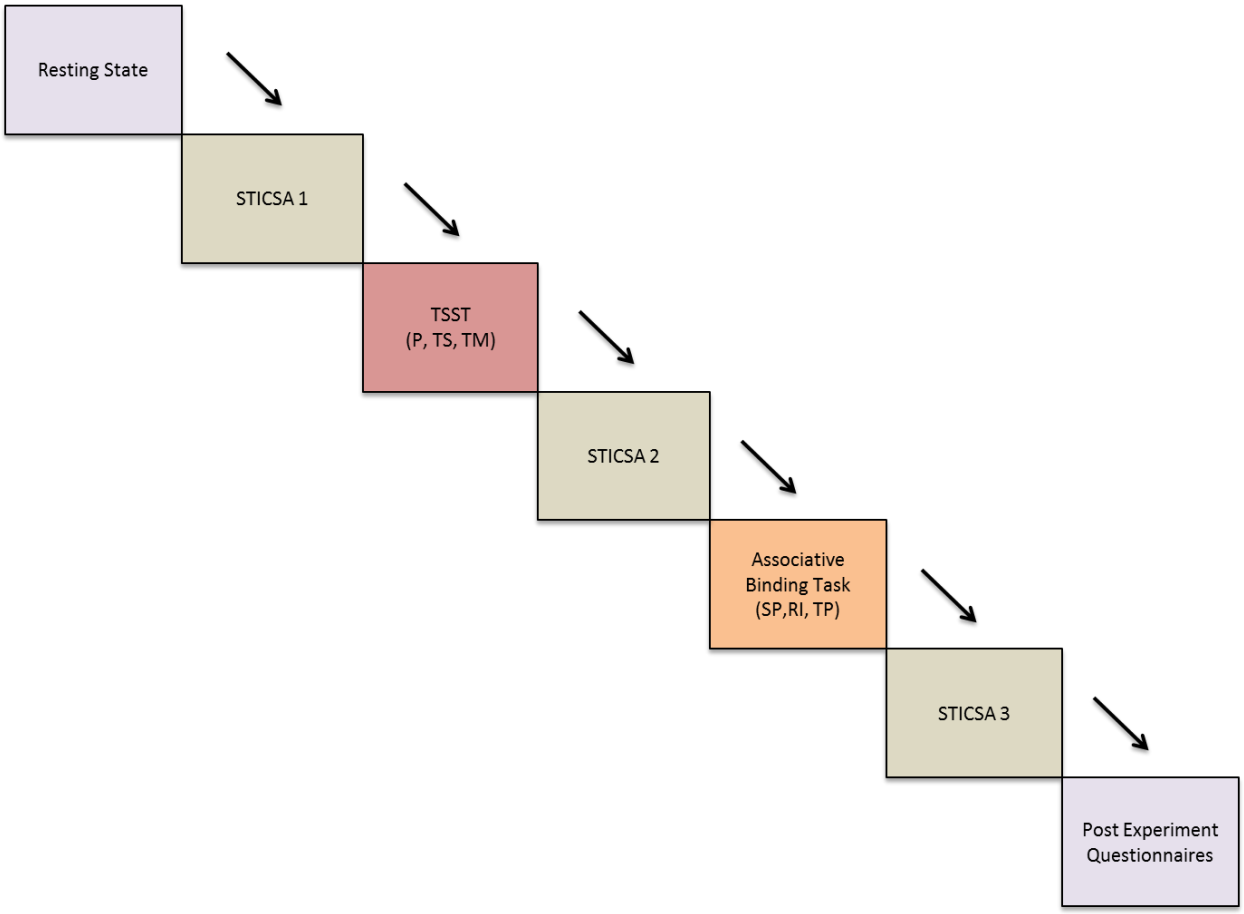

Figure 1. *Schematic for the study procedures.* Abbreviations are as follows. STICSA= State-Trait Inventory for Cognitive and Somatic Anxiety (this was administered at three time points, as indicated). TSST = Trier Social Stress Test. P = prep period. TS = speech task. TM = math task. SP = speech phase of associative binding task (ABT). RI = retention interval of ABT. TP = test phase of ABT.

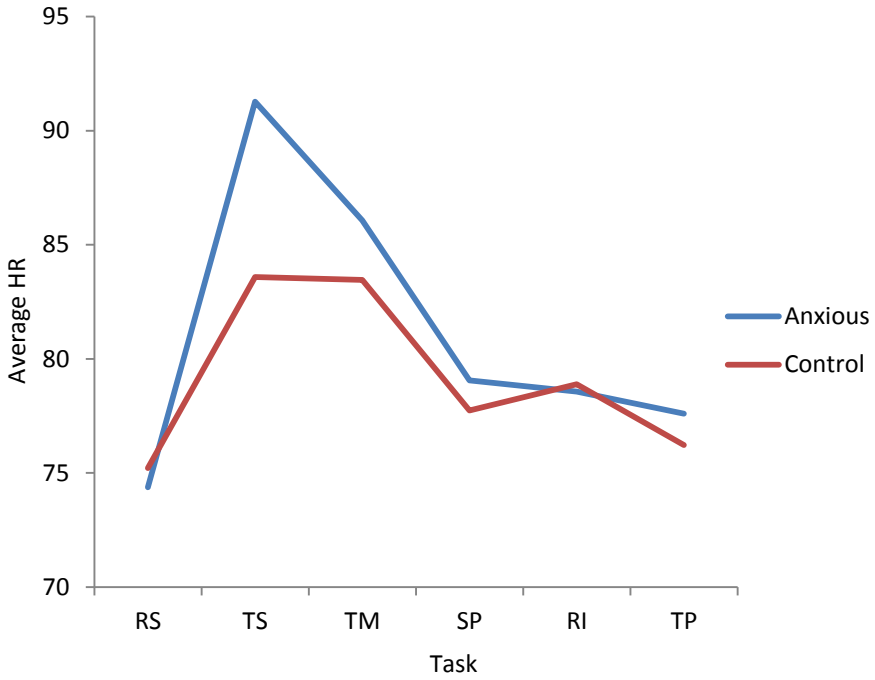

Figure 2. *Average Heart Rate (HR) across Tasks.* Abbreviations of tasks are as follows. RS = resting state. TS = TSST speech task. TM = TSST math task. SP = study phase of associative binding task (ABT). RI = retention interval during ABT. TP = test phase of ABT.

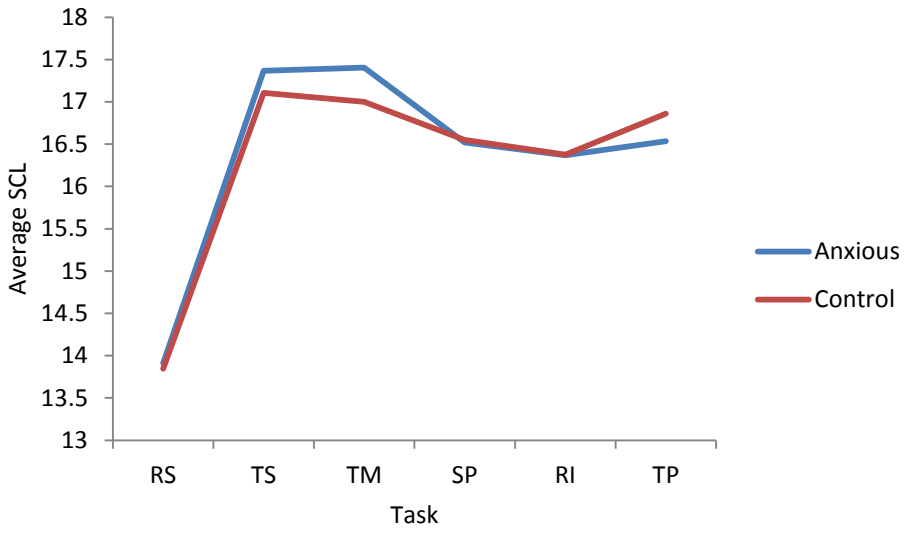

Figure 3. *Average Skin Conductance Level (SCL) across Tasks.* Abbreviations of tasks are as follows. RS = resting state. TS = TSST speech task. TM = TSST math task. SP = study phase of associative binding task (ABT). RI = retention interval during ABT. TP = test phase of ABT.

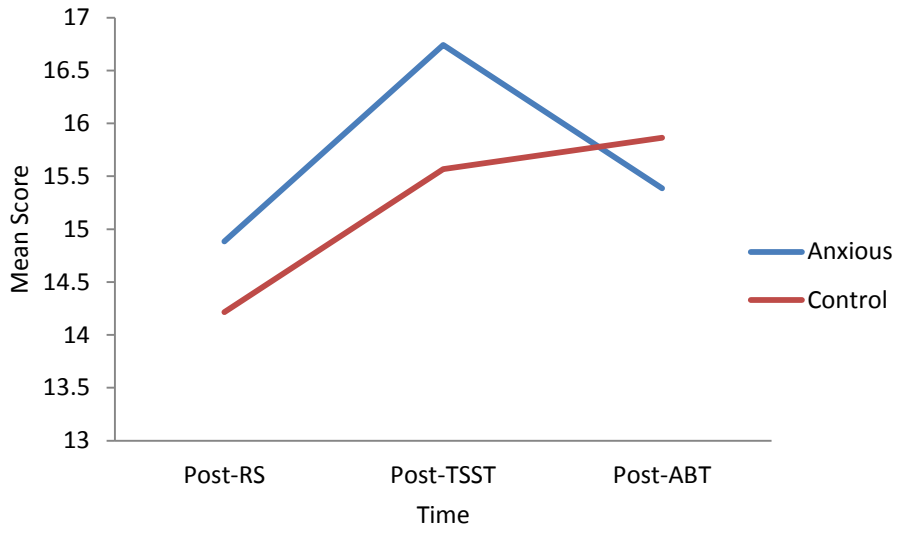

Figure 4. *Average STICSA Somatic Score across Time Points.* Abbreviations of time points are as follows. RS = resting state. TSST = Trier Social Stress Test. ABT = associative binding task.

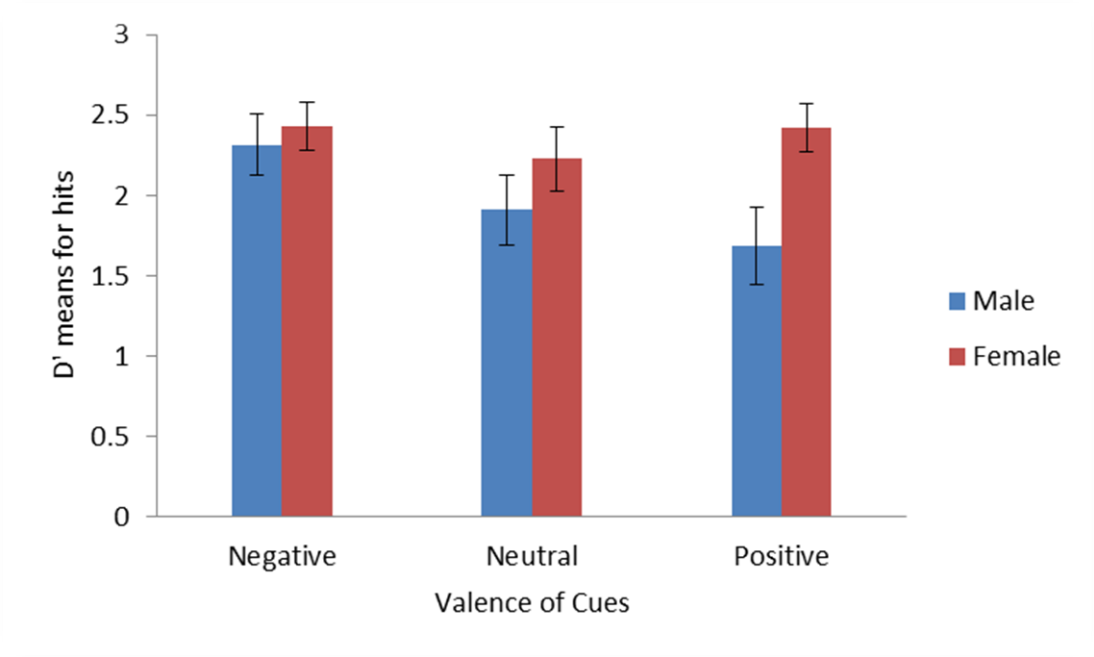

Figure 5. *Valence by Gender Interaction for Recognition of Cues.* Error bars represent +/- 1 standard error of the mean (SEM).

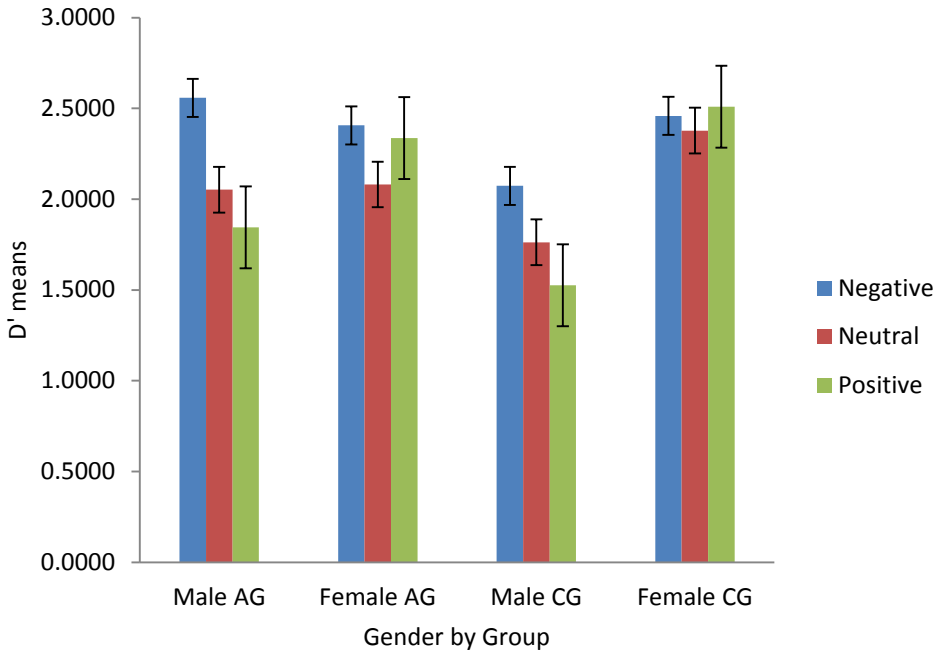

Figure 6. *Group by Gender by Valence for Recognition of Emotional Cues.* AG= anxious group. CG= control group. Error bars represent +/- 1 standard error of the mean (SEM).

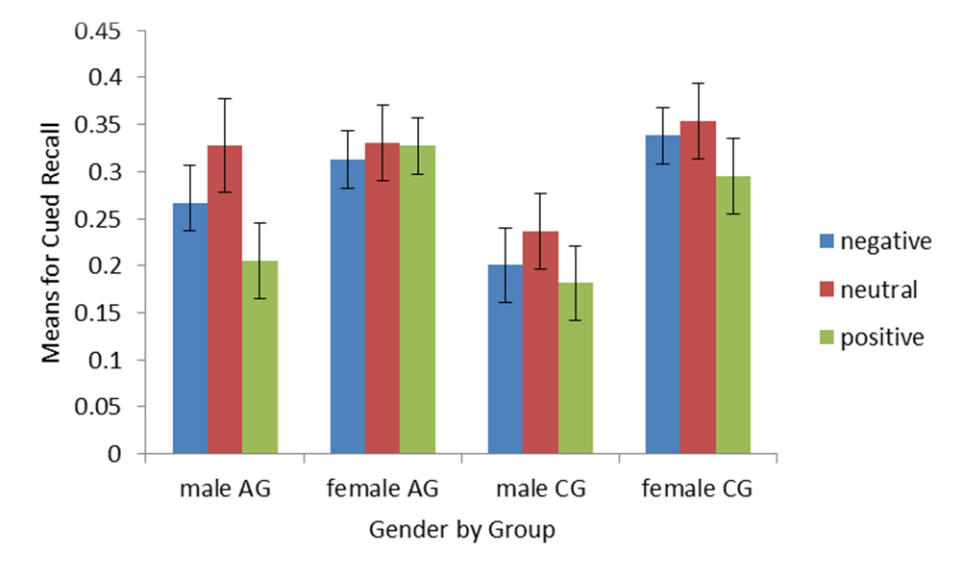

Figure 7. *Group by Gender by Valence in Cued Recall.* AG= anxious group. CG= control group. Error bars represent +/- 1 standard error of the mean (SEM).