Running Head: FACIAL EXPRESSION AND ASSOCIATIVE MEMORY

The Effect of Emotion on Memory: Faces and Names

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Abstract

Emotion has been shown to demonstrate a modulating effect on memory, generally enhancing recall and recognition of stimuli. The goal of the current study was to determine the effect of emotion on associative memory between faces and names. Across three separate experiments, 45 participants viewed 120 face-name pairs (names paired with fearful, happy, and neutral faces) and later performed a forced-choice recognition memory task. The results showed that memory for fearful and happy face-name pairs was not better than that for neutral face-name pairs; however in the first experiment, we found significantly greater recognition of happy pairs than fearful pairs. There was no significant relationship between measures of valence, arousal, and attractiveness and memory performance in any of the experiments. Explanations for the results as well as possibilities for future research are discussed. Our study suggests that emotional face-name memory involves complex processes which merit further investigation.

The claim that emotion has an effect on memory likely provokes little surprise, and indeed would appear to be obvious to most people. After all, many of the most memorable life events tend to be the most negative (e.g., death, crisis, injury, heartbreak) and the most positive (e.g., holidays, marriage, graduation). G.M. Stratton explored the effect of emotion on memory after his student inquired about the intensity and clarity of his personal recollection of a 1906 earthquake in San Francisco (Stratton, 1919). Stratton was inspired to collect hundreds of written and oral accounts recounting a number of traumatic events, many of which demonstrated the same heightened level of recall. Not only were the crises themselves remembered, but even seemingly innocuous minutia of the environment and situation, from carpet patterns to exact dialogues to specific facial expressions were described with incredible detail. Stratton described this phenomenon as retroactive hypermnesia: possessing an exceptionally good memory for a past event, particularly for those which are very emotional or traumatic.

The following review delves into research concerning memory, emotion, and the interaction between these two factors. The influence of emotion on the memory of past events, as observed by Stratton, will be further investigated, leading to an analysis of emotion though more quantitative measures: valence and arousal. Valence and arousal can modulate memory in a variety of ways, as has been demonstrated by both behavioral and neuroimaging research. The review will then focus on memory studies that have used facial expressions as stimuli. The review will conclude with an introduction to the current study, which was inspired by a lack of research of the possible effects of emotion on associative memory.

Memory for Past Events

Thompson (1985) further investigated the effect of emotion on personal memory in a more structured manner. He asked 30 students to record unique personal events over a three month period, rating both memorability and pleasantness of each event. A subsequent memory test revealed that highly emotional events (regardless of valence) were subject to better recall. However, valence did have an effect on the memory for dates of the specific events, with the greatest accuracy for dates of highly pleasant events and the lowest accuracy for dates associated with highly unpleasant events (average dating accuracy for neutral events was between that of high and low valence events). Thompson stated that these findings reflected the concept of a "red letter day", for which one might be more likely to recall dates of fondly remembered events (e.g., birthdays and holidays). In an even more streamlined experiment involving pre-established sets of storytelling slides, participants were found to demonstrate better memory for an emotionally arousing slide show than for a neutral set of slides, yet the majority of the memory enhancement was attributed to the images of intense, negative scenes (in this case, graphic depictions of accident and surgery scenes) (Cahill & McGaugh, 1995).

Another study of personal memory recall involved student memories of the September 11, 2001 terrorist attacks (Talarico & Rubin, 2003). The authors describe this type of event as a "flashbulb memory": a term made famous by researcher Roger Brown, defined as memory generated from an unexpected, highly arousing and consequential event (such as events prompting the questions, "Where were you when ______ happened?, e.g., the Kennedy assassination") (Brown & Kulik, 1977). Students described their memories of the incident, as well as a neutral, unarousing event (taking place within a couple of days of Sep. 11th) at intervals of 1, 6, and 32 weeks (separate groups of students for each interval). Surprisingly, it was found that recall accuracy for both the 9/11 memory and the mundane event decreased at the same rate. However, in spite of the lack of memory differences, participants possessed a greater conviction that their recollection of their September 11th "flashbulb memory" was more accurate. This suggests that the intensity and arousal associated with such memories might instill greater confidence, but not necessarily greater accuracy, in one’s recollection.

From even these three relatively simple studies, one can see how behavioral data concerning the effects of emotion on memory can substantially differ depending on the subject of the memory, how such memories are subjectively rated, by what factors are they rated, the measure of recall ability, the interval between the event and recall, the presence of comparative factors, as well as a multitude of other soon-to-be-discussed variables. Indeed, both emotion and memory are incredibly dense concepts, each with many varied implications and implementations in both academia and in everyday life, psychological or otherwise. The great extent to which both factors contribute to human function and behavior creates a vast potential for research. This concept is perhaps best (and most parsimoniously) stated by Levine and Pizarro (2004), “Once one moves beyond the simple statement that emotion strengthens memory, things get complicated quickly.” In their appropriately titled article, “Emotion and memory research: A grumpy overview”, Levine and Pizarro express their frustration over how, despite vast research on the topic, there still exists many unresolved questions, contradicting information, and competing theories. Many of the hypotheses and studies that they discussed will be addressed in the following review.

Studying Brain Activity

Many researchers now attempt to allay the confusion caused by the interpretations of behavioral data by incorporating neuroimaging into their studies of emotion and memory. Using relatively modern technology such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) can provide direct visual evidence of activation in the brain as well as the connections between key areas. A multitude of brain structures are analyzed in such studies, with the amygdala, hippocampus, and prefrontal cortex among the most notable (Kensinger & Corkin, 2004). However, as with non-imaging studies, many variables can influence both participant behavior and brain activation. That is not to say that major trends have not been observed; indeed the last couple of decades have provided a wealth of compelling information which, bit by bit, elucidates the substantial topic of emotion and memory. This review aims to highlight many of these findings and, along with the current experiment, incorporate these studies into a larger, more cohesive picture.

Arousal and Valence

One of the most basic hurdles encountered when conducting empirical studies on emotion and memory is how to measure emotion. Although there exist many synonymous terms for feelings such as happiness, sadness, fear, and anger, it can be quite difficult to clearly describe the complete experience of a given emotion. In order to help quantify emotion in research, the terms *arousal* and *valence* are often employed. Arousal refers to the magnitude of excitement or provocation one experiences in response to a given stimulus, while valence is a measure of how positive or negative a stimulus is (Kensinger & Corkin, 2004). Although arousal and valence are often correlated (as more negative/positive valence stimuli tend to elicit higher emotional responses), they are generally considered as independent measures. After all, a picture of a blue and pink striped zebra may be exciting and surprising (leading to high arousal) but may not be considered generally positive or negative (neutral valence). Likewise, the word "sadness" is of negative valence, but may not instill much emotional excitement (as compared to, for example, a grisly picture of a corpse, or even more provocative words such as "rape" or "torture").

In an early experiment, participants learned and were tested (shortly thereafter) on a list of pleasant, unpleasant, and neutral words (Silverman & Cason, 1934). The researchers found that participants were quicker to rate words as pleasant or unpleasant than neutral, and that pleasant words possessed the greatest recall, followed by unpleasant words, and lastly neutral words. Kensinger and Corkin (2003) similarly observed greater recollection for negative, high arousal words compared to neutral words (no pleasant word stimuli were used). The findings of another study suggest that the memory effect for pleasantness may only be short term (Bradley et al., 1992). Participants viewed and rated a series of slides drawn from the International Affective Picture System (IAPS; Lang, Öhman, & Vaitl, 1988), and were tested on free-recall memory both immediately after encoding and one year later. It was found that both pleasantness (i.e., valence) and arousal had a significant effect on memory for initial recall, but only the arousal effect continued through the one year interval.

There is also some evidence that emotion can affect memory of neutral stimuli within certain paradigms (Anderson, Wais, & Gabrieli, 2006). Participants viewed a series of neutral, low arousal images of faces and houses, some of which were followed by emotional stimuli (from the IAPS). A memory task, conducted one week after encoding, revealed that arousal and distinctiveness ratings of the emotional stimuli (but not valence) predicted subsequent memory for the proximate neutral stimuli. Interestingly, the researchers observed that this memory enhancement occurred when the neutral and emotional stimuli were separated by a 4 second interval, but ceased after this interval was raised to 9 seconds, suggesting a specific time frame for this effect to occur.

Remembering and Knowing

Some studies focus not only on the accuracy of participant memory, but also the state of awareness in which the stimuli are recalled. Instead of simply employing a yes/no or new/old recognition test for memory, some researchers choose to further divide positive recall into "remember" and "know" categories. In a remember/know (R/K) procedure, an "R" response indicates an episodic recall of the stimulus in which the subject remembers the situational aspects (thoughts, feelings, details, etc) concerning the initial encounter with the stimulus (also linked to the term recollection), while a "K" response indicates that the subject recognizes having seen the stimulus before, but only with a general sense of familiarity and lacking the episodic details that would constitute "R" (Ochsner, 2000). In Ochsner's study, subjects viewed a series of negative, neutral, and positive photographs from the IAPS and participated in a subsequent new/remember/know memory task 2 weeks later. He found that significantly more negative stimuli were "remembered" than positive and neutral (along with greater recognition accuracy). Positive stimuli approached significantly higher "R" ratings than neutral stimuli, and were significantly more likely to be "known" than negative photos. Another phase of the study, in which participants made no valence or arousal ratings on the stimuli yielded similar results, suggesting that these measures do not need to be explicitly considered by the participant to have a memory effect. A similar study (sans positive images) conducted by Sharot, Delgado, and Phelps (2004) found that, while more negative, emotionally arousing stimuli (IAPS photos) were rated as "remembered" than neutral images as in the previous study, the actual accuracy of memory did not differ between stimulus categories (memory task 1 hour after stimuli encoding). This hearkens back to the aforementioned concept that emotional arousal may confer a better sense of remembering, but may not always increase accuracy.

Neuroimaging Studies of Emotion and Memory

The use of neuroimaging techniques such as fMRI and PET in neuroimaging research has helped associate brain activation with various behavioral responses to viewing and recalling emotional stimuli. The hippocampus has been long associated with memory processes, and the inclusion of emotion (particularly negative) often brings the amygdala into discussion (Kötter & Meyer, 1992). Using PET, Cahill and his colleagues found that not only were significantly more negative emotional films remembered (3 weeks after encoding) than non-emotional neutral films, but that this increase in memory correlated with increased activation in the right amygdaloid complex (AC) (Cahill et al., 1996). In another PET study, eight male participants were scanned while viewing 4 types of scenes: pleasant, aversive, neutral, and interesting (but unarousing). Participants were administered memory tasks both immediately after the scanning session, as well as 4 weeks later (free recall for both, as well as a new/old task in the 4-week session) (Hamann et al, 1999). Participants demonstrated better memory for pleasant, aversive, and interesting stimuli compared to neutral stimuli, but amygdala activation was only observed during the encoding of the pleasant and aversive scenes. Amygdala activity recorded during stimulus encoding did not correlate with performance on the initial recall task; however amygdala activity in response to pleasant and aversive scenes during encoding did positively correlate with memory for those stimuli for the 4-week test (although the effect for aversive scenes was less significant and right-lateralized). There was also a significant positive correlation between bilateral hippocampal activity observed during encoding and subsequent memory for the emotional stimuli. These results suggest that the amygdala may play a larger role in consolidating long term memory than short term, and that there exists a connection between amygdala and hippocampal activity. Indeed, many argue that the activation of the amygdala does not directly result in improved memory, but rather that amygdala activation influences other brain regions such as the hippocampus and prefrontal cortex which are more explicitly in charge of memory (Cahill & McGaugh, 1998). The results are further supported by a PET study in which the encoding of negative scenes versus neutral scenes by eight female participants produced a significant activation of the left amygdaloid complex (and moderate activity in the right AC), but this activation was not observed when participants were scanned during the recognition task, which occurred immediately after encoding, although there was significant activity in the lingual gyrus observed during recognition of negative stimuli (Taylor et al., 1998). No differences in memory recall between negative and neutral stimuli were observed, due likely to a ceiling effect. Also complimentary were the results from Canli et al. (2000), which through fMRI revealed a significant positive correlation between bilateral amygdala activity during encoding with subjective ratings of stimulus emotional intensity, as well as a significant positive correlation between left amygdala activity during encoding and subsequent memory (test 3 weeks after encoding, outside the scanner) for highly arousing negative pictures in female participants. Another study also reported greater left amygdala activity during the retrieval of emotional stimuli (positive and negative objects and scenes from the IAPS) compared to neutral stimuli, even though there was no difference in memory performance in a yes/no recognition task (immediately after encoding) due likely to a ceiling effect (Dolan et al., 2000).

Indeed, there exists compelling evidence for the role of the amygdala in emotional memory, particularly for arousing stimuli, yet, again, one must not over-generalize either the effect of arousal on the amygdala or the effect of amygdala activity on memory. In his literature review, Stephan Hamann (2001) discusses how there is likely a threshold for amygdala activity, below which no enhancement of memory will occur. Hamann also explains how activation of the amygdala likely affects encoding and consolidation activity in the hippocampus.

There has been debate as to whether amygdala activity is associated with all aspects surrounding the encoding of an emotional stimulus, or only those that involve the emotion itself. Kensinger and Schacter (2006) analyzed this idea using fMRI by inserting neutral tasks during the encoding of positive, negative, and neutral words and pictures. After viewing each stimulus, participants were asked one of two questions: was the stimulus animate or was the stimulus common. For the recognition task (outside of the scanner, 30 minutes after the encoding fMRI scan), participants were shown a stimulus and asked whether it was previously shown and asked about animacy, previously shown and asked about commonness, or new (foil). Emotion was shown to have an effect on memory of the items in general (with both positive and negative stimuli remembered better than neutral), but there was no effect of emotion concerning memory of the specific context of the stimulus (remembering whether the animacy or commonness question was asked). Interestingly, amygdala activity positively correlated with memory for positive and negative stimuli, but not with memory of the additional question asked. This suggests that the amygdala may help encode emotional stimuli. Interestingly, it was the hippocampus which demonstrated activation that correlated with increased memory for the specific task performed during encoding (i.e., whether participants had been asked about animacy or commonness for each stimulus).

Other studies have further investigated the interplay between the amygdala and hippocampus. In a fMRI study conducted by Kensinger and Corkin (2004), male and female participants viewed and rated neutral words, negative non-arousing words (e.g., “sorrow”), and negative arousing words (e.g., “rape”). After a 10-minute delay, they completed a remember/know/new memory task (also during scanning), in which both non-arousing and arousing negative words were better remembered than neutral words. Both types of negative words activated the left hippocampus, amygdala, and inferior parietal lobule more so than neutral words during encoding. However, during the memory task, the researchers observed an amygdala-hippocampal activation for arousing negative words, and a prefrontal cortex-hippocampal activation for non-arousing negative words. Interestingly, when a distractor task was implemented during the encoding process, the researchers found that subsequent memory for non-arousing negative words was diminished, but that a memory enhancement effect still occurred for arousing negative words. This suggested differentiating neural processes for processing valence and arousal, specifically that arousal based circuits appear to be more automatic and subconscious. These results supported behavioral findings from a previous study conducted by the same research team, which found that both taboo words (highly arousing) and negative words (lower valence than taboo, but lower arousal) were remembered better than neutral words, but that the taboo words (more indicative of arousal than valence) were remembered significantly better than negative words (which were more representative of valence) (Kensinger & Corkin, 2003).

Brain imaging has suggested differing neural activity between remember and know processes between varying levels of arousal. The aforementioned remember/know study from Sharot, Delgado, & Phelps (2004) also employed an fMRI component, which revealed that remembering neutral stimuli was associated with a mainly parahippocampal activation, while remembering emotional stimuli was correlated with heightened amygdala activity, suggesting that one may draw upon different types of information depending on the stimulus when making memory based judgments, or perhaps that different areas of the brain are responsible for different memory related processes. Another fMRI based remember/know paradigm was conducted by Mickley & Kensinger (2008) which involved participants studying and recalling positive, negative, and neutral words and pictures. Scanning during the studying session revealed that all stimuli stimulated activation in the inferior prefrontal cortex, hippocampus, and parahippocampal gyrus during. Negative stimuli that were remembered (memory task was 30 minutes after encoding, outside of the scanner) were associated with activation in temporo-occipital regions (associated with sensory processing) more so than remembered positive and neutral stimuli. Positive stimuli that were “known” were linked to activation in the cingulate gyrus and bilateral frontal and parietal areas (associated with semantic and episodic memory) more so than known negative and neutral stimuli. Amygdala activity was found in accordance with correct memory for positive and negative stimuli (left stronger in women), but not neutral. This enhancement of amygdala activity during the recollection of positive and negative emotional stimuli has even been observed a year after initial encoding (Dolcos, LaBar, & Cabeza, 2005).

Face Perception and Memory

The studies discussed above employed stimuli that were generally affective words or scenes. When specific focus is placed on the effect of facial expression on memory, as with the current study, new considerations must be given to experimental design and results. Unlike many scenic or word stimuli, which often remain static in their valence and arousal (a mutilated body is generally considered negative and highly arousing), human facial expression is extraordinarily malleable, as a single person can produce a stunning array of emotions, conveying their thoughts and feelings. While much of the arousing imagery used in research displays scenes that can be quite uncommon in everyday life, and indeed many of which one hopes to never see in reality, facial expressions are one of the most prominent factors in social communication. As a result, research involving facial expression and memory can provide an intriguing look into one of humanity’s oldest social processes.

And this process is indeed quite old, as suggested by distinguished researcher Paul Ekman, whose article in *Science* described one of the most famous observations on human emotion (Ekman, Sorenson, & Friesen, 1969). Ekman and his colleagues observed that social groups, such as the Fore people of New Guinea, who had remained isolated from all other civilizations, demonstrated recognizable emotional expressions for their expected social context. This led Ekman to postulate that certain “primary emotions” - happy, fear, disgust-contempt, anger, surprise, and sadness – are resultant of evolutionary origin, and are not born out of an individual’s social upbringing. This provided evidence to a similar, controversial theory on the instinctive nature of human emotion proposed by Charles Darwin (Darwin, 1890). It was a groundbreaking discovery which opened up bold new research opportunities, and Ekman continued to expand, and occasionally defend, his theories (see Ekman, 1992 for a skillful and passionate defense of his work).

The perception of facial expression entails unique processes compared to viewing other types of stimuli. In a recent article, Oosterhof & Todorov (2008) attempted to construct a model of facial evaluation. They found that many of the judgments made on faces were based on two important orthogonal dimensions: valence (in this case referring to approachability) and dominance (referring to the strength or weakness of an individual). Note that these ratings were based on emotionally neutral faces, so arousal was not as high a factor in this study as it is in many others. Their findings suggested that these dimensions help individuals make snap judgments of faces, although these judgments do have the tendency to be overgeneralized.

The unique nature of facial expression has also been noted in neuroimaging research. In an MEG study, researchers found that the activation of the inferior frontal cortex, amygdala, and sections of the temporal cortex observed during face presentation differed from activation in response to other living or non-living stimuli (Streit et al., 1999).

Anderson et al (2006) provides an interesting comparison of face and scene stimuli concerning their effects on memory. Participants rated emotional scenes as more intense than emotional faces. The researchers found that negative scenes were remembered significantly better than neutral scenes, but that fearful faces were not remembered better than neutral faces (the interval between encoding and the memory task ranged from 15 minutes to 2 weeks; the memory patterns remained constant for all intervals, although overall recognition decreased over time). A second part of their study revealed increased galvanic skin response for negative events compared to neutral events, but, again, not with negative faces compared to neutral faces (and negative scenes were again remembered best, even significantly more so than negative faces). The authors suggest that the content of the scenes was more emotionally arousing than that of the fearful faces. While this idea certainly holds some credence, it would be wrong to conclude that the results demonstrate that facial expression has no effect on behavior. It is quite possible that the more provocative scenes drew attention away from the faces, thus inhibiting memory for these stimuli (the researchers attempted to minimize this effect by blocking the scene and face stimuli, but the notion of a hierarchical emotional effect, especially with the longer memory intervals, still seems plausible). There also remains the possibility that the scene stimuli may have been more unique or distinct than the more homogeneous faces, and would thus be easier to recall.

There is evidence that certain facial expressions can alter subsequent perception behavior. Davis et al. (submitted) showed participants blocks of fearful and neutral faces or angry and neutral faces, all interleaved with neutral words. Using an old/new recognition task, the researchers found that participants demonstrated better memory for the words in the fearful blocks compared to neutral blocks, but no difference in memory for the words in the angry blocks compared to neutral blocks. A second experiment with new participants revealed a better memory for the faces in the angry blocks compared to fearful blocks as well as better memory for the words in the fearful blocks compared to the angry blocks. They suggested that these results supported the concept that angry faces may be better remembered since they are the apparent source of threat, while fearful faces can enhance memory for contextual information, as such an expression forces one to seek out the source (threat) causing the observed fear.

These studies exhibit that face stimuli can produce distinct responses, and the following experiments demonstrate that facial valence and arousal certainly can have a profound effect on the brain activity as well as behavior.

Neuroimaging Studies of Facial Expression

Although it has been previously emphasized that face stimuli are distinct from scene or word stimuli, this is not to say that the processes involving recall of facial expressions do not involve similar brain structures. Indeed, the amygdala, hippocampus, and prefrontal cortex still rate among the most involved brain regions in such research, with particular focus on the amygdala's role during the perception of negative emotion faces. Sergerie, Lepage, and Armony (2006) studied amygdala activity during both encoding and retrieval (new/old task) of fearful, happy, and neutral faces. Their behavioral results demonstrated significantly better memory for fearful faces compared to positive and neutral faces, and fMRI data suggested that right amygdala activity was associated with encoding emotional faces, while the activity in the left amygdala was involved with the retrieval of such stimuli.

An fMRI study of emotional faces and scenes revealed contrasting evidence to the conclusions drawn from the similar aforementioned study conducted by Anderson (2006) and his colleagues (Hariri et al., 2002). Participants viewed negative faces (angry/fearful) and negative images from the IAPS. The researchers observed stronger amygdala activation in response to viewing the negative faces than for the other threatening images. Furthermore, activation of the right amygdala was more associated with faces, while left amygdala activation was associated with pictures, although right amygdala activation was greater overall. These results seem to contradict those from Anderson et al (2006), although a memory task was not available from Hariri's study for comparison. The authors suggest that negative faces may instigate a more intrinsic, evolutionary based response, distinguishing these stimuli from more "learned" dangers displayed in the IAPS, such as weapons.

Another neuroimaging study, this one employing PET, measured rCBF activity in the brain during presentation of happy and fearful faces of varying levels of intensity (i.e., increasingly stronger representations of the given emotion) (Morris et al., 1996). Significant activation of the left amygdala was reported for fearful vs. happy faces, as well as a significant interaction between amygdala activity and stimulus intensity level (increasing amygdala with higher negative intensity, decreasing amygdala activity with higher positive intensity). Other notable areas of brain activation included the left cerebellum, left cingulate gyrus, and right superior frontal gyrus.

Researchers often inquire as to exactly how automatic our response to facial stimuli can be, and may employ masked-stimuli paradigms in attempts to answer this question. Whalen and colleagues organized a backward masking paradigm, in which 33 msec presentations of fearful or happy faces (blocked) were immediately followed by 167 msec presentations of neutral faces (Whalen et al., 1998). The stimulus onset asynchrony (SOA), the period between the target and mask stimulus, was shortened to 33 msec, which caused the mask to fall below the threshold for conscious awareness (Esteves & Öhman, 1993). Despite remaining unaware of the presence of the emotional face stimuli, participants displayed BOLD levels in the amygdala that were significantly higher in response to masked fearful faces than masked happy faces. This suggests the incredible speed at which the amygdala can respond to highly arousing faces, even when they are not consciously perceived. Suslow et al. (2006) conducted another fMRI based, backward-matching paradigm (33 msec mask, 467 msec target) in which participants viewed neutral faces with fearful, angry, and happy masks. The researchers studied brain activation as well as participants' conscious detection of the emotional masks (as measured by a yes/no recognition task post-scanning). No differences in detection rate between emotions were found, however bilateral amygdala activation was found to be correlated with fearful face detection, while right amygdala activity correlated with angry face detection. Critchley at al. (2005) investigated the interplay between brain activation and autonomic response to facial expression in hopes of better understanding the true nature of emotion. They presented happy, angry, sad, and disgusted faces to participants and measured the subsequent brain activity using fMRI and also measured participants' heart rates. The researchers found differential changes in heart rate depending on the emotion depicted; greater increases for angry and sad faces compared to happy and disgusted. It was also observed that activation in the amygdala (associated with emotion) and in the fusiform and adjacent lingual gyrus (associated with face processing), among other structures, displayed a positive correlation with these increases in heart rate.

An experiment conducted by Pessoa and colleagues challenged the idea that direct conscious perception of emotional faces is not needed to cause amygdala activity (Pessoa et al., 2002). Participants viewed fearful, happy, and neutral faces under an attended condition, in which participants identified the gender of the face during encoding (to keep attention on the face), or an unattended condition, in which participants performed a task involving geometric objects surrounding the face (to draw focus away from the face). fMRI data revealed *only in the* *attended condition* greater activity in the right amygdala for fearful vs. neutral faces, and greater activity in the left amygdala for both fearful and happy faces vs. neutral faces.

Effects of Attractiveness and Other Face-Related Measures

Valence and arousal may be the most relevant measures pertaining to facial emotion, but one must not discount the influence of other facial attributes, the effects of which can be seen from even a casual, purely social perspective. Attractiveness is a good example; it can certainly affect judgement of character as well as memory for a person. Surely most individuals have experienced the phenomenon of remembering a particularly attractive (or unattractive) face from a social situation long since passed, and, of course, structured research has explored this concept as well. In one such study, male and female participants studied a set of female faces of varying attractiveness, and were administered memory tests based on these faces immediately, 6 days, and 35 days after (Shepherd & Ellis, 1973). No effect of attractiveness on memory was observed for the same-day memory task or after 6 days, however the 35-day interval task revealed significant decreases in memory for the moderately attractive faces, but not for either the low or high attractiveness faces (no measures of arousal were taken). A study by Deblieck and Zaidel (2003) suggested that this effect of attractiveness on memory may have a hemispheric specificity component; there was greater overall memory for faces presented in the right visual field (RVF) than the left visual field (LFV), women remembered the high attractiveness faces of both genders best and specifically in the RFV, and men tended to remember best the least attractive male faces (displaying significantly more activity in the LVF than the RVF) and female faces (displaying significantly more activity in the RVF than the LVF).

While there exists evidence for a substantial effect of attractiveness of memory, other researchers flag measurements of “distinctiveness” as having a greater effect on memory. Sarno

& Alley (1997) found that increased recognition for faces correlated significantly with participants' higher subjective ratings of distinctiveness, but not attractiveness, of the stimuli. Another study using a remember/know paradigm task found similar results, with high distinctiveness ratings serving as the greatest predictor for "remember" responses for face recall (with lesser, but still noteworthy correlations with ratings of familiarity, attractiveness, memorability, and atypicality) (Dewhurst , Hay, & Wickham, 2005). Interestingly, the effect of these rating dimensions were all similarly moderate in relation to "know" response, suggesting a more general feeling of having seen a face before, but lacking the distinct memory that leads to a "remember" response.

Prior familiarity to a face can also influence encoding and memory strategies. Kaufmann and Schweinberger (2004) used a morphing program to alter face stimuli of both celebrities and unknown individuals; warping familiar faces to become unfamiliar and changing happy expressions to angry. The researchers found that participants exhibited the fastest reaction times in response to labeling celebrity faces as familiar when they displayed a moderately happy expression, even if it was a morphed image. This may represent a type of "perceptual learning"; in which one may develop an association between a face and the expression which is normally demonstrated. The celebrities depicted were mostly politicians, who commonly display a reserved but happy expression, which would account for the faster reaction times.

In an interesting twist, Cutler and Penrod (1989) studied another aspect of facial perception and memory: the removal of certain facial features. Participants viewed a set of face stimuli, however half of the individuals depicted in the stimuli were wearing hats, covering their hair, resulting in what the authors termed as "cue degradation". In addition, the researchers told participants varying percentages of already seen faces that would be used in the new/old task (when the proportion of new faces/old faces remained 50% for all participants) to assess the effects of altering base-rate information on confidence (participants reported their confidence in their decisions on the memory task). Confidence-accuracy correlation was stronger for faces without cue degradation, as well as for faces that were rated as more distinctive. Again, attractiveness did not have an effect on this correlation. Surprisingly, changes in base-rate information (i.e., the new/old stimuli ratio that participants were told to expect in the recognition task) also had no effect on confidence ratings suggesting that participants tended to stick to their instincts. Another confidence-accuracy study was quite unique due to its use of live stimuli (Brigham, 1990). Participants viewed in person line-ups of a total of 33 white males, which were rated on distinctiveness and attractiveness. In contrast to Cutler and Penrod (1989), Brigham found a high confidence-accuracy correlation for memory and both distinctiveness and attractiveness.

Face-Name Associations

Developing face-name associations is an everyday demand for most individuals, whether it is within an interpersonal social situation, reading the newspaper, or watching a television program. For all of the face-name pairs that are established, many are also lost, especially those to which we have had short exposure. A review of literature by Cohen and Burke (1993) attempts to explain why it is so easy to forget proper names. The authors explain that proper names are often subject to the well known “tip-of-the-tongue” phenomenon, in which an individual is unable to produce a name despite being sure that they know it (an embarrassing situation that nearly all of us have experienced). Proper names have been shown to be one of the worst remembered pieces of basic biographical information for a given face; individuals are more likely to recall given occupations or hobbies for a face stimulus than its assigned name

(Cohen and Burke, 1993). There is almost never a situation in which participants would remember a face's name, but not the occupation (provided that both were given, of course). This may be that these names are inherently, to quote, the authors, "meaningless and arbitrary." A person's given name is generally inconsequential, only serving as identification, and holding no further social connotation. It is, in a sense, a unique, tiny, isolated entity in one's bank of knowledge. The result of this, the authors postulate, is that there is much less neural connectivity to a proper name of a given face than an occupation (e.g., policeman) or hobby (e.g., snorkeling), which possesses much greater networks of semantic connotations and can thus be more easily recalled.

Craigie and Hanley (1997) further investigated the interplay between face, name, and occupation. After studying a set of 18 face-name-occupation groups, participants were immediately administered a memory task in which they were given one of a stimulus' three identification pieces, and were asked to provide the other two. When given either the face or name, participants were more likely to remember the occupation than the other item. However, there was no difference in memory for faces and names for a given occupation. Furthermore, in the cases in which participants were able to link faces and names without the aid of occupation, they often revealed a contextual hint that allowed them to remember the other piece (such as having a friend with the same name). This continues to support the idea that strong cognitive links can be formed much more easily between faces and occupations as well as between names and occupations, but not between faces and names.

Neuroimaging evidence contributes further explanation of why such a commonplace task is somehow so complicated. Startling discrepancies were found between PET activation for novel words and novel faces (Kim et al., 1999). Novel words stimulated activation mostly in the left hemisphere, including the orbital and inferior frontal gyri, middle and inferior temporal gyri, and insula, while activation for novel faces was mostly observed in the right hemisphere, particularly in the left and right occipital areas, right parietal cortex, and right lingual and fusiform gyri (a structure often associated with face recognition). Using ERPs, Sommer, Komoss, and Schweinberger (1997) also found substantial variations in ERP amplitude topographies in the perception of faces vs. the perception of uncommon names. Not only are faces and names intrinsically segregated on a semantic basis, the neural mechanisms that govern their perception are surprisingly different.

And yet we continue to make such associations casually and without further thought, and such pairing can hold surprising longevity, as demonstrated by an impressive cross sectional study of face-name memory that lasted over 50 years (Bahrick, Bahrick, & Wittlinger, 1975). The researchers divided 392 high school graduates into 9 groups, each of which were administered a battery of memory tasks based on their individual high school yearbooks at intervals ranging from 2 weeks to 57 years (one group per interval). The memory tasks included name alone recognition (select the correct name of a student from a set of foils), picture alone recognition, selecting a picture to match a given name, selecting a name to match a given picture, and a picture cuing task (in which a picture was presented and the participant freely recalled the correct name). The researchers noted that face-name matching performance remained at around 90% correct for at least 15 years, and that choosing a picture to match a given name was easier for participants than selecting a name to match a given picture. Picture cuing (providing the name without aid for a picture) resulted in the worst memory performance. Visual recognition of one's student peers was retained quite strongly for approximately 30 years, but only half as long for verbal (name) recognition. Interestingly, while women had better memory after shorter intervals, the male participants actually demonstrated better memory after about 50 years. Lastly, the authors emphasized the significance that their memory task was more ecologically valid in nature, using stimuli consisting of previously and naturally learned faces and names, unlike many other experiments in which participants are exposed to novel stimuli in an unnatural environment, resulting in different (and most likely lessened) recall abilities.

More traditional experimental designs still remain important, as such designs allow for heightened levels of control and greater confidence in the cause and effect relationship from one's findings. Sperling and colleagues have performed robust analyses of brain activity in response to face-name association. In one study, Sperling's research team used fMRI to study brain activation during the encoding of novel and repeated face-name pairs (Sperling et al., 2001). They observed that the encoding of novel face-name pairs was associated with activation in the hippocampal formation, dorsolateral prefrontal cortex (DLPFC), pulvinar nuclear of thalamus, fusiform, and areas of the visual association cortex. They found a particularly interesting activation in the anterior hippocampus (not present in repeated stimuli), which was hypothesized to be involved with forming associations between unlike information (e.g. faces and names). A positive correlation between BOLD levels and memory test scores approached significance. The researchers further investigated this noteworthy anterior hippocampal activity in a subsequent fMRI experiment (Sperling et al., 2003). The post-scanning face-name recognition task employed in this study (immediately after encoding) merits particular mention, as it is very similar to that used in the current study. Participants were presented one of the faces from the earlier encoded face-name pairs along with two names, one being the name it was originally paired with, the other a foil from another face-name pair. Participants were to selected the name associated with the original pairing, and also noted their confidence (high or low) in their decision. Participants demonstrated an overall 66.2% memory accuracy for face-name pairs, and 77.5% accuracy for high confidence responses. During encoding, face-name pairs that were later remembered were associated with bilateral activation in the anterior hippocampal formation (thus confirming their previous findings) as well as the left inferior prefrontal cortex. There was a significant correlation between bilateral hippocampal and neocortical activation during these “successful” encoding trials, highlighting neural connections involved in face-name associative memory. A significant positive correlation was also observed between encoding activity in the inferior prefrontal cortex and subsequent high confidence ratings for both correct and incorrect responses. This paradigm was used in yet another study which further confirmed the correlation between anterior hippocampal activity and successful face-name association encoding (Chua et al., 2007, which was very similar to design to Sperling et al. (2003), but also included a face-only yes/no recognition task prior to the forced choice face-name recognition task as seen in Sperling).

Small et al. (2001) designed a paradigm to examine the patterns of hippocampal activation in response to face-name pairs as compared to activation for viewing faces alone and hearing names alone. Participants demonstrated primarily posterior hippocampal activation in response to viewing just faces and primarily anterior hippocampal activation in response to hearing just names. Most importantly, hippocampal activation produced by combining the presented face and spoken name was not merely a summation of the activity generated by each stimulus separately; there was a unique pattern of brain activation, particularly in the middle of the hippocampus. Subsequent reactivation of these neural patterns during recall further suggests that the brain activity involved in face-name association is more complex than a simple combination of face memory and name memory processes. Although the face-name activation in the hippocampus did not exactly match that from the Sperling studies, recall that Sperling's experiments (Sperling et al., 2001, Sperling et al., 2003) visually portrayed the associated names with the faces, while Small and colleagues presented spoken names to accompany the faces.

Kirwan & Stark (2004) also observed that face-name encoding activation is more than the sum of its parts. In their recognition task, participants indicated whether the presented face-name pair was previously seen, novel, or a recombination of a previous face and name that were not originally paired together. This allowed the researchers to compare responses to associative memory and non-associative memory (just for the face or name). There was indeed a difference; participants demonstrated greater activation in the right hippocampus, right parahippocampal cortex, and left amygdala when encoding associative information vs. non-associative information. The right hippocampus was also more active during retrieval of encoded face-name pairs than non-associative memory, further supporting the role of the hippocampus in associative memory.

Zeineh et al. (2003) attempted to further elucidate specific regions of hippocampal activation during face-name pair encoding and retrieval. They observed activation in the cornu ammonis (CA) fields 2 and 3 as well as the dentate gyrus in relation to face-name pair encoding. The subiculum showed activation corresponding with recall of names associated with the face stimuli. There was also significant activation in the fusiform gyrus in response to novel face-name pairs during retrieval.

An intriguing study conducted by Tsukiura and Cabeza (2008) incorporates an added variable of facial expression, smiles in particular, in their research of face-name associations. Participants completed alternating blocks of encoding and retrieval. The stimuli consisted of neutral and happy faces. For the recognition task, participants were presented a previously seen name, and were asked whether the associated face was happy, neutral, if they forgot the emotion, or if the name was completely new. Happy face-name pairs were found to be retrieved both faster and more accurately than neutral stimuli. fMRI data revealed greater activation during both encoding and retrieval in the orbitofrontal cortex and medial temporal lobe for happy face-name association, specifically a strong connection between the orbitofrontal cortex and hippocampus (no substantial amygdala activity was noted). Another study also found that happy, smiling faces were better remembered than surprised, angry, or fearful faces, even when faces were inverted or when factoring in an extra “grimace” category, in which inverted smiles were placed onto faces (Shimamura, Ross, & Bennett, 2006). These results provide evidence that happy faces can instigate a possible reward effect which can be associated with the orbitofrontal cortex.

Implications in Posttraumatic Stress Disorder

The aforementioned imaging studies have revealed a number of brain structures that are involved in emotion and associative memory, especially the amygdala and hippocampus. It would thus be important to note that these two structures are also highly studied in posttraumatic stress disorder (PTSD) research, as they tend to exhibit abnormalities when compared to normal participants or even trauma-exposed normal controls (TENCs) (Shin & Handwerger, 2009). PTSD is a phenomenon that emerges as a result of exposure to past trauma, so it would naturally make sense that the brain structures most associated with memory and arousal (particularly intense arousal for the amygdala) would have some relation to this disorder. Research supports this idea, as PTSD patients have demonstrated exaggerated amygdala activation to fearful faces vs. happy faces, both in masked and unmasked paradigms (Rauch et al., 2000; Shin et al., 2005). Continued research concerning emotion and memory could provide insight into the neural circuitry and biological bases of PTSD, possibly leading to improved diagnosis, understanding, and treatment of the disorder.

The Current Study

While there has been much research devoted the behavioral and neurological effects of arousal, valence, and attractiveness on memory, as well as a multitude of studies exploring the bases of associative face-name memory, there has been surprisingly little investigation into the combination of these two topics. The goal of the current study was to elucidate the possible effects of emotion on face-name associative memory through three separate experiments. Participants viewed a total of 120 face-name pairs (40 fearful, 40 happy, 40 neutral). In the first experiment, paired faces and names were presented simultaneously and in an event-related design. In the second experiment with a new group of participants, faces and names were presented sequentially, with the name immediately following its associated face (retaining an event-related design). In the third experiment with a new group of participants, faces and names were presented sequentially (as in the second experiment), but stimuli were blocked by emotion. In all experiments, participants completed a recognition task 10 minutes after encoding, in which they indicated which of two presented names was originally paired with the displayed face. Based on the previous research of factors contributing to memory, we hypothesized that names associated with faces expressing an emotion (fearful and happy, i.e., low and high valence ratings) would be better remembered than names associated with neutral faces. We also expected higher arousal ratings to predict better subsequent associative memory. Significant behavioral findings would lead to a subsequent fMRI study to assess brain activation in response to emotional face-name pairs.

Experiment 1 – Faces and Names

Method

Participants

Participants consisted of 15 Tufts University students and community members (7 female). Recruitment was conducted via advertisements placed on http://www.tuftslife.com as well as through Sona Systems (http://tufts.sona-systems.com), which allows students enrolled in undergraduate psychology classes (e.g. PSY 1) to participate in university psychology studies as a way to fulfill required credit hours. Participants were compensated for the two-hour study session with $20 or 2 credit hours, depending on the manner of recruitment. Participants were excluded if they did not have normal or corrected to normal vision, were under the age of 18 or over the age of 30, had a neurological illness such as seizures or brain tumors, were currently taking psychoactive medications (antidepressants, anti-anxiety medications, narcotic pain medications, sleep medications, etc), or had a history of significant head injury or brain surgery. Prescreening to ensure qualification for participation occurred at time of recruitment. All participants provided written informed consent. The study was approved by the Tufts University Institutional Review Board.

Procedure

After participants gave written informed consent, they were seated in front of a Macintosh desktop computer and viewed two sets of face-name pairs (60 pairs per set, 120 in total) using the Macstim program. All images in the program were shown on a black background. The faces displayed an expression of fear, neutrality, or happiness. Each emotion accounted for 1/3 of the stimuli, and emotions were presented in pseudo-random order, with no more than three faces of the same expression in a row. Each face was matched with a proper name. The assigned name appeared directly below the picture of the face, and each pair was presented for approximately 3 seconds (see Figure 1). White fixation crosses were shown between face-name pairs in all paradigms for a variable amount of time (1-10s). The order of the runs was counter-balanced across participants for each paradigm.

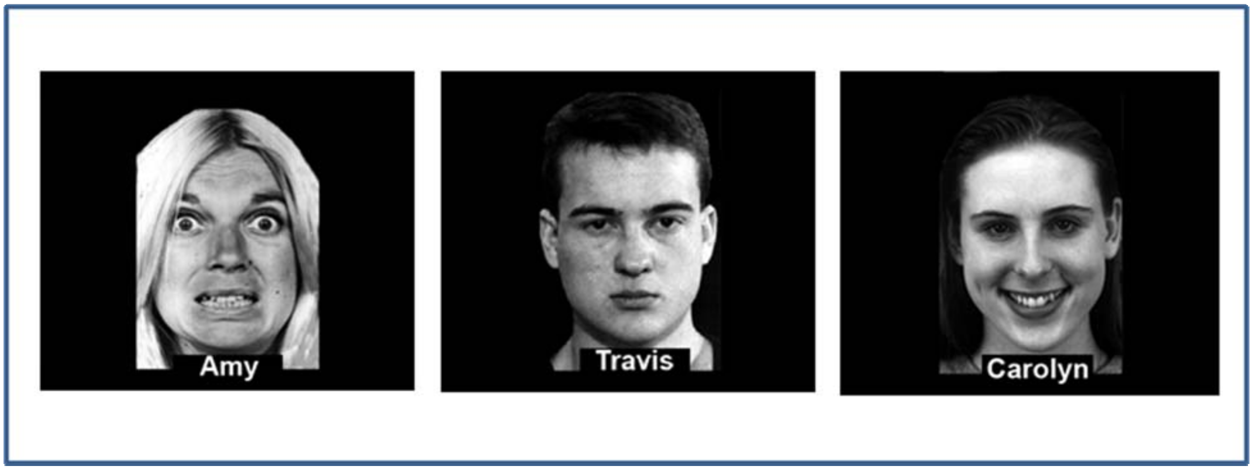

Figure 1: Examples of fearful, neutral, and happy stimuli from the first paradigm

After viewing the stimuli, participants were asked to complete four different questionnaires: the Beck Anxiety Inventory (BAI) (Beck & Steer, 1993), the Neuroticism-Extroversion-Openness-Five Factor Inventory (NEO-FFI) (Costa & McCrae, 1985), and the Spielberger State/Trait Anxiety Inventories (STAI-S and STAI-T) (Spielberger, Gorsuch, & Lushene, 1970). Participants could choose to omit any question they wished to omit. After completing the questionnaires, participants completed a memory task based on the previously viewed face-name pairs.

In the recognition test, participants were shown a face from the encoding stimuli with two names appearing below; one on the left and one on the right. Participants used two keyboard keys labeled “L” for left and “R” for right to indicate which of the two names they believed to have been originally paired with that face. They were asked to rate their confidence in their decision on a scale from 1, indicating a blind guess, to 3, indicating certainty, via labeled keys on the keyboard. This procedure was repeated for all 120 faces. After completion of the memory task, participants completed an on-paper assessment of all of the faces and rated each stimulus on valence (how positive or negative the emotion of the face was), arousal (how exciting or provocative the face was) and attractiveness (how visually appealing the face was). Participants were also asked to list any names that may have helped them remember the associated face due to personal significance (and, optionally, to list the reason of significance), as well as the number of hours of sleep they received the night before the experimental session. Participants were then debriefed, appropriately compensated based on their manner of recruitment, and had any questions answered.

Stimuli

The stimuli for the encoding task were 120 faces (40 fearful, 40 happy, and 40 neutral) gathered from seven different sets of facial expressions which were all released into the public domain for experimental use. Seven faces were used from the Ekman set (Ekman, 1976), 25 faces from the Cohn-Kanade database (Kanade, Cohn, & Tian, 2000), 23 faces from the Karolinska set (Lundqvist, Flykt, & Ohman, 1998), 26 faces from the Productive Aging Laboratory (Minear & Park, 2004), 9 faces from the NimStim set (Tottenham et al, 2009), 27 faces from the Psychological Image Collection at Stirling University (Hancock, 2000), and 3 from a Georgia Institute of Technology database (Nefian & Hayes, 1999). See Figure 2 for the breakdown of face stimuli based on their database of origin.

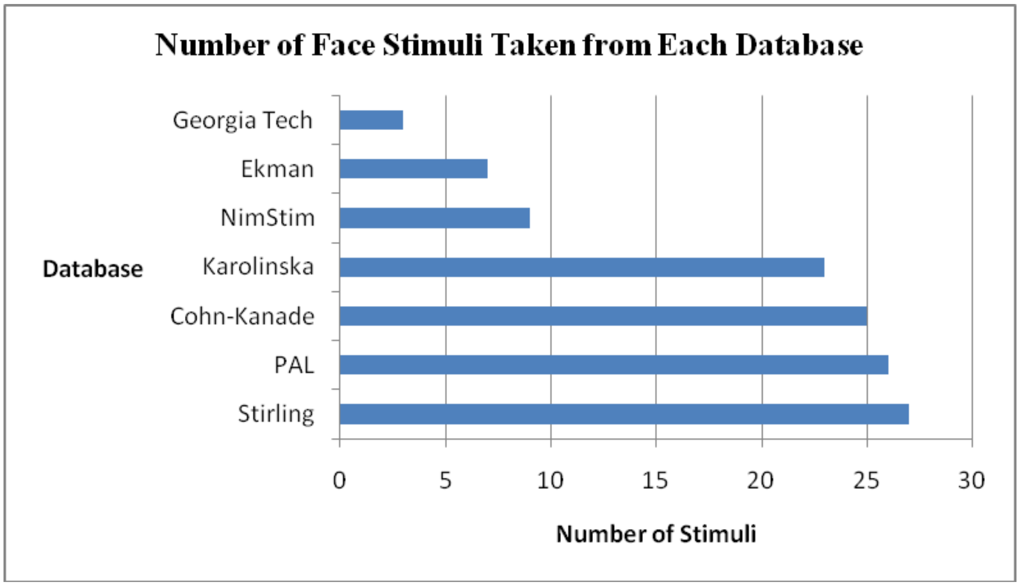

Figure 2: Face stimuli which were taken from each database.

Face stimuli were acquired from a previous study. The experimenter standardized all of the original images by converting them to grayscale and resizing them to a size of 410 (width/X) by 312 (height/Y) pixels. Each face was then lined up by aligning the glabella (bridge of nose) with the same coordinates, which prevented jittering as the participants viewed the faces. Black bars were placed on all sides of the face to frame each face. The assigned proper name was presented on the bottom black bar in Arial font.

Names were assigned based on their frequencies as stated by the Social Security Administration's records from 1980 to 1989 (Social Security Administration, 2008). Each of the two runs contained 60 faces, 30 of each gender, and 10 of each valence category (fearful, neutral, happy) per gender. Name frequency did not differ between valence categories, $F(2,117) = .345$, $p = .709$, or between runs, $F(1,118) = .196$, $p = .659$. Name frequency also did not differ between valence categories within each gender; female: $F(2,57) = .042$, $p = .959$, male: $F(2,57) =. 675$, $p = .513$. Faces were chosen based on valence, arousal, and attractiveness ratings gathered from healthy college-age participants from a previous study (on a Likert scale from 1-9, with 9 being the highest arousal/valence/attractiveness). Arousal ratings did not significantly differ between the fearful and happy faces, $t(78) = 1.399$, p =. 166. Fearful faces were rated significantly higher in arousal than neutral faces, $t(78) = 30.219$, $p < .001$ and happy faces were rated significantly higher than neutral faces, $t(78) = -35.084$, $p < .001$. Happy faces were also rated significantly more attractive than both fearful faces, t(78) = -9.60, p < .01, and neutral faces, t(78) = 77.612, p < .01. See Table 1 for the breakdown of face ratings by emotion. There were no significant differences between arousal, valence, and attractiveness between genders within each valence category, with the exception that female happy faces were rated as significantly more attractive than male happy faces t(38) = 3.386, p = .002. The stimuli in the encoding runs were counterbalanced, so that the average valance, arousal, and attractiveness ratings for each valence category in the first run did not significantly differ from the second run (see Table 2).

Category	**Average Rating**	**Standard Deviation**
Arousal Fearful	5.342	0.488
Arousal Neutral	2.813	0.204
Arousal Happy	5.205	0.380
Valence Fearful	3.107	0.231
Valence Neutral	4.440	0.236
Valence Happy	7.247	0.279
Attractiveness Fearful	3.664	0.759
Attractiveness Neutral	3.968	0.136
Attractiveness Happy	5.514	0.954
Overall Arousal	4.453	1.224
Overall Valence	4.932	1.750
Overall Attractiveness	4.382	1.180

Table 1: Breakdown of arousal, valence, and attractiveness ratings for each valence category.

Valence Category	Rating Measure	Set A Average	Set A S.D.	Set B Average	Set B S.D.
Fearful	Arousal	5.288	0.517	5.395	0.465
Fearful	Valence	3.130	0.271	3.085	0.187
Fearful	Attractiveness	3.694	0.814	3.633	0.718
Neutral	Arousal	2.810	0.217	2.815	0.196
Neutral	Valence	4.415	0.228	4.466	0.247
Neutral	Attractiveness	3.932	0.975	4.003	0.754
Happy	Arousal	5.157	0.342	5.252	0.418
Happy	Valence	7.230	0.234	7.264	0.324
Happy	Attractiveness	5.412	0.955	5.616	0.966

Table 2: Arousal, valence, and attractiveness ratings between stimulus sets.

During the recognition task, each of the previous faces was presented with two proper names below, one on the left and one on the right. The faces and names were the same size, shape, and font as during the encoding task. One of the two names was that which was originally paired with the face, and the other was a “foil” which was originally pared with a different face. The locations of the correct name were randomized, appearing on the left in half of the stimuli and right in the other half. See Figure 3 for examples of the recognition task stimuli. Half of the “foil” names came from the same run as the correct name, and half were from the other run. Furthermore, foils were counterbalanced by facial expressions (e.g. for fearful recognition stimuli, 1/3 of the foil names were originally paired with other fearful faces, 1/3 with neutral faces, and 1/3 with happy faces).

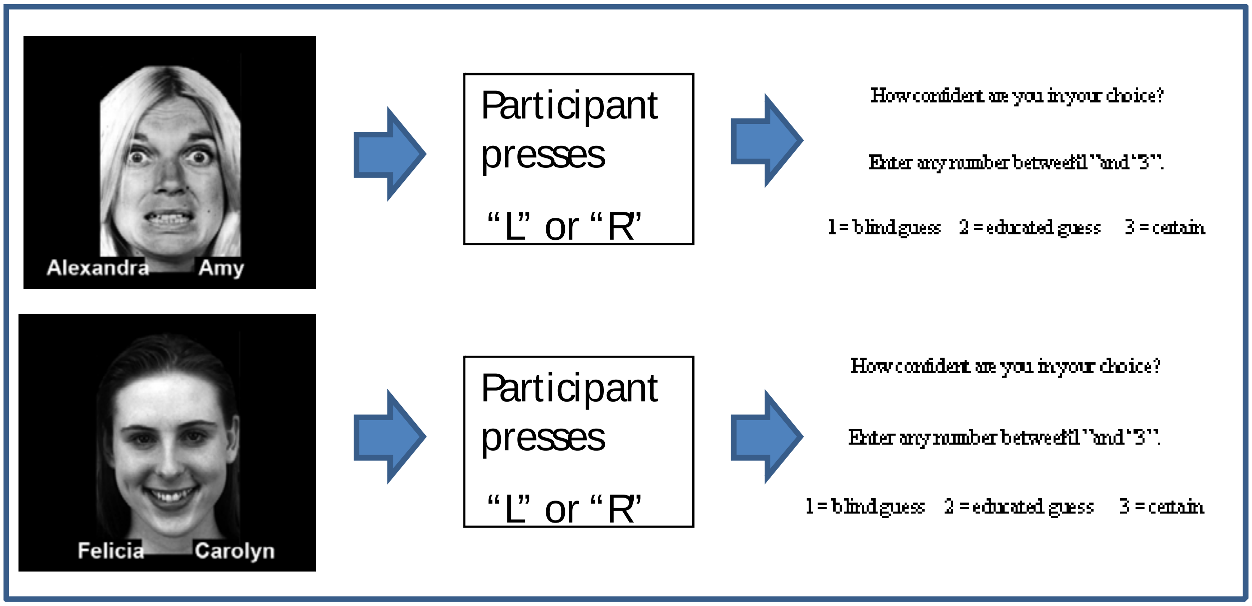

Figure 3: Examples of stimuli from the recognition task

The paper rating packet presented each face-name pair (.85” height by .97” width) with three Likert scales (range from 1-9) for valence, arousal, and attractiveness.

Results

Self-Report Scales

All participants completed the BAI, NEO-FFI, STAI-S, and STAI-T (except for one individual who did not complete the STAI-T). See Table 3 for mean scores and standard deviations for these questionnaires.

Measure	Score Mean +/- SD
BAI	10.0 +/- 7.1
STAI-S	38.53 +/- 11.1
STAI-T	37.29 +/- 9.2
NEO-FFI	
Neuroticism	29.93+/-10.3
Extroversion	40.93 +/- 7.4
Openness	32.33 +/- 2.4
Agreeableness	38.73 +/- 4.0
Conscientiousness	43.53 +/- 8.1

Table 3: Means and standard deviations for self-report scales for Experiment 1

Arousal Ratings

Following the memory task, all participants completed an assessment of the stimuli, rating each face on arousal, valence, and attractiveness. Table 4 displays the means and standard deviations for the arousal rating scores for each Facial Expression. A oneway ANOVA demonstrated a significant main effect of Facial Expression on arousal rating, $F(2,117) = 503.505$, $p < 0.001$. Post-hoc testing revealed that arousal ratings for fearful faces and happy faces were significantly higher than those for neutral faces (both $p < 0.001$), and that arousal ratings for fearful faces were significantly higher than those for happy faces ($p = 0.004$). This last observation is particularly noteworthy, as the stimuli were originally selected based on previous arousal, valence, and attractiveness ratings so that (among other criteria) arousal ratings specifically did not differ between happy and fearful faces.

Facial Expression	Arousal Rating (M +/- SD)
Fearful	5.97 +/- 0.6
Happy	5.60 +/- 0.5
Neutral	2.69 +/- 0.4

Table 4: Means and standard deviations for arousal ratings of each Facial Expression for Experiment 1 (Faces and Names)

Valence Ratings

The post-test assessment packet also collected valence ratings for each face. Refer to Table 5 for the means and standard deviations for the valence rating scores for each Facial Expression. A oneway ANOVA revealed a significant main effect of Facial Expression on valence rating, $F(2,117) = 1452.660$, $p < 0.001$. A post-hoc Tukey HSD test revealed that valence ratings for happy faces were significantly higher than those for both neutral and fearful faces, and that valence ratings for neutral faces were also significantly higher than those for fearful faces ($p < 0.001$ for all comparisons).

Facial Expression	Valence Rating (M +/- SD)
Fearful	2.76 +/- 0.4
Happy	7.23 +/- 0.4
Neutral	4.18 +/- 0.4

Table 5: Means and standard deviations for valence ratings of each Facial Expression for Experiment 1 (Faces and Names)

Attractiveness Ratings

The last measure on which participants rated the facial stimuli was attractiveness. Table 6 displays the means and standard deviations for the attractiveness rating scores for each Facial Expression. A oneway ANOVA revealed a significant main effect of Facial Expression on attractiveness rating $F(2,117) = 28.86$, $p < 0.001$. Using a post-hoc Tukey HSD test, it was found that attractiveness ratings for happy faces were significantly higher than both those for fearful faces ($p < 0.001$) and neutral faces ($p < 0.001$), and that attractiveness ratings for fearful faces did not significantly differ from those for neutral faces ($p = 0.356$).

Facial Expression	**Attractiveness Rating (M +/- SD)**
Fearful	3.67 +/- 0.7
Happy	5.03 +/- 0.9
Neutral	3.93 +/- 0.9

Table 6: Means and standard deviations for attractiveness ratings of each Facial Expression for Experiment 1 (Faces and Names)

Memory Effects

Participant memory for face-name pairs was above chance both across all stimuli, t(14) = 8.33, $p < 0.001$, and for each facial expression; Fearful: t(14) = 6.56, $p < 0.001$, Happy: t(14) = 7.14, $p < 0.001$, Neutral: t(14) = 7.17, $p < 0.001$. A repeated measures ANOVA was conducted to compare the number of successfully remembered faces-name pairs (“hits”) between the three valence categories: fearful, happy, and neutral. The test revealed a significant main effect of Facial Expression on memory, F(2,28) = 5.126, $p = 0.019$. Subsequent paired t-tests revealed significantly better memory for happy face-name pairs than for fearful face-name pairs, t(14) = 2.855, $p = 0.013$. Refer to Figure 4 for a graphical representation of this data.

Facial Expression	**Mean Hits**	**SD**
Fearful	24.93	2.9
Happy	27.80	4.2
Neutral	26.67	3.6

Table 7: Means and standard deviations for successively remembered face-name pairs (hits) for each Facial expression within Experiment 1 (Faces and Names)

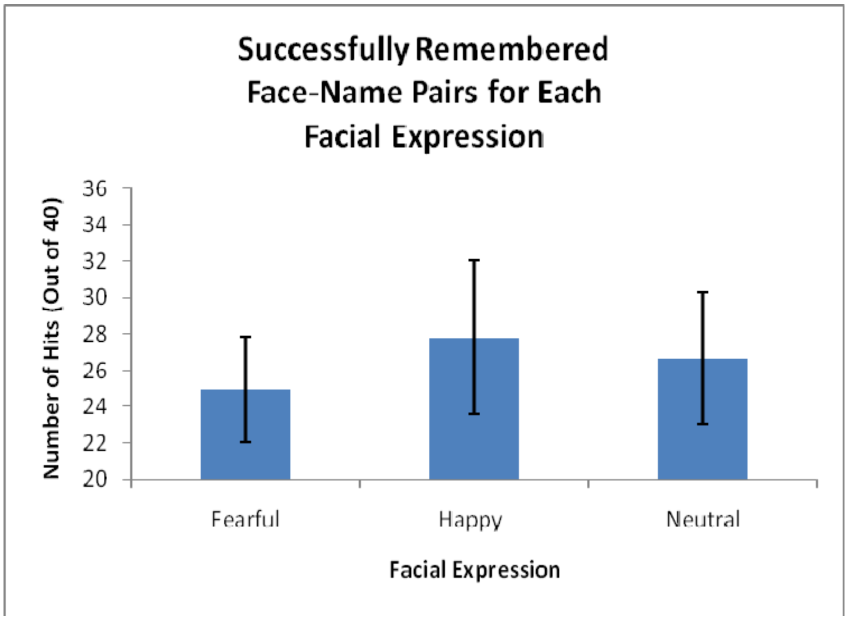

Figure 4: Average memory task performance for each Facial Expression in Experiment 1

High Arousal and Valence

We narrowed our analysis of the stimuli to the 20 most arousing fearful faces, the 20 most arousing happy faces, and the 20 least arousing neutral faces, in order to ascertain whether this greater disparity in arousal ratings could isolate a more pronounced effect of Facial Expression on memory. However, a repeated measures ANOVA found no significant main effect of Facial Expression on memory performance for these selected stimuli, $F(2,28) = 0.867$, $p = 0.429$. Conducting a similar analysis for valence, we narrowed the stimuli to the 20 lowest valence fearful faces, the 20 highest valence happy faces, and the 20 middle valence neutral faces. However, a repeated measures ANOVA found no significant main effects of Facial Expression on memory performance for these selected stimuli, $F(2,28) = 0.242$, $p = 0.748$.

Sex Differences

A 2 (Sex: male, female) by 3 (Facial Expression: fearful, happy, neutral) mixed models ANOVA was used to ascertain any possible effects of sex on memory performance. No significant interaction between participant Sex and Facial Expression was found, $F(2,26) = 0.717$, $p = 0.470$, as well as no significant main effect of Sex on memory performance, $F(1,13) = 0.002$, $p = 0.965$. Table 8 lists the means and standard deviations, separated by participant sex, for successfully remembered face-name pairs for each Facial Expression.

Facial Expression	**Mean Hits Male**	**SD Male**	**Mean Hits Female**	**SD Female**
Fearful	24.88	2.4	25.00	3.7
Happy	27.38	4.4	28.29	4.3
Neutral	27.25	3.5	26.00	3.9

Table 8: Means and standard deviations for successively remembered face-pair names (hits), separated by participant sex for each Facial Expression within Experiment 1

Correlations between Arousal/Valence/Attractiveness and Memory

In addition to testing the possible effects of Facial Expression on memory, we also sought to investigate potential correlations between arousal, valence, and attractiveness ratings on memory task performance. No significant correlations were found between these measures and number of face-name pairs remembered. Refer to Table 9 for a review of the correlation tests conducted

	Arousal Rating	**Valence Rating**	**Attractiveness Rating**
Total Hits	r = -0.057 p = 0.535	r = 0.150 p = 0.101	r = 0.013 p = 0.890
Fearful Hits	r = 0.071 p = 0.662	r = -0.068 p = 0.675	r = -0.163 p = 0.314
Happy Hits	r = 0.025 p = 0.879	r = 0.036 p = 0.828	r = -0.145 p = 0.371
Neutral Hits	r = -0.054 p = 0.739	r = -0.139 p = 0.394	r = 0.045 p = 0.784

Table 9: Summary of correlation tests between memory performance (overall and per valence category) and arousal, valence, and attractiveness ratings in Experiment 1

Confidence Effects

During the memory task, participants were asked to rate their confidence in their decision (1 = blind guess, 2 = educated guess, 3 = certain). We sought to examine possible effects of Facial Expression on high confidence memory accuracy. For these tests, an “HC hit” is defined as a successfully remembered face-name pairs for which the participant responded “certain” when asked of his/her confidence in their answer. A repeated measures ANOVA revealed a significant main effect of Facial Expression on HC hits, $F(2,28) = 7.570$, $p = 0.006$. Paired t-tests further revealed that there were significantly more HC hits for happy face-name pairs than fearful face-name pairs, $t(14) = 2.855$, $p = 0.013$, significantly more HC hits for neutral face-name pairs than fearful face-name pairs, $t(14) = 2.664$, $p = 0.019$, but no significant difference between HC hits between happy and neutral face-name pairs $t(14) = 1.129$, $p = 0.278$. See Figure 5 for a graphical representation of high confidence averages. A similar analysis was conducted for successfully remembered face-name pairs for which the participant responded “educated guess” (moderate confidence). However, we found no significant main effect of Facial Expression on “Educated Guess Hits”, $F(2,28) = 0.020$, $p = 0.976$.

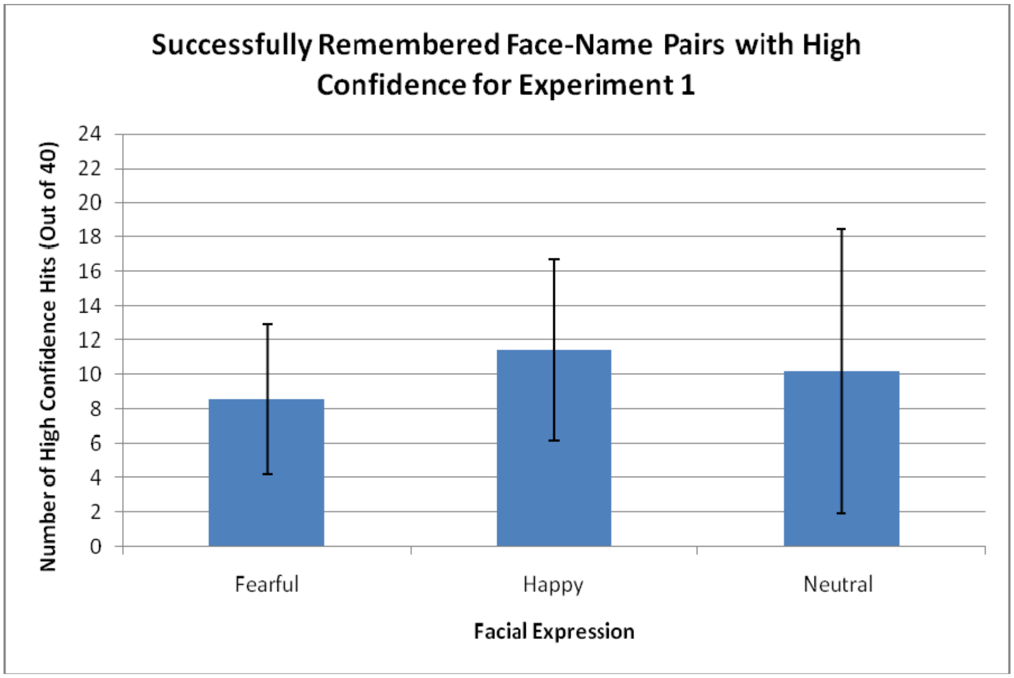

Figure 5: Average number of high confidence hits for each Facial Expression in Experiment 1

Miscellaneous Measures

Participants viewed 120 face-name pairs over the course of the study, and many commented on the high number of stimuli and/or the daunting task of remembering as many pairs as possible. To help test for possible effects of participant fatigue or loss of attention, we focused our analysis to memory of the first 60 stimuli presented during encoding. However, a repeated-measures ANOVA revealed no significant main effect of Facial Expression on memory performance when considering only these stimuli, $F(2,28) = 2.337$, $p = 0.115$.

We also focused our analysis to memory for the first 10 and last 10 stimuli of each facial expression presented during encoding to ascertain any influence of primacy-recency order effects. However, we also found no significant main effect of Facial Expression on memory for these stimuli, $F(2,28) = 1.216$, $p = 0.311$.

In order to test for possible effects of anxiety level (based on the BAI) on memory performance, we performed a median split of BAI scores, labeling all participants matching the median score and below as “low” anxiety and those above as “high” anxiety. A 3 (Facial Expression: fearful, happy, neutral) by 2 (Anxiety Group: low, high) mixed model ANOVA found no interaction between Facial Expression and Anxiety Group, $F(2,26) = 1.703$, $p = 0.207$, as well as no significant main effect of Anxiety Group on memory performance, $F(1,13) = 0.366$, $p = 0.555$.

To ascertain any possible effects of sleep deprivation on general memory performance, participants were also asked to provide the approximate number of hours of sleep they had received the night before the study. However, no significant correlation was found between the number of hours of sleep and total face-name pairs remembered, $r(13) = 0.352$, $p = 0.198$.

Discussion

The results of this study did not support our hypothesis. Names associated with emotional faces (fearful and happy) were not better remembered than names associated with neutral faces. Names associated with happy faces, however, were significantly better remembered than names paired with fearful faces. Despite this improved memory for happy face-name pairs compared to fearful face-name pairs, we were surprisingly unable to find significant associations between either valence or arousal and memory.

Failure to support the a priori hypothesis should not be attributed to participants’ inability to correctly identify the intended Facial Expression of each stimulus, as happy faces were rated as having significantly higher valence than neutral faces, which were in turn rated as having higher valence than fearful faces. As expected, positive and fearful faces were rated as more arousing than neutral faces. However, fearful faces were rated as more arousing than happy faces. This finding is of particular interest, as face stimuli were specifically selected based on participant valence and arousal ratings from a previous iteration of this study so that happy and fearful faces did not differ in original arousal ratings. Perhaps, since participants rated all of the stimuli together at the end of the study, their individual ratings were based on comparisons to the other faces. If participants generally considered fearful faces to be more arousing than happy faces, it may have led them to rate the faces based on this preconceived notion.

The stimuli used in our study were quite complex, as they involved faces displaying a range of expressions, as well as simultaneous presentations of names which were expected to be associated to a particular face. It seems possible that these multiple pieces of information in such a short period may have been overwhelming, or that certain aspects, such as very arousing or distinct facial expressions, may have drawn focus away from other parts of the stimuli. Pessoa et al. (2002) observed that enhanced amygdala activation for positive and negative faces occurred only in an attended condition and not during the unattended condition, which involved redirected attention to stimuli that were placed on the periphery of the displayed face. The names displayed in our study were probably less distracting than the geometric images used by Pessoa, as the names at least had a contextual relevance to the faces; however there is still the chance that viewing either the name or face may have decreased attention from the other.

Experiment 2 sought to address the possible issues of distraction and sensory/stimuli overload by separating the presentation of faces and names, so that each name was displayed immediately after its paired face.

Experiment 2 – Face then Name

Method

Participants

Participants consisted of 15 Tufts University students and community members (10 female). Recruitment method was identical to that of Experiment 1.

Procedure

The general procedures and stimuli were identical to those of Experiment 1. However, the faces and names were presented separately (approximately 1.5 seconds for each), with the presentation of each name immediately following the presentation of its corresponding face (see Figure 6). The assigned proper name was centered on a blank screen at the level of the eyes of the previous presented face (205 pixels (width/X) and 150 pixels (height/Y). As in the previous experiment, stimuli from the different valence categories were intermixed and presented in a pseudorandom order, so that no more than three faces of the same valence were shown in a row.

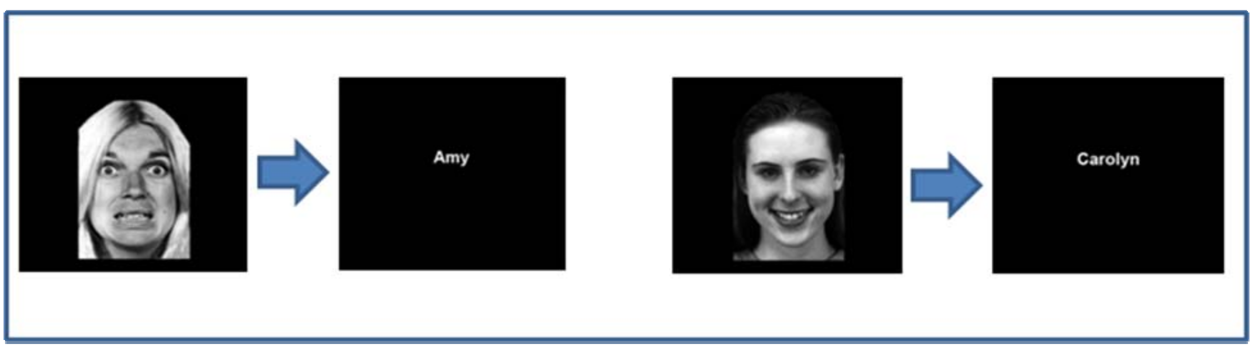

Figure 6: Examples of face-then-name stimuli from the second paradigm

Results

Self-Report Scales

All participants completed the BAI, NEO-FFI, STAI-S, and STAI-T. Refer to Table 10 for mean scores and standard deviations for these questionnaires.

Measure	Score Mean +/- SD
BAI	8.33 +/- 5.9
STAI-S	35.73 +/- 6.7
STAI-T	41.33 +/- 8.9
NEO-FFI	
Neuroticism	32.60 +/- 7.9
Extroversion	41.47 +/- 8.6
Openness	33.20 +/- 3.7
Agreeableness	40.13 +/- 5.2
Conscientiousness	41.47 +/- 9.8

Table 10: Means and standard deviations for self-report scales for Experiment 2

Arousal Ratings

Table 11 displays the means and standard deviations for the arousal rating scores for each Facial Expression. A oneway ANOVA demonstrated a significant main effect of Facial Expression on arousal rating, $F(2,117) = 389.051$, $p < 0.001$. Post-hoc testing revealed that arousal ratings for fearful faces and happy faces were significantly higher than those for neutral faces (for both: $p < 0.001$), and that arousal ratings for fearful faces displayed a trend towards significance as higher than those for happy faces ($p = 0.054$).

Facial Expression	Arousal Rating (M +/- SD)
Fearful	5.41 +/- 0.6
Happy	5.13 +/- 0.6
Neutral	2.38 +/- 0.4

Table 11: Means and standard deviations for arousal ratings of each Facial Expression for Experiment 2 (Face the Name)

Valence Ratings

Refer to Table 12 for the means and standard deviations for the valence rating scores for each Facial Expression. A oneway ANOVA showed a significant main effect of Facial Expression on valence rating, Face then Name: $F(2,117) = 1122.548$. A post-hoc Tukey HSD test revealed that valence ratings for happy faces were significantly higher than those for both neutral and fearful faces, and that valence ratings for neutral faces were also significantly higher than those for fearful faces ($p < 0.001$ for all comparisons).

Facial Expression	Valence Rating (M +/- SD)
Fearful	3.16 +/- 0.3
Happy	6.79 +/- 0.4
Neutral	4.53 +/- 0.3

Table 12: Means and standard deviations for valence ratings of each Facial Expression for Experiment 2 (Face then Name)

Attractiveness Ratings

Table 13 displays the means and standard deviations for the attractiveness rating scores for each Facial Expression. A oneway ANOVA revealed a significant main effect of Facial Expression on attractiveness rating $F(2,117) = 36.38$, $p < 0.001$. Using a post-hoc Tukey HSD test, it was found that attractiveness ratings for happy faces were significantly higher than both those for fearful faces ($p < 0.001$) and neutral faces ($p < 0.001$), and that attractiveness ratings for fearful faces did not significantly differ from those for neutral faces ($p = 0.293$).

Facial Expression	**Attractiveness Rating (M +/- SD)**
Fearful	3.44 +/- 0.8
Happy	5.18 +/- 1.1
Neutral	3.77 +/- 0.9

Table 13: Means and standard deviations for attractiveness ratings of each Facial Expression for Experiment 2 (Face then Name)

Memory Effects

Participant memory for face-name pairs was above chance both across all stimuli, t(14) = 5.91, $p < 0.001$, and for each facial expression; Fearful: t(14) = 6.23, $p < 0.001$, Happy: t(14) = 4.76, $p < 0.001$, Neutral: t(14) = 4.97, $p < 0.001$. Contrary to the findings from the previous experiment, a repeated measures ANOVA revealed no significant main effect of Facial Expression on memory for the Face then Name paradigm, F(2,28) = 0.064, $p = 0.892$. Refer to Figure 7 for a graphical representation of this data.

Facial Expression	**Mean Hits**	**SD**
Fearful	26.07	3.8
Happy	26.40	5.2
Neutral	26.13	4.8

Table 14: Means and standard deviations for successively remembered face-name pairs (hits) for each Facial Expression within Experiment 2 (Face then Name)

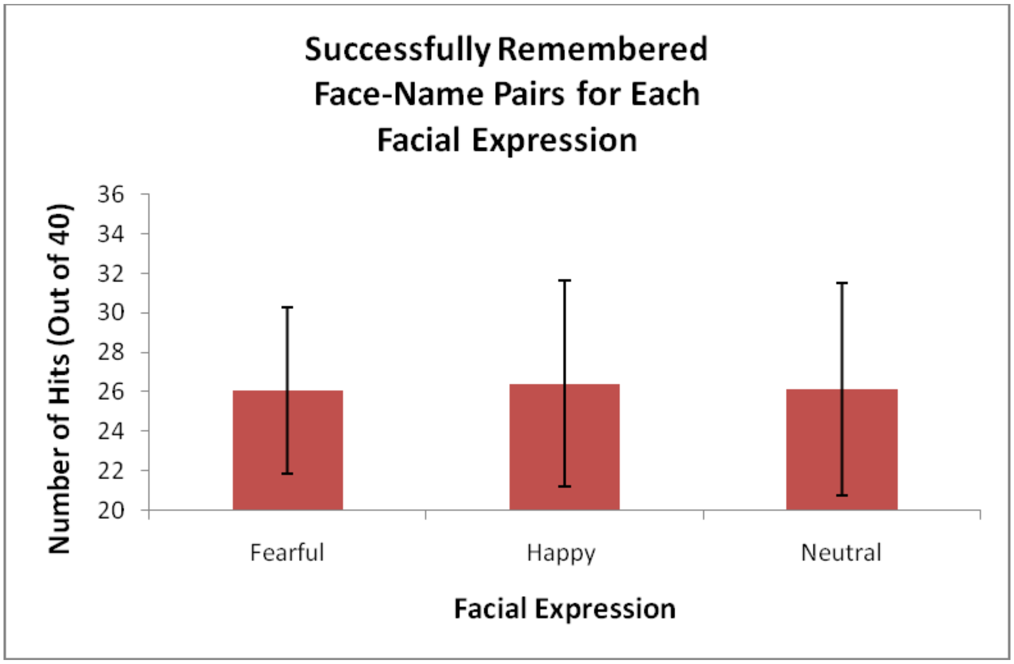

Figure 7: Average memory task performance for each Facial Expression in Experiment 2

High Arousal and Valence

As in Experiment 1, the 20 most arousing fearful faces, the 20 most arousing happy faces, and the 20 least arousing neutral faces were isolated for further analysis. A repeated measures ANOVA found no significant main effect of Facial Expression on memory performance for these selected stimuli, $F(2,28) = 0.918$, $p = 0.408$. When analyzing the 20 lowest valence fearful faces, the 20 highest valence happy faces, and the 20 middle valence neutral faces, a repeated measures ANOVA found no significant main effects of Facial Expression on memory performance for these selected stimuli, $F(2,28) = 1.677$, $p = 0.207$.

Sex Differences

A 2 (Sex: male, female) by 3 (Facial Expression: fearful, happy, neutral) mixed models ANOVA was used to ascertain any possible effects of participant sex on memory performance. No significant interaction between participant Sex and Facial Expression was found, $F(2,26) = 0.119$, $p = 0.831$, as well as no main effect of Sex on memory performance, $F(1,13) = 0.017$, $p =$

0.899. Table 15 lists the means and standard deviations, separated by participant sex, for successfully remembered face-name pairs for each Facial Expression.

Facial Expression	**Mean Hits Male**	**SD Male**	**Mean Hits Female**	**SD Female**
Fearful	26.00	2.0	26.10	4.5
Happy	27.00	5.0	26.10	5.5
Neutral	26.20	4.7	26.10	5.1

Table 15: Means and standard deviations for successively remembered face-pair names (hits), separated by participant sex for each Facial Expression within Experiment 2

Correlations between Arousal/Valence/Attractiveness and Memory

No significant correlations were found between arousal, valence, and attractiveness ratings on memory task performance. Refer to Table 16 for a review of the correlation tests conducted.

	Arousal Rating	**Valence Rating**	**Attractiveness Rating**
Total Hits	r = -0.041 p = 0.658	r = 0.140 p = 0.126	r = -0.040 p = 0.667
Fearful Hits	r = 0.107 p = 0.510	r = -0.227 p = 0.159	r = -0.277 p = 0.083
Happy Hits	r = 0.097 p = 0.554	r = 0.093 p = 0.569	r = -0.197 p = 0.223
Neutral Hits	r = -0.091 p = 0.575	r = -0.100 p = 0.538	r = -0.013 p = 0.938

Table 16: Summary of correlation tests between memory performance (overall and per valence category) and arousal, valence, and attractiveness in Experiment 2

Confidence Effects

We found no significant main effect of Facial Expression on High Confidence Hits, $F(2,28) = 2.571$, $p = 0.104$ (See Figure 8). We also found no significant main effect of Facial Expression on Educated Guess Hits, $F(2,28) = 0.246$, $p = 0.710$.

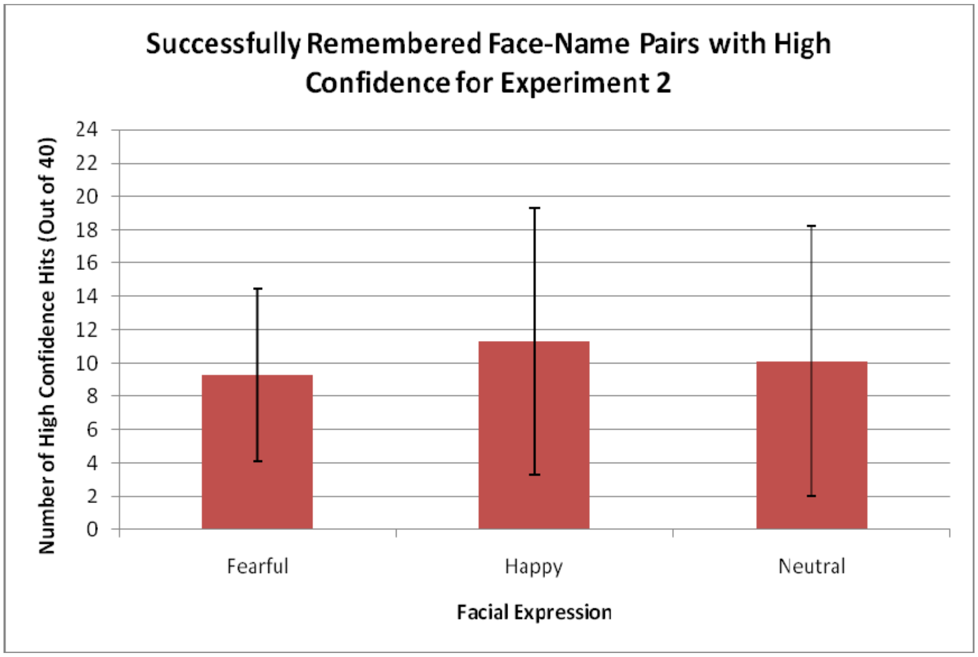

Figure 8: Average number of high confidence hits for each Facial Expression in Experiment 2

Miscellaneous Measures

A repeated measures ANOVA found no significant main effect of Facial Expression on memory for the first half of stimuli presented during encoding, F(2,28) = 0.105, p = 0.896. There was also no significant main effect of Facial Expression on memory for the first and last 10 stimuli presented during encoding from each facial expression, F(2,28) = 0.159, p = 0.827.

A 3 (Facial Expression: fearful, happy, neutral) by 2 (Anxiety Group: low, high) mixed model ANOVA found a significant interaction between Facial Expression and Anxiety Group, F(2,26) = 5.169, p = 0.023, but no significant main effect of Anxiety Group on memory performance, F(1,13) = 0.008, p = 0.930. Paired t-tests revealed that high anxiety participants tended to remember significantly more happy face-name pairs than neutral face-name pairs, t(7) = 2.043, p = 0.08, and that low anxiety participants remembered significantly more neutral face-name pairs than fearful face-name pairs, t(6) = 4.768, p = 0.003.

No significant correlation was found between the number of hours of sleep and total face-name pairs remembered $r(13) = -0.068$, $p = 0.809$.

Discussion

The results of Experiment 2 also did not support our hypothesis. Names associated with emotional faces (fearful and happy) were not better remembered than names associated with neutral faces. Unlike in Experiment 1, no significant effect of Facial Expression on memory was found at all. Again, failure to support the a priori hypothesis should not be attributed to participants' inability to correctly identify the intended Facial Expression of each stimulus, as valence and arousal rating patterns generally followed expected trends, as seen in Experiment 1, however there was no significant difference in arousal ratings between fearful and happy faces (albeit a trend was observed for fearful arousal > happy arousal).

Unfortunately, the results from this experiment did little to explain or justify the perplexing findings from the previous paradigm, calling for further experimentation with procedural design. For Experiment 3, we decided to implement a blocked paradigm, presenting alternating blocks, each consisting of stimuli featuring the same expression. One reason for this was that Davis et al (submitted) found significant effects of facial expression on memory for neutral words presented in context with fearful stimuli (the names used in our study can generally be considered neutral). Also, certain blocked paradigms, such as those used in emotional Stroop studies, have shown greater effects of emotion than mixed or event-related designs (Phaf & Kan, 2007). Anderson and colleagues (2006) found that highly arousing images can also enhance memory for unrelated neutral images presented immediately before. This could be problematic in our study, as neutral face-name pairs were presented alongside emotional face-name pairs; a blocked paradigm in the next experiment could therefore better isolate any effects of emotion to just the emotional stimuli. Another reason for the implementation of a blocked design was in consideration of possible subsequent studies that would involve neuroimaging techniques. When using blocked stimuli in fMRI, the entire block is averaged and analyzed as a whole. In event-related paradigms, the BOLD response to each individual stimulus can be measured, allowing the ability to subtract out mistakes on a memory task. However, the BOLD signal changes for individual stimuli are less than that for an entire block, and stimuli may be presented faster than the time it takes to reach peak BOLD signal levels.

Experiment 3 – Blocked

Methods

Participants

Participants consisted of 15 Tufts University students and community members (13 female). Recruitment method was identical to that of the previous two experiments.

Procedure

The general procedures and stimuli were identical to those of Experiment 2. While this paradigm retained the “face-then-name” presentation of the second experiment, face-name pairs were now blocked by emotion within each set (as opposed to the event-related presentation in the first two paradigms; see Figure 9). Faces and names were presented for approximately 1.5 seconds each.

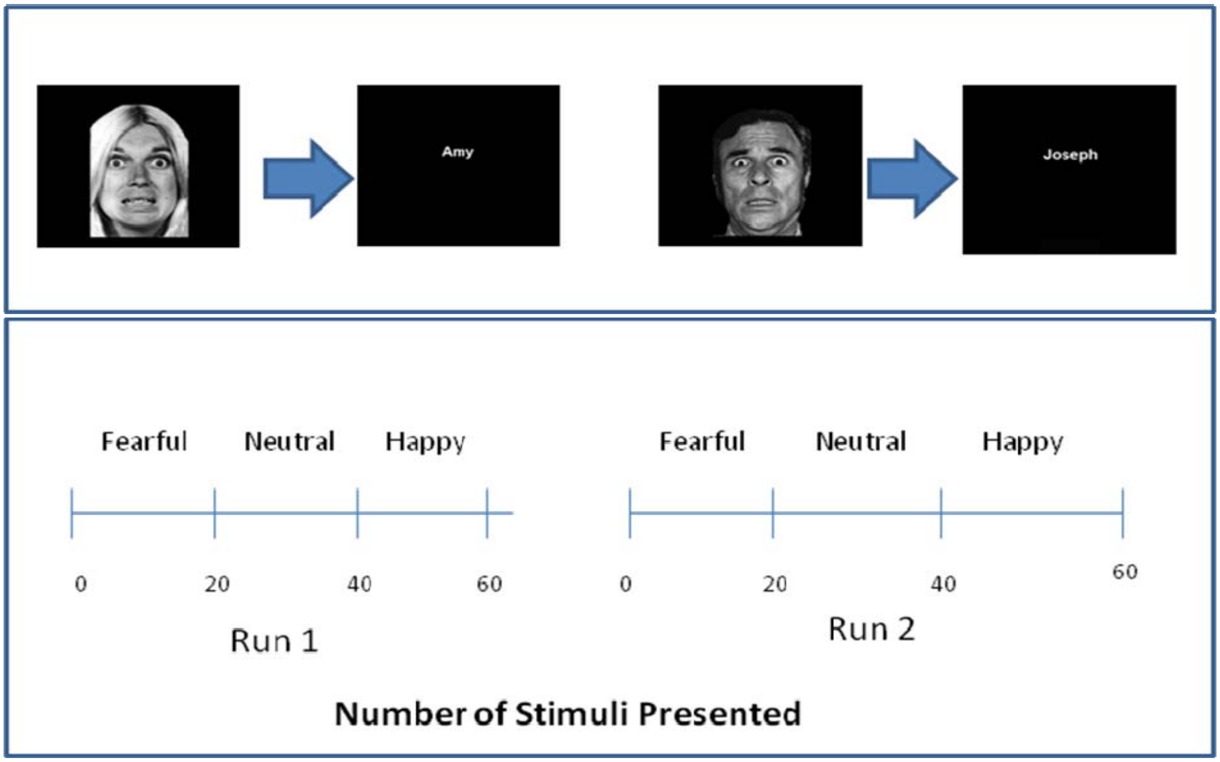

Figure 9: Examples of face-then-name stimuli and structure of third paradigm. Each block contained 20 stimuli from one of the three valence categories. Each of the two runs contained three blocks, one from each valence category.

Results

Self-Report Scales

All participants completed the BAI, NEO-FFI, STAI-S, and STAI-T. Refer to Table 17 for mean scores and standard deviations for these questionnaires.

Measure	Score Mean +/- SD
BAI	7.93 +/- 6.3
STAI-S	36.93 +/- 6.7
STAI-T	40.47 +/- 8.8
NEO-FFI	
Neuroticism	33.60 +/- 5.6
Extroversion	41.27 +/- 6.6
Openness	33.53 +/- 3.5
Agreeableness	39.33 +/- 4.6
Conscientiousness	45.27 +/- 6.4

Table 17: Means and standard deviations for self-report scales for Experiment 3

Arousal Ratings

Table 18 displays the means and standard deviations for the arousal rating scores for each Facial Expression. A oneway ANOVA demonstrated a significant main effect of Facial Expression on arousal ratings, $F(2,117) = 368.857$, $p < 0.001$. Post-hoc testing revealed that arousal ratings for fearful faces and happy faces were significantly higher than those for neutral faces (for both: $p < 0.001$), but that arousal ratings for fearful faces did not significantly differ from those for happy faces ($p = 0.419$).

Facial Expression	**Arousal Rating (M +/- SD)**
Fearful	6.11 +/- 0.6
Happy	5.96 +/- 0.6
Neutral	3.24 +/- 0.4

Table 18: Means and standard deviations for arousal ratings of each Facial Expression for Experiment 3 (Blocked)

Valence Ratings

Refer to Table 19 for the means and standard deviations for the valence rating scores for each Facial Expression. A oneway ANOVA showed a significant main effect of Facial Expression on valence rating, $F(2,117) = 929.627$, $p < 0.001$. A post-hoc Tukey HSD test revealed that valence ratings for happy faces were significantly higher than those for both neutral and fearful faces, and that valence ratings for neutral faces were also significantly higher than those for fearful faces ($p < 0.001$ for all comparisons).

Facial Expression	**Valence Rating (M +/- SD)**
Fearful	3.17 +/- 0.3
Happy	7.14 +/- 0.4
Neutral	4.54 +/- 0.5

Table 19: Means and standard deviations for valence ratings of each Facial Expression for Experiment 3 (Blocked)

Attractiveness Ratings

Table 20 displays the means and standard deviations for the attractiveness rating scores for each Facial Expression. A oneway ANOVA revealed a significant main effect of Facial Expression on attractiveness rating $F(2,117) = 26.36$, $p < 0.001$. Using a post-hoc Tukey HSD test, it was found that attractiveness ratings for happy faces were significantly higher than both those for fearful faces ($p < 0.001$) and neutral faces ($p < 0.001$), and that attractiveness ratings for fearful faces did not significantly differ from those for neutral faces ($p = 0.630$).

Facial Expression	**Attractiveness Rating (M +/- SD)**
Fearful	3.70 +/- 0.9
Happy	5.27 +/- 1.2
Neutral	3.92 +/- 1.0

Table 20: Means and standard deviations for attractiveness ratings of each Facial Expression for Experiment 3 (Blocked)

Memory Effects

Participant memory for face-name pairs was above chance both across all stimuli, t(14) = 7.11, $p < 0.001$, and for each facial expression; Fearful: t(14) = 5.00, $p < 0.001$, Happy: t(14) = 6.67, $p < 0.001$, Neutral: t(14) = 8.23, $p < 0.001$. A repeated measures ANOVA revealed no significant main effect of Facial Expression on memory for the Blocked Paradigm, F(2,28) = 1.620, $p = 0.221$. Refer to Figure 10 for a graphical representation of this data.

Facial Expression	Mean Hits	SD
Fearful	27.87	6.1
Happy	29.27	5.4
Neutral	29.60	4.5

Table 21: Means and standard deviations for successively remembered face-name pairs (hits) for each Facial Expression within Experiment 3 (Blocked)

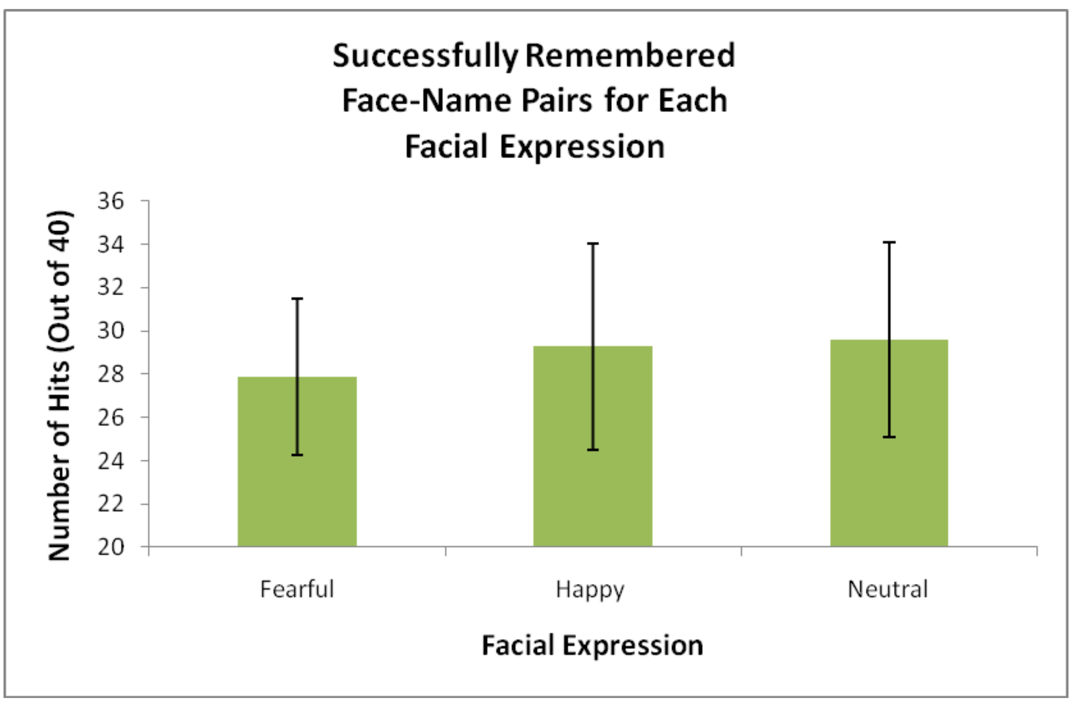

Figure 10: Average memory task performance for each Facial Expression in Experiment 3

High Arousal and Valence

As in Experiment 1 and 2, the 20 most arousing fearful faces, the 20 most arousing happy faces, and the 20 least arousing neutral faces were isolated for further analysis. A repeated measures ANOVA found no significant main effect of Facial Expression on memory performance for these selected stimuli, $F(2,28) = 0.318$, $p = 0.702$. When analyzing the 20 lowest valence fearful faces, the 20 highest valence happy faces, and the 20 middle valence neutral faces, a repeated measures ANOVA found no significant main effects of Facial Expression on memory performance for these selected stimuli, $F(2,28) = 1.317$, $p = 0.283$.

Sex Differences

A 2 (Sex: male, female) by 3 (Facial Expression: fearful, happy, neutral) mixed models ANOVA was used to ascertain any possible effects of participant sex on memory performance within each experiment. No significant interaction between participant Sex and Facial Expression was found, $F(2,26) = 0.091$, $p = 0.874$, as well as no significant main effect of participant Sex on memory performance, $F(1,13) = 0.076$, $p = 0.787$. Table 22 lists the means and standard deviations, separated by participant sex, for successfully remembered face-name pairs for each Facial Expression.

Facial Expression	**Mean Hits Male**	**SD Male**	**Mean Hits Female**	**SD Female**
Fearful	26.50	2.1	28.08	6.5
Happy	29.00	4.2	29.31	5.7
Neutral	28.50	6.4	29.77	4.5

Table 22: Means and standard deviations for successively remembered face-pair names (hits), separated by participant sex for each Facial Expression within Experiment 3

Correlations between Arousal/Valence/Attractiveness and Memory

No significant correlations were found between arousal, valence, and attractiveness ratings on memory task performance. Refer to Table 23 for a review of the correlation tests conducted.

	Arousal Rating	**Valence Rating**	**Attractiveness Rating**
Total Hits	r = -0.040 p = 0.666	r = 0.128 p = 0.163	r = -0.076 p = 0.411
Fearful Hits	r = -0.013 p = 0.937	r = -0.015 p = 0.926	r = -0.228 p = 0.071
Happy Hits	r = 0.087 p = 0.593	r = -0.167 p = 0.303	r = -0.301 p = 0.059
Neutral Hits	r = 0.053 p = 0.746	r = -0.100 p = 0.539	r = 0.079 p = 0.629

Table 23: Summary of correlation tests between memory performance (overall and per valence category) and arousal, valence, and attractiveness in Experiment 3

Confidence Effects

There was no significant main effect of Facial Expression on High Confidence Hits, $F(2,28) = 3.063$, $p = 0.069$ (See Figure 11). We also found no significant main effect of Facial Expression on Educated Guess Hits, $F(2,28) = 0.129$, $p = 0.850$.

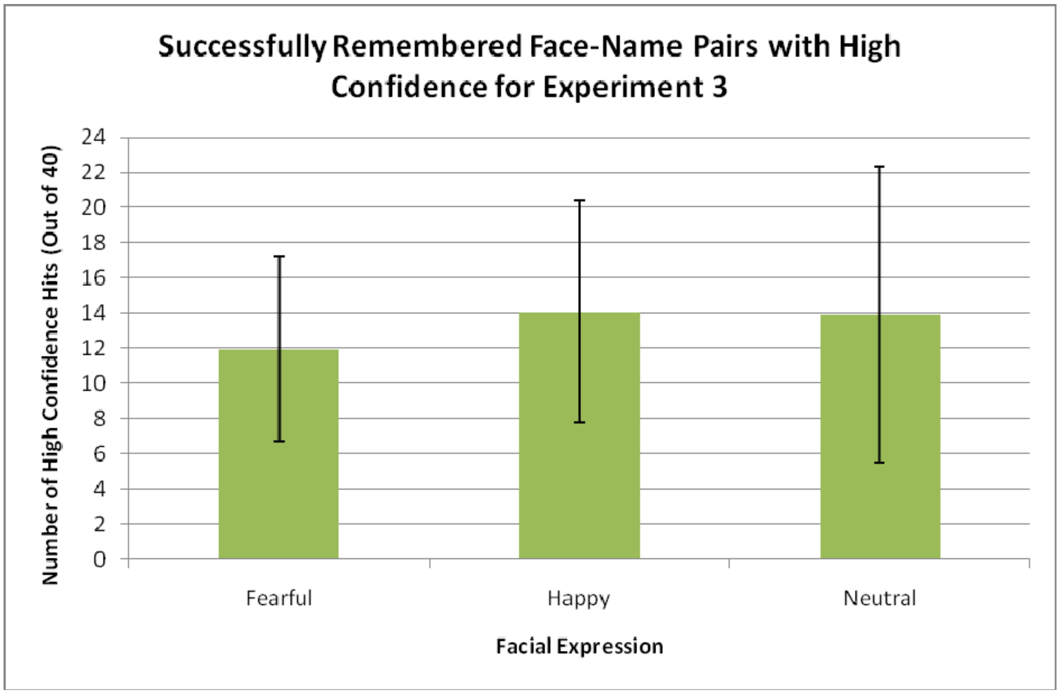

Figure 11: Average number of high confidence hits for each Facial Expression in Experiment 3

Miscellaneous Measures

A repeated measures ANOVA found no significant main effect of Facial Expression on memory for the first half of stimuli presented during encoding, F(2,28) = 0.969, *p* = 0.372. Due to the blocked nature of this paradigm, primacy-recency analyses were not applicable.

A 3 (Facial Expression: fearful, happy, neutral) by 2 (Anxiety Group: low, high) mixed model ANOVA found no significant interaction between Facial Expression and Anxiety Group, F(2,26) = 2.201, *p* = 0.145, as well as no significant main effect of Anxiety Group on memory performance, F(1,13) = 1.267, *p* = 0.281.

No significant correlation was found between the number of hours of sleep and total face-name pairs remembered, r(13) = -0.227, *p* = 415.

Discussion

The results of Experiment 3 also did not support our hypothesis. Names associated with emotional faces (fearful and happy) were not better remembered than names associated with neutral faces when the trials were blocked on emotional facial expression. As with the previous two paradigms, failure to support the a priori hypothesis is most likely not attributable to participants' failure to identify the intended Facial Expression of each stimulus, as valence and arousal rating patterns were comparable to those from the previous paradigms (there was no significant difference in arousal ratings between fearful and happy faces).

Comparison between Experiments

Refer to Figure 12 for a summary of the overall memory performance results. Due to the differences in memory task performance, we wanted to determine whether arousal, valence, and attractiveness ratings varied between experiments. Specifically, we wanted to assess whether these ratings from the Faces and Names task (Experiment 1), in which a significant effect of Facial Expression on memory was found, differed from the other two paradigms, in which no such effect was found.

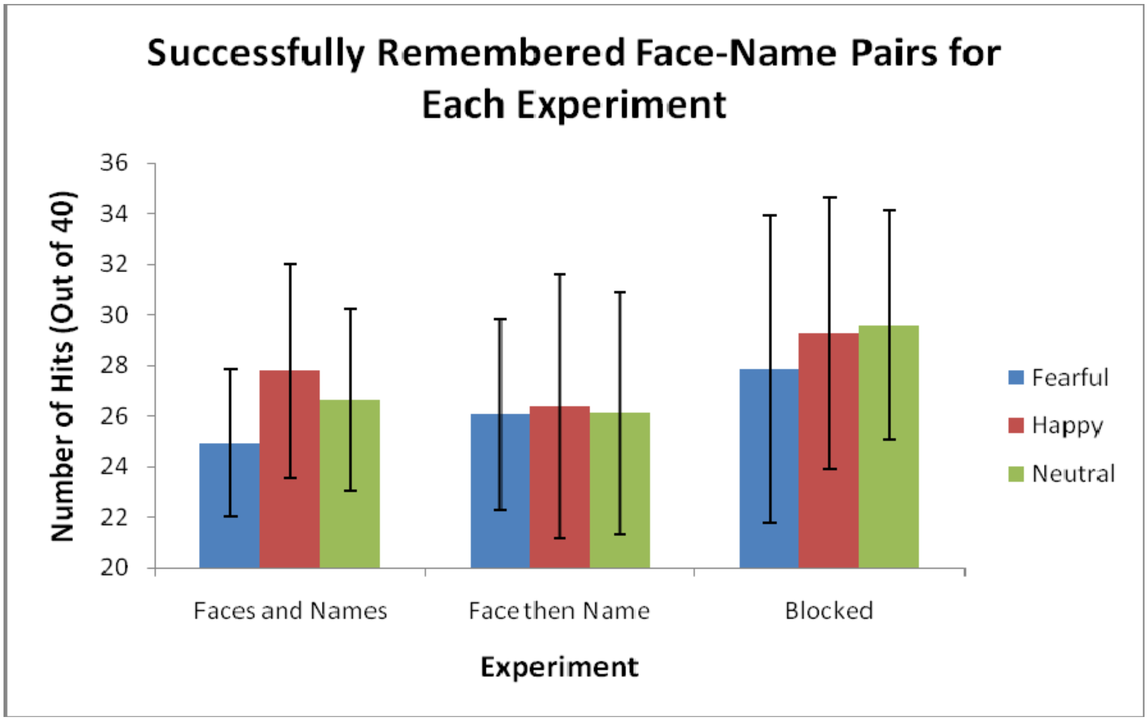

Figure 12: Average memory task performance for each Facial Expression per experiment.

Paradigm Differences in Arousal Ratings

Arousal ratings for fearful faces in Experiment 1 (Faces and Names) were significantly higher than in Experiment 2 (Face then Name), t(78) = 3.950, $p < 0.01$, but were not significantly different from Experiment 3 (Blocked), t(78) = 1.072, $p = 0.287$. Arousal ratings for happy faces in Experiment 1 were significantly higher than in Experiment 2, t(78) = 3.992, $p < 0.01$, but were significantly lower than for Experiment 3, t(78) = 2.966, $p = 0.004$. Arousal ratings for neutral faces in Experiment 1 were significantly higher than those in Experiment 2, t(78) = 3.667, $p < 0.01$, and significantly lower than those in Experiment 3, t(78) = 6.141, $p < 0.01$. Based on these findings, subjective arousal does not seem to explain the differences in memory task performance between the three experiments.

Paradigm Differences in Valence Ratings

Valences ratings for fearful faces in Experiment 1 were significantly lower than those in both Experiment 2, t(78) = 5.182, $p < 0.01$, and Experiment 3, t(78) = 5.269, $p < 0.01$. Valence ratings for happy faces in Experiment 1 were significantly higher than those in Experiment 2, t(78) = 5.476, $p < 0.01$, but were not significantly different from those in Experiment 3, t(78) = 1.043, $p = 0.300$. Valence ratings for neutral faces from the Experiment 1 stimuli were significantly lower than both those from Experiment 2, t(78) = 4.215, $p < 0.01$, and Experiment 3, t(78)=3.617, $p < 0.01$. Based on these findings, subjective valence ratings do not seem to explain the differences in memory task performance between the three experiments.

Paradigm Differences in Attractiveness Ratings

Differences for attractiveness ratings demonstrated far less variability between paradigms than arousal or valence. There were no significant differences in attractive ratings for fearful faces from Experiment 1 and those from either Experiment 2, t(78) = 1.351, $p = 0.181$, or Experiment 3, t(78) = 0.175, $p = 0.862$. Likewise, there were no significant difference in attractiveness ratings for happy faces from Experiment 1 and those from Experiment 2, t(78) = 1.351, $p = 0.496$, or Experiment 3, t(78) = 1.024, $p = 0.309$, as well as no differences in attractiveness ratings for neutral faces between Experiment 1 stimuli and those from Experiment 2, t(78) = 0.780, $p = .438$, or Experiment 3, t(78) = 0.065, $p = 0.948$. Based on these findings, subjective attractiveness ratings do not seem to explain the differences in memory task performance between the three experiments.

Paradigm Differences in Memory

Although the memory task results for each paradigm have already been calculated above, we wished to directly compare the paradigms to determine whether any differences existed in memory between paradigms/encoding type (Face and Name, Face then Name, Blocked). A 3

(Paradigm: Faces and Names, Face then Name, Blocked) by 3 (Facial Expression: fearful, happy, neutral) mixed models ANOVA found no significant interaction between Paradigm type and Facial Expression, $F(4,84) = 1.088$, $p = 0.367$, as well as no significant main effect of Paradigm on memory performance, $F(2,42) = 2.045$, $p = 0.142$. However, an overall significant main effect of facial expression on memory was found, $F(2,88) = 4.070$, $p = 0.022$. Paired t-tests revealed that significantly more happy face-name pairs were remembered than fearful face-name pairs, $t(44) = 2.534$, $p = 0.015$, similar to the findings from Experiment 1.

General Discussion

As previously stated, the results of this study did not support our hypothesis. For all three experiments, names associated with fearful and happy faces were not better remembered than names associated with neutral faces. Names associated with happy faces, however, were significantly better remembered than names paired with fearful faces in Experiment 1 (Faces and Names paradigm). For the other two paradigms we found no significant effect of facial expression on memory.

These results were unexpected given the concurrent literature. Shimamura, Ross, and Bennett (2006) observed that happy, smiling faces were better remembered that surprised, angry, and fearful faces, but there was no associative memory involved as in our study. Tsukiura and Cabeza (2008) also found an increased memory effect of smiling face-name pairs, but this was in comparison only to neutral stimuli, while the current study did not find a significant memory difference between happy and neutral face-name pairs. The lack of any arousal effect on memory conflicts with much of the literature (Kensinger & Corkin, 2003; Ochsner, 2000; Cahill et al., 1996; and Hamann et al., 1999 to name a few). Again, this should not be attributed to a lack of understanding of the concept of arousal, as emotional faces were indeed rated as more arousing than neutral.

Although happy faces were rated as significantly more attractive than both fearful and neutral faces in each paradigm, we did not find any significant correlations between attractiveness ratings and memory. Oddly enough the trend closest to significance was a negative association between attractiveness and happy face-name hits in Experiment 3 (Blocked paradigm). Another near-significance trend, a negative association between attractiveness and fearful face-name pairs in the Blocked paradigm, seems more logical (pairing negative emotion with low attractiveness), but neither of these findings are particularly noteworthy due to the lack of significant overall memory effects. Shepherd and Ellis (1973) did not observe a significant effect of attractiveness on memory directly after encoding; this effect was not evident until about a month later. Since our happy faces were also rated as more attractive, it is possible that attractiveness could play a role in the enhanced memory for smiling faces as seen in studies such as Tsukiura and Cabeza (2008). Kampe et al. (2001) found that attractiveness can increase activation in the ventral striatum (a brain region associated with reward) when viewing faces displaying direct eye contact, which may also lend credence to a combined effect of attractiveness and high valence. However, this still begs the question why, in Experiment 1, happy face-name pairs were not remembered more than neutral face-name pairs, as well as why the significant effect of facial expression on memory was not seen in Experiments 2 and 3. Studies such as Sarno and Alley (1997) and Dewhurst, Hay, & Wickham (2005) have also found that distinctiveness can play a large role in memory, but this factor was not controlled or measured for in the current study, and certainly remains a consideration for future research.

In the current study, we decided to employ several different encoding paradigms. One factor that differentiated the paradigms was the order in which the stimuli were presented. The first two paradigms used an event-related approach, in which all face-name pairs were intermixed in a pseudorandom order, while the last paradigm blocked the stimuli by emotion. However, the use of event-related and blocked paradigms ultimately had little effect on the outcome of our study, as the results from neither Experiment 2 nor Experiment 3 revealed a significant effect of Facial Expression on memory.

The second distinguishing feature between the paradigms was whether the two associative pieces to each stimulus, the face and its paired name, were presented simultaneously (Experiment 1) or sequentially (Experiments 2 and 3). Considering the implications of each system could be beneficial, as it is this factor which separated the paradigm that procured significant results to those which did not. Recall the observation from Davis et al. (submitted), in which the interleaved neutral words, and not the faces themselves, were better remembered in fearful face blocks compared to neutral face blocks. These findings, combined with the fact that the enhanced memory for happy face-name pairs in Experiment 1 was only in comparison to fearful, and not neutral, face-name pairs, may lead one to postulate that, in the case of the Faces and Names paradigm, it was not so much that happy face-name pairs were better remembered, but more so that fearful face-name pairs were more poorly remembered. There are problems with this hypothesis, however, in that, first, fearful face-name memory did not significantly differ between paradigms, and, second, that the Davis et al. study involved the independent encoding and recall of faces and words, while the current study focused on the associative memory between the faces and names, which is a complex and unique process that involves much more than the sum of its parts.

Using computer generated faces, N’Diaye, Sander, and Vuilleumier (2009) studied the implications of eye gaze when viewing faces. Participants rated angry faces as more emotionally intense when they displayed a direct gaze (eye to eye contact), while fearful faces were rated more emotionally intense when displaying an averted gaze. As with Davis et al., these findings suggest that angry faces may represent a direct threat, while fearful faces indicate the presence of an unknown threat. This also brings up an interesting point concerning face stimuli: it can be quite natural in the real world to make eye to eye contact with individuals who display happy and neutral emotions, but not necessarily for fearful faces. A direct gaze fearful face may be confusing out of context, as it could even seem that the face is perceived by the participant as a threat, while an averted gaze fearful expression may be more realistic. Experiment 2 was included in part to lessen any distracting effects of the face stimuli (such as viewing a normally rare intense fearful face) by presenting the associated name separate; however, as the data shows, this did not result in any further support of our a priori hypothesis.

We also wished to consider any associations between emotion and confidence during the memory task. We found that, in Experiment 1 (but not the other paradigms), there were significantly more high confidence hits for happy face-name pairs than fearful face-name pairs, and significantly more high confidence hits for neutral face-name pairs than fearful face-name pairs. Sharot, Delgado, and Phelps (2004) observed that, while negative stimuli were rated more frequently as being “remembered” than neutral stimuli, the actual memory accuracy between the two stimuli types did not differ. While negative stimuli actually had the fewest high confidence ratings in this paradigm, the results also suggest that high confidence does not necessarily confer better memory recall, as neutral face-name pairs were not actually remembered significantly better than fearful.

There were several other measures through which we analyzed the data, but these had little overall impact on our findings. Although studies including Canli et al. (2002) and Armony and Sergerie (2007) reported sex differences in the memory of emotional stimuli, the current study did not produce any effects of participant sex on memory. However, it is important to note that we recruited twice as many female participants as male, and that the sex ratio was highly variable between the three paradigms. We also administered the Beck Anxiety Inventory to assess any possible effects of anxiety on memory, but found no substantial associations between BAI scores and memory for each expression. There were a couple of more specific significant interactions, such as greater memory for happy face-name pairs than neutral in high anxiety participants in Experiment 2, but these do not hold high importance within the overall analysis of the results, and may very well be likely due to low sample sizes (the anxiety group split resulted in a group of 7 low anxiety participants and a group of 8 high anxiety participants). Participants also provided the number of hours of sleep they had received the night before participation, so that we could assess any possible effects of fatigue or sleep deprivation. However, there was a lack of association between hours of sleep and memory performance.

In a previous iteration of this study, which included 240 face-name pairs, Pfaff (2009) suggested that the lack of significant findings may have been due to participant fatigue. We attempted to alleviate this problem by reducing the number of face-name stimuli to 120, although fatigue and boredom still remain possible factors. Indeed, several participants commented on the large number of stimuli and/or their anxiety concerning the subsequent memory task. These comments were not a reliable indicator of performance, as some of the most concerned participants actually demonstrated some of the best performances on the memory task. Because we did not administer a task during the encoding phase, there is a chance that participant attention may have decreased over time. Some studies have demonstrated that full attention is not necessary to process and react to emotional stimuli (Suslow et al., 2006; Whalen et al., 1998); however the current study required participants to make associative memories for face-name pairs, which involves more complicated cognitive processes, and therefore would likely require more attention during encoding. In order to reduce the loss of attention, future studies could employ a task during encoding; however care must be taken so that this task itself is not distracting. Sperling et al. (2003) asked participants whether each name “fit” the face it was paired with; such a task in future research could both increase focus on the stimuli presentation, as well as possibly allow participants to form a stronger associative memory for the pairs.

The environmental context of the encoding process may have influenced participant behavior. Participants viewed black and white photos of unknown individual paired with names on a computer screen in a research lab, which is certainly not the usual situation in which one tends to make face-name associations. As Cohen and Burke (1993) stated, it is difficult enough to remember first names of recently met individuals in an ordinary real-life situation; the removal of social motivation and consequence in an experimental setting could only exacerbate this issue. Furthermore, one would not normally associate one facial expression per person, and it is quite unrealistic that one would learn the name of an individual during a time in which s/he was extraordinarily afraid. Seeing a fearful face may be inherently emotionally arousing, but once the emphasis is placed on remembering an associated name, the effects of this instinctual arousal may diminish. A future paradigm, therefore, could implement an incidental memory task (as opposed to the current study, in which participants were informed of the subsequent memory task prior to encoding). It may also prove interesting to reduce the stimulus durations (e.g., Davis et al. (submitted) presented a face for 200ms followed by a 800ms neutral word), which may better highlight any “automatic arousal” effects of emotional face stimuli. Bahrick, Bahrick, & Wittlinger (1975) discussed the importance of more “organic” memory studies and the many downfalls of strictly structured laboratory research. Obviously it would be extraordinarily difficult to create a more natural, believable study that accurately tests our same hypothesis, but issues of realism are still worth considering in the context of this type of research.

The memory task employed in the current study had been used in a similar form in a previous study (Sperling et al., 2003), although that study did not involve varying emotional content. Perhaps future research could implement an initial yes/no memory task for just the faces and/or names (as in Chua et al., 2007), and then only test the face-name associative memory for those stimuli which the individual piece was remembered. This might help determine if behavioral response to viewing emotional faces and names is altered if the stimuli are presented in an associative context. Another alternative memory task was seen in Kirwan & Stark (2004), in which participants indicated whether the presented face-name pair was previously seen, novel, or a recombination of a previous face and name that were not originally paired together. Bahrick, Bahrick, & Wittlinger (1975) observed that recognition tasks involving the participant choosing a name to match a given picture were more difficult than choosing a picture to match a name. The memory task of Tsukiura and Cabeza (2008) involved participants choosing an associated facial expression to a given name.

Another important consideration for future memory tasks is the interval between encoding and retrieval. The previous iteration of this study administered the memory task 24, 48, or 96 hours after encoding, although no significant main effect of time interval or interaction between time interval and facial expression was found. There have been significant memory related findings in studies in which the memory task occurred immediately after encoding

(Sperling et al., 2003; Tsukiura & Cabeza, 2008; Kensinger & Schacter, 2006, for example) as well as weeks, months, and years post encoding (Hamann et al, 1999; Bradley et al., 1992; Shepherd & Ellis, 1973, for example). Unfortunately the lack of available research concerning effects of emotion on associative memory (in particular faces and names) renders it difficult to propose a specific time interval at which more significant behavioral data may be gathered. However, the findings from imaging studies such as in Hamann et al. (1999) suggest that the amygdala may play a larger role in the consolidation of long term memory than facilitating short term memory, which may lend some explanation as to why our hypothesized effects of emotional stimuli on memory were not observed for a same-day recognition task.

Another conflicting factor concerning the memory task is varying baseline levels of familiarity to the individual names. While a specific name might hold no associations to one participant, to another it may be the name of a family member, friend, or loved one. Possessing previous familiarity to a name could potentially help one form better associations, and thus improve memory for those face-name pairs. After rating the faces on arousal, valence, and attractiveness, participants were also asked to list any names that may have helped them remember the associated face due to personal significance, and, optionally, to list the reason of significance. The number of names listed by each participant greatly varied (and it is clear that some spent minimal time on the question, or chose not to answer it altogether), and the most common associations listed were family members, friends and acquaintances, and characters from television/film/literature. To ensure that the significant effect of facial expression on memory found in Experiment 1 could not be attributed to this increased memory for familiar names (in the possible event in which more familiar names happened to be those of happy faces), we removed the successfully remembered familiar names from participants’ responses and reanalyzed the memory performance data. A repeated measures ANOVA found a significant main effect of Facial Expression on memory performance, $F(2,28) = 4.483$, $p = 0.031$. Happy face-name pairs were still remembered at a significantly higher rate than fearful face-name pairs, $t(14) = 2.93$, $p = 0.0143$. This analysis, however, still found no significant main effect of Facial Expression on memory performance in Experiment 2, $F(2, 28) = 0.329$, $p = 0.693$, or Experiment 3, $F(2,28) = 1.874$, $p = 0.185$. This factor can be difficult to properly control, as all participants possess a different database of familiar names and reasons for why these names would be particularly memorable. Sommer, Komoss, and Schweinberger (1997) used very uncommon names in their study, which could help prevent this phenomenon, but would also further reduce the realism of the study.

Due to the lack of similar studies to which we can compare our results, it is difficult to determine whether our failure to support our hypothesis was due more to limitations in the experimental design, or whether these findings are in fact indicative of human behavior. The finding of greater memory for happy face-name pairs than fearful face-name pairs in Experiment 1 (Faces and Names) is certainly interesting, but would likely be more substantial if happy face-name pair memory was also better than that for neutral face-name pairs, or if these findings were replicated across the other paradigms. At this point, especially due to relatively low sample sizes, it is difficult to assess the true significance of this observation. There is certainly much research that demonstrates that emotion can have a substantial effect on memory, and this concept is rarely argued, but once we begin to investigate more specific details, to once again quote Levine and Pizarro (2004), “things get complicated quickly”. Through both behavioral and imaging studies, it is clear that associative memory, even for seemingly innocuous and commonplace items such as faces and names, is a surprisingly complicated and cognitively taxing process. One cannot assume that the results of studies that analyze just face, scene, or word stimuli perception will be necessarily indicative of associative memory. Is it possible that the mental demands of forming face-name associations can trump, or at least inhibit, the modulating effects of emotion and arousal? It seems possible, but it would be best to test this idea in a neuroimaging study to assess possible differences in brain activity, both regarding and independent of behavioral data. Behavioral findings may also differ in a clinical setting, as PTSD patients have demonstrated greater sensitivity towards emotional stimuli, and such a paradigm could even be eventually administered as a form of clinical diagnostic. Through continued research, we have the potential to understand the complex interaction between emotion and varying types of memory. Such knowledge has far reaching implications, from the study of abnormal brain activation in mental disorders to comprehending our instinctual thoughts, reactions, and memories for people and events to which we are exposed to every day.

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