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Previous studies using an incidental learning paradigm have found that facial emotion enhances subsequent face recognition. The present study examined whether emotion enhances only memory for the specific emotional features, or whether it also enhances general memory of that person's identity. Prior to the study, we had 20 participants validate the face stimuli with emotion valence (how positive or negative) and arousal (how exciting or calming) ratings. In Experiments 1 and 2, participants performed a gender discrimination task on a face expressing either an angry or a happy emotion, unaware that they would later be tested on their recognition of those faces (i.e., incidental learning). They then performed a 20-minute distraction task. Finally, they performed a recognition test, judging whether each face identity was previously shown ("old") or not ("new"). We found enhanced memory of angry faces, relative to happy faces, when the exact same face – showing the same emotion – was used during the later recognition test (Experiment 1), but not when a neutral face was used at test (Experiment 2). This finding suggests that negative emotional expressions improve memory for that specific emotional expression, without improving general memory for that person's identity.

The Effect of Emotional Valence on Memory for Face Identity

by
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APPROVED:

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Major Professor, representing Psychology

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Director of the Interdisciplinary Studies Program

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Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Nathan Herdener, Author

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# INTRODUCTION

The ability to process and remember faces plays a crucial role in our society. Not only does a face convey an abundance of information about the internal state of an individual, but a face also serves as a unique marker to distinguish that individual. Face processing is automatic, with the fusiform face area in the fusiform gyrus dedicated to processing facial information (Grill-Spectorm, Knouf & Kanwisher, 2004). The significance of facial information is so great to the human mind that we commonly perceive human faces in inanimate objects or patterns of simple shapes (e.g., the man in the moon, the smiley-face emoticon [☺], the shell of Heikegani "Samurai crab"), a phenomenon known as pareidolia (Summerfield, Egner, Mangels, & Hirsch, 2006). Recognition for faces develops early in infancy, with infants learning to identify the faces of their mothers as early as three months (Nelson, 2001). By 4-9 months, infants can discriminate between a number of facial expressions, including happiness, anger, fear, sadness and surprise (Grossmann, 2010). The importance of understanding this cognitive skill of interpreting and remembering faces goes beyond normal social interactions, with expanding diagnostic applications for clinical disorders (e.g., autism) and forensic situations (e.g., eyewitness testimony). Because of this, enormous effort has been put forward to understand the mechanisms underlying face perception and memory (for reviews, see Allen, Lien, & Ruthruff, 2011; Calder, Rhodes, Johnson, & Haxby, 2011). Of particular interest in the present study is how information carried by the face, specifically emotional expression, influences the ability to subsequently recognize identity.

## Recognition Memory vs. Recollection Memory

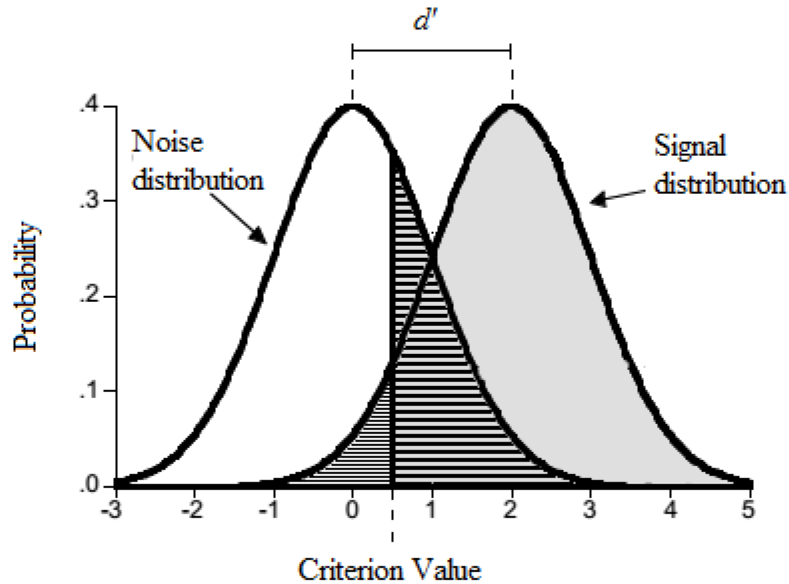
Memory has been a topic of human interest for millennia, and its study has filled many textbooks and journal articles (a simple search of APA PsychNET for the term "memory" reveals over 148,000 peer reviewed journal articles). It is considered an integral aspect of our experience, and the term encompasses a boggling array of processes and features of cognition. As such, it is well beyond the scope of this thesis to approach the subject in its entirety. Instead we will focus on *recognition memory*, which is expansive in its own right. At its etymological roots, to "recognize" is to perceive, know or become aware of again. In a stricter psychological sense, recognition is the act of determining whether an event or stimuli has been previously encountered. This definition has developed as a counterpart to the idea of *recall* or *recollection memory*, which refers to the retrieval of contextual and conceptual information regarding previous events. In many instances, recognition and recollection occur together, if not simultaneously. For example, in daily life you might recognize a familiar face at the grocery store but be unable to initially recall where you know said person from. After mentally searching through several contexts, you might be able to recall that the person works as a hygienist for your dentist.

However, it is also true that you may be left with the feeling of knowing that you have seen the person before but be frustratingly unable to place the person in a proper context. This phenomenon is accounted for by the *dual-process model of memory*, which was developed after Mandler, Pearlstone and Koopmans (1969) demonstrated that recognition and recollection were differentially affected by organizational strategies. Participants were asked to sort a set of words into categories of their own choosing and were subsequently given recognition or recall tests for the sorted items. Mandler et al. found that the number of categories used initially accounted for a large portion of the variance for recall and a very minimal amount of the variance for recognition. However, when the participants were tested after five weeks, the pattern of results was reversed; more variance of the recognition was explained by the organizational strategy employed, while the organizational strategy explained less of the recall performance. These findings suggest that recognition and recall are separate entities that can be influenced independently. Moreover, the dual-process model of recognition memory posits that the initial recognition or familiarity judgment occurs rapidly upon presentation of an event, whereas recall or recollection is a slower process involving the search and retrieval of potential contextual candidates.

## Signal Detection Theory

One popular form of studying recognition memory is the old/new discrimination task, in which participants are presented with a series of items (e.g., words, images, or faces) and subsequently asked to determine if a presented item was encountered before or if the item is new. This paradigm follows the framework of signal detection theory (SDT; Green & Swets, 1966), treating the decision to label a test item as old or new as an comparison between the strength of the memory signal and a decision criterion (Banks, 1970; Macmillan & Creelman, 2004). The memory signal is referred to as a memory trace and models the activation of neural pathways that are sensitive to the stimuli. If items have been remembered, encountering them again should lead to greater recruitment of neural pathways and therefore greater trace strength than previously unseen items. While items that were previously seen should have a stronger trace value, it must be noted that there is often a great deal of variance in the trace strength of an item. There is the common experience of encountering a stranger who has “one of those faces,” that you swear you have seen before, or the unfortunate descriptor of someone having a "forgettable face." To account for this variance, SDT compares the distributions of trace strength of previously encountered items (the *signal distribution*) with the trace strength of new items (the *noise distribution*). Since the strength of a given memory trace lies along a continuous axis, a *criterion* value is needed to convert the strength to a binary response for a decision like old/new, accept/reject or true/false. If an item produces strength of the memory trace is greater than the criterion, it is declared to be old, or accepted. If the strength of an item fails to reach the criterion value, it is declared to be new. In this model, there are two ways in which the participant can be correct. The participant can identify an old (previously seen) as an old item, which is considered a *hit*, and they can identify a new (previously unseen) item as new, which is labeled a *correct rejection*. Conversely, a when an old item is identified as new, this is considered a *miss*, and when an new item is called old it is considered a *false alarm* (See Figure 1 on next page).

The decision to classify an item as old or new is based on both the *response bias* (the tendency to respond one way over another) of an individual as well as their *sensitivity* to detect differences between old and new items. While criterion values are usually assumed to be stable for a given class of stimuli within a task, they vary among individuals and the response bias can be further manipulated by task demands, rewards, and other contextual influences. A *liberal bias* exists when there is an overall tendency to accept items as old, independent of actual status, and represents a lower criterion value. When it is important to accurately identify something as previously seen and the penalty for a false alarm is low, such as when a TSA agent scans passenger manifests for




| | **Old Item** | **New Item** |
|---|---|---|
| **Respond Old** | *Hit* | *False Alarm* |
| **Respond New** | *Miss* | *Correct rejection* |

*Figure 1.* Distribution of response strength across signal and noise trials, showing *d'* and the criterion value. Also shown are the regions corresponding to hits, false alarms, misses, and correct rejections. Modified from Stanislaw and Todorov (1999).

names from a terrorist watch list, a liberal bias can be beneficial since it maximizes catching a potential threat. When the criterion value is set high, a *conservative bias* exists, and there is a tendency to report fewer items as old. A conservative bias is most beneficial when the penalty for false alarms outweighs the penalty for misses. If one is concerned about embarrassment, a conservative bias might be used in deciding whether to approach a potential celebrity for an autograph. Since response bias operates independently of the ability to detect differences between old and new items, hit rate, false-alarm rate, and proportion of correct response alone are poor measures of recognition memory (Stanislaw & Todorov, 1999).

To account for this, sensitivity is often measured using *d'* (Green & Swets, 1966). Given that the ability to detect differences is related to the differences between the signal and noise distributions, *d'* is defined as the distance between the peaks of the distributions (See Figure 1). Noting that as the distance between the peaks increases, so does the overlap between the distributions, allowing *d'* to be quantified as

$$d' = Z(\text{Hit Rate}) - Z(\text{False Alarm Rate})$$

in units of standard deviation (a *d'* value of 1 indicates that the means are a single standard deviation apart). The hit rate for old items is conceptualized as the proportion of the signal distribution that exceeds the criterion value, while the false alarm rate is the proportion of the noise distribution that exceeds the criterion, providing the necessary components to measure the overlap. The use of *d'* provides a measure of sensitivity that is unbiased and independent of any strategic influences on the criterion, as well as other factors that influence response bias (Stanislaw & Todorov, 1999).

While *d'* is commonly used because it provides an unbiased measure of sensitivity, some researchers prefer to use alternate measures that are tied to two-high threshold model of memory (Snodgrass & Corwin, 1988). The two-high threshold model does not assume that there is a continuum of memory strengths, as in SDT, but rather that memory operates in discrete states of old recognition, new recognition and uncertainty. New items are only compared against a new recognition threshold and old items are only compared against an old recognition threshold, with items that fail to reach threshold in either category classified as uncertain. Response bias dictates the classification of items in the uncertain state, meaning that false alarms and misses are always generated in this state. With the assumption that both old and new thresholds are equivalent, the false alarm rate can be used as an estimate of the guess rate for the old recognition judgment. This allows discrimination (*Pr*) to be calculated as

$$Pr = p(\text{Hit}) - p(\text{False Alarm})$$

This measure is often called the "corrected recognition" score, as it is corrected for guessing, and thereby limiting the influence of response bias. However, *Pr* by itself does not remove the effect of response bias and a complementary measure of response bias (*Br*) is calculated by

$$Br = \text{False alarm rate} / (1 - Pr)$$

A *Br* score of 0.5 indicates no bias in either direction, whereas scores greater than 0.5 indicates a liberal response bias (more likely to respond positively) and a score less than 0.5 indicates a conservative response bias (more likely to respond negatively). While these measures have been used historically – the discrimination index was first used by Woodworth in 1938 (as cited in Snodgrass & Corwin, 1988) – recent literature has suggested that signal detection grounded approaches consistently predict the user response data in recognition memory tasks (Stanislaw & Todorov, 1999; Wixted, 2007; but see Bröder, & Schütz, 2009). These measures are still commonly used, even without reference to their theoretical underpinnings.

A further exploration of the ability for individuals to recognize prior events comes from the work of Endel Tulving (1985), who elaborated on the distinction between recognition and recollection by noting that we consciously experience them in different ways. The experience of recalling information necessarily carries with it a context in which it was originally encountered (although not necessarily an accurate or error-free representation of the context), whereas the experience of knowing carries no such information. Noting that individuals had conscious access to the information regarding the source (or lack thereof) of their memory, Tulving added a simple question after each item in a memory task: was the item specifically “remembered” or did they simply “know” the item? This additional information provided by the Remember/Know/Guess (RKG; guess is usually presented as an option for when the observer does not recognize the item at all) paradigm gives insight into how strongly items are remembered beyond what is given by looking at response rate and discrimination.

In the framework of SDT, observers in a RKG task will adopt two criteria points corresponding to know and remember responses, with the remember criteria situated relatively higher along the decision axis than the know criteria (Wixted, 2007). Under this model, both familiarity and recollection contribute to the strength of the memory trace, and recollection is not assumed to be an all-or-none process that necessarily leads to a remember response. Instead, recollection is a graded process with varying degrees of information, such that it is possible that a “know” response still carries with it some degree of recollection. For example, Eldridge, Engel, Zeineh, Bookheimer, and Knowlton (2005) illustrated that participants could recollect details (such as color or orientation) of items they reported know responses for at above chance levels. Likewise it is also possible for a high degree of familiarity to contribute to a remember response. Thus, “know” and “remember” responses are imperfectly correlated with recognition and recollection, but still can be useful as additional measures of memory strength.

## Emotion and Memory

Numerous factors at encoding and retrieval can influence the overall strength of a memory. The likelihood that a person will recognize or recall an event is highly correlated with the subjective relevance of the event to the individual (Schacter, Gutchess, & Kensinger, 2009). While some information may be perceived as highly relevant for one individual, a different individual may not perceive the same information as important. For example, sports fans are notorious for the ability to remember obscure scores and statistics, while non-sports fans are less likely to perceive that information as relevant and are therefore less likely to remember it. However, unlike batting averages, there are some categories of events and stimuli that are universally relevant and have strong adaptive value. Notably, emotion has a powerful influence on memory at encoding, consolidation and retrieval. Emotional events have such an impact, that it was once believed that events associated with strongly emotional memories might be immune to forgetting or disruption (Brown & Kulik, 1977). While this is not the case, multiple dimensions of emotion have been shown to have a unique impact on memory accuracy.

Emotional arousal has been demonstrated to lead to a reliable enhancement in memory using a variety of stimuli and paradigms (Kensinger, 2009). It is theorized that this enhancement stems from the attentional effect that stimuli that elicit an arousing response are more likely to be detected and therefore encoded than information that is non-arousing (Dolan & Vuilleumier, 2003; Kensinger, 2004). Additionally, information that is not arousing is less likely to be consolidated in as durable a fashion, with emotionally arousing information showing an increasing advantage (over non emotional information) as retention interval increases (Labar & Phelps, 1998). Because arousal influences attention, the impact of emotional arousal also extends to what is remembered. Arousal narrows focus to the aspects of the event that are producing arousal at the expense of peripheral aspects. For example, after studying an image of an accident victim in a hospital ward, observers will have a good memory for the victim but below baseline memory for the hospital room (compared to observers who have seen an emotionally neutral image of the hospital ward). This trade-off occurs temporally as well as spatially; neutral items are less likely to be remembered if they follow an arousing word (Hurlemann et al., 2005). Additional evidence of arousal/attention interaction comes from experimental designs that have instructed participants to intentionally attend to all aspects of an event. Under these conditions, participants' memory performance for background details is equivalent to the emotionally arousing details (Kensinger, Piguet, Krendl & Corkin, 2005). However, if the participants were encouraged to attend to the arousing aspects by being required to make an affective judgment (such as to approach or avoid a threatening scene), the trade-off between central and peripheral items increased. This relationship between arousal and memory has been supported by neurophysiological evidence as well, with neuroimaging showing activity in the amygdala during the encoding of arousing items that corresponded to the level of later recall (Vuilleumier, Armony, Driver & Dolan, 2001).

However, the arousal account of memory enhancement does not capture the whole contribution of emotion to memory. While it is often confounded with arousal, the valence of an emotional event also impacts the information that one is able to recall. Since many negative stimuli are inherently arousing, they are often used when studying the impact of emotion on memory. After controlling for arousal, there is evidence to suggest that positive information is remembered differently than negative information. Both positive and negative emotions have been shown to enhance memory over emotionally neutral stimuli, but focal enhancements may occur more readily for negative information (Kensinger, 2009). Not only do people tend to report more “remember” judgments for negative events, but they are also able to recall negative items with greater visual detail than for positive items. For example, when presented with a previously item among similar items (e.g., a previously seen snake among novel snakes, or a previously seen cake among novel cakes), participants are more accurate at deciding which snake they saw compared to which cake they saw. In addition to being better able to distinguish between alike negative items, people are less likely to make false alarms when asked whether a negative item is old or new (Kensinger, 2009). On the other hand, items that generate positive emotions tend to elicit a greater memory confidence, despite an increased propensity for memory errors.

Although experimental manipulations of valence are helpful because they provides information regarding the cause of memory enhancements, it is recognized that non-valence stimuli characteristics (e.g., arousal, distinctiveness, semantic associations) are difficult to equate between positive and negative stimuli. Ameliorating this potential problem, there is compelling converging evidence for the effect of valence on memory accuracy from studies exploring how the valence of a person’s response to an event outcome impacts the accuracy of that person’s memory for the event. In these studies, the memory accuracy for event details is compared between individuals who had positive emotions resulting from the event and individuals who found the outcome to be negative. Levine and Bluck (2004) utilized the O.J. Simpson trial, asking participants who had strong opinions about the outcome to take a recognition task about real and fictional events that occurred in the trial. Those who found the outcome positive had more memory errors, reporting more of the fictitious events as real than individuals who were displeased by the verdict. A similar study by Kensinger and Schacter (2006) asked elated Red Sox fans and disappointed Yankees fans to report details from the 2004 American League Championship final, in which the Red Sox defeated the Yankees. Red Sox fans were more likely to be overconfident in their memories, despite showing greater memory inconsistencies than Yankee fans. Additionally, these valence effects on memory have also been found with induced moods in a laboratory. After being induced into a negative mood, participants tend to respond more conservatively and report fewer lures as previously encountered than those induced into a positive mood (Storbeck & Clore, 2005). These converging findings suggest that negative emotional valence leads to greater detail orientation, while positive emotional valence leads to only enhance the memory for the gist of the event with little or no benefit for details.

## Memory for Faces

Studying the impact of emotion on recognition has largely used words and images (of scenes or items) as the material to be remembered, but recently there has been an interest in determining if the emotional enhancement effects carry over to faces. Facial expressions are natural carriers of emotional information in the social environment and provide meaningful insight into the intentions and behavior of others. Despite the wide body of research on emotion and recognition memory, as well as the extensive literature on face perception, the exploration of the connection between emotional expressions and memory has so far been inconclusive.

Two different paradigms have been used to study face memory – incidental and intentional learning. In *incidental* learning, participants study face stimuli (e.g., performing a gender task on those faces) without knowing that their memory of those face stimuli will be tested later. They are then typically given a recognition test on a mixture of new (not shown during the study session) and old faces (shown during the study session), and their ability to discriminate old faces from new faces is measured (e.g., D'Argembeau, Van der Linden, Comblain, & Etienne, 2003; Johansson, Mecklinger, & Treese, 2004; Patel, Girard, & Green, 2012; Shimamura, Ross, & Bennett, 2006; Wang, 2013). In *intentional* learning, however, participants are explicitly told to study face stimuli in order to be able to recognize them later (e.g., D'Argembeau & Van der Linden, 2011; D'Argembeau et al., 2003) or are explicitly told to attend and process the emotion (e.g., Grady, Hongwanishkul, Keightley, Lee, & Hasher, 2007; Patel et al., 2012).

While the studies with *intentional* learning have found evidence for memory enhancement by emotional faces, such an effect might simply reflect deliberate strategies to remember the most salient features of the face. Arguably a much more impressive demonstration of the power of emotional expressions is that they influence memory recognition even when people are not trying to remember the face and have no incentive to allocate attention to emotional features (e.g., incidental learning). For such *incidental* learning, however, the evidence is inconclusive. One limitation is that studies showing memory enhancement for emotional faces in incidental learning have typically used the same exact emotional face images during study and test (e.g., Johansson et al., 2004; Patel et al., 2012; Wang, 2013; but see D'Argembeau et al., 2003; Shimamura et al., 2013), raising questions about how "deep" the encoding is. The enhancement with the same faces during study and recognition test might merely reflect enhanced encoding of emotion-specific features, rather than enhanced encoding of identity per se.

**Recognition Bias for Facial Expression vs. Facial Identity**

D'Argembeau et al. (2003) first addressed the issue of whether emotional expressions improve memory for the details that specific face image or improve general memory for that person's identity (see also Shimamura et al., 2006). They used 24 face identities that expressed with three different emotions (happy, angry, and neutral) and presented 6 happy and 6 angry faces during the study session (the faces were counterbalanced to reduce the confound of differences in face memorability). Participants were divided into an intentional learning condition, in which they were told that they should carefully look at the faces in order to recognize them later, or an incidental learning condition in which the participants were asked to estimate the age of individual in the image (they were not informed a test would follow). After a 5-minute retention interval without a distraction task, participants took a recognition task in which they were asked to recognize the same faces with neutral emotion intermixed with 12 previously unseen faces (also neutral). When participants classified a neutral face as an old identity during the recognition test, they were asked to further classify the recognition as "remember," "know," or "guess" (the RKG rating).

In the intentional learning condition (which directly instructed participants to remember the faces), the authors found that neutral faces that were previously presented with a happy expression were better recognized and more likely to receive a remember response (52% for happy vs. 44% for angry). However, in the incidental learning condition (in which participants were instructed to estimate the age of the individual shown on the image), D'Argembeau et al. (2003) found that the overall hit rate was similar for happy and angry faces (0.69 vs. 0.72) and the proportion of "remember" responses was not significantly modulated by emotion type (41% for happy faces and 47% for angry faces), *F*s < 1.0. They concluded that negative valence did not enhance the likelihood of remembering for those faces. Nevertheless, D'Argembeau et al.'s (2003) results did demonstrate slight trend ($p$ = .16) toward better recognition of angry faces (47%) than happy faces (41%). It is possible that this trend was due to low power (e.g., only 32 participants in the incidental learning condition and 24 trials). Additionally, while the intentional learning results were replicated in D'Argembeau and Van der Linden (2007), other studies using a similar experimental design (although using an increased number of faces) found enhanced accuracy for negative emotional expressions (Grady et al. 2007; Righi et al., 2012). The inconsistency between these findings suggests that further research is needed before accepting the findings from the incidental learning condition D'Argembeau et al. (2003) as conclusive.

Using an incidental learning paradigm Johansson et al. (2004; Experiment 1) measured event-related potentials (ERPs) for old/new effects in addition to behavioral discrimination. During the study session, participants were asked to identify the gender of 51 faces (with positive, negative, and neutral emotions being equally likely). After completion of the gender task, they were given a 30-sec distraction task (counting backward by threes) and then administrated a recognition test containing 102 faces (34 per emotion type). Behavioral measures (hit rates and false alarms) indicated that participants' ability to discriminate between old and new faces was not influenced by emotion. However, the ERP data showed differences between old and new faces for negative emotions at the posterior electrode sites. For the correctly rejected new faces, the negative faces also elicited a larger frontal ERP than positive and neutral faces. They argued that faces with negative emotion were "recollected to a higher degree" than positive and neutral faces even when they produced similar recognition accuracy (p. 1846). To follow this argument, they performed a recognition test (Experiment 2) asking participants to classify their response of "old" faces as "remember," "know," or "guess." They found that the probability of "remember" responses was higher for negative emotion than positive and neutral emotion (see their Table 4). Thus, despite similar degree of recognition accuracy between positive and negative emotions, as indicated by similar Pr (discrimination), the higher proportion of "remember" responses led Johansson et al. (2004) to conclude that negative emotion enhanced face recognition. This enhancement also was accompanied by a more liberal response bias when recognizing negative facial expressions, increasing hit and false alarm rates as well as the proportion of remember judgments.

The implications of Johansson et al.'s (2004) findings, is that faces with negative valence enhance memory recognition for those faces. This finding seems to be supported by the attention literature showing that stimuli with negative emotion (e.g., anger, fear, threat) tend to attract attention more than stimuli with other emotion (e.g., happy or neutral). The common rationale for allocating attention to negative emotion is that rapid detection of threatening stimuli has potential adaptive value (e.g., Fox, Russo, & Dutton, 2002; Shaw, Lien, Ruthruff, & Allen, 2011; Öhman, Lundqvist, & Esteves, 2001; Vuilleumier & Huang, 2009), and it is reasonable to argue that attention helps to improve memory encoding of the faces (e.g., for a review, see Chun & Turk-Browne, 2007). However, in Johansson et al. (2004), the same face images with the exact same emotional expression were used in both the study and recognition test sessions (e.g., Patel et al., 2012; Wang, 2013). Thus, their results do not necessarily indicate that an expression of negative emotion boosts general memory for that person's identity, as the enhancement could be specifically limited to a particular emotional expression or even the specific image (see Bruce, 1982, for an example of poor facial recognition when changing some features, such as viewing angle and presence/absence of a smile). To claim that a negative emotion enhances memory, the face should still be recognized if presented at test with a neutral facial expression.

# THE PRESENT STUDY

To briefly summarize, previous studies suggest that emotion during incidental learning can enhance recognition of the exact same face (e.g., Johansson et al., 2004; Patel et al., 2012; Wang, 2013). However, the enhancement might apply only to encoding of specific emotional features or the image itself. To establish that the enhancement also applies to general memory for facial identity, the effect needs to be shown for neutral faces at recognition test. Most studies have not examined this issue, and studies with neutral faces at recognition test have been inconclusive (D'Argembeau et al, 2003). The present study, therefore, examined whether the emotional valence of faces during incidental learning differentially influences subsequent identity recognition.

Our study had three sequential sessions: study, distraction, and then a recognition test. In Experiment 1, we first replicated previous studies for the condition in which the exact same face is presented at study and recognition test. Johansson et al. (2004) argued for memory enhancement based on ERP data, but it is disconcerting that they found little or no supporting evidence in the behavioral data for Old/New face recognition. We examined whether their findings can be reproduced in the behavioral data with a larger sample size and a large set of face stimuli. Experiment 2, using nearly identical methods, examined whether emotion also enhances memory with emotional faces at study but neutral faces at recognition test. This design allowed us to directly compare the effect of emotional valence on memory of facial identity when the same emotional expression at study was identical (Experiment 1) or different (Experiment 2), which has not been done in previous studies. This is critical for establishing how emotion enhances the encoding of the faces.

<u>General Method and Stimuli</u>

In the study session, participants were given a single face on the screen and were to make a gender discrimination task in both Experiments 1 and 2. They were not informed that they would later be tested on those faces. Half of the face images expressed an angry emotion, whereas the other half expressed a happy emotion. In the distraction session, participants performed a simple matching pairs game on an iPad for 20 minutes[1]. In the recognition test session, they were to determine whether the face shown in the display was seen in the study session ("old") or had not been seen before ("new") – half of the faces were the same identity as those shown in the study session and the other half were different identities. Experiment 1 followed Johansson et al.'s (2004) study and used the same pictures, expressing the same emotion, for both the study and recognition test sessions. Experiment 2 was similar to Experiment 1, except that neutral faces were used in the recognition test session of Experiment 2.

The face stimuli were taken from three sources: NimStim (Tottenham et al., 2009), Max Planck Institute for Human Development FACES (Ebner, Riediger, & Lindenberger, 2010), and the Karolinska Directed Emotional Faces (KDEF) database (Lundqvist, Flykt, & Öhman, 1998)[2]. A total of 600 face images with 200 identities expressing 3 different emotions (angry, happy, and neutral) were used in this study. Half

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[1] The game was a free Apple App downloaded directly from https://itunes.apple.com/us/app/memory-game!/id404606335?mt=8

[2] In addition to face stimuli from NimStim, we used the younger adults' face images from the Max Planck Institute for Human Development FACES database and the face images from the Karolinska Directed Emotional Faces (KDEF) database in which the person is directly facing the camera. Permission to use those images was obtained from the organizations by email.

of them were males and the other half were females. Each picture was 9.70° (width) × 12.51° (height) with the average viewing distance being about 55 cm. The 200 identities were divided into four subsets, with every two subsets being used as an "old" set and the other two as a "new" set, which were counterbalanced across participants. This arrangement resulted in each identity of face images being presented only once for one specific emotion for each participant (but repeated one more time in the recognition test session if it was from an old set).

Initial ratings for the emotional valence (how positive or negative) and arousal (how exciting or calming) of those face images were obtained from twenty individuals (15 females, 5 males; age range: 18-23 years, $M = 20$ years old) from the same participant pool but they did not participate in Experiments 1 or 2. Participants rated each face image for emotional valence on a scale from 1-9 (1 = *the most negative*, 9 = *the most positive*), and for arousal level on a scale from 1-9 (1 = *low*, 9 = *high*). Mean ratings for each emotion type and gender of face images are presented in Table 1. For emotional valence, mean ratings were the highest for happy faces ($M = 7.33$), neutral faces ($M = 4.81$), and then angry faces ($M = 2.50$), $F(2, 38) = 344.98$, $p < .0001$, $\eta_p^2 = 0.95$. The ratings between every two emotion types were significantly different from each other, $F$s(1, 19) ≥ 289.47, $p$s ≤ .0001, $\eta_p^2 s \geq 0.95$. This finding suggests the emotion valence (positive, negative, vs. neutral) shown in those faces was distinct from each other. For arousal, mean ratings were higher for happy faces ($M = 6.24$) and angry faces ($M = 6.99$) than neutral faces ($M = 4.34$), $F(2, 38) = 25.14$, $p < .0001$, $\eta_p^2 = 0.57$. Arousal for both happy and angry faces were rated equivalent, $F(1, 19) = 4.16$, $p = .0556$, $\eta_p^2 = 0.18$, with both rated more arousing than neutral faces, $F$s(1, 19) ≥ 17.80, $p$s ≤ .001, $\eta_p^2$s ≥ 0.48.

Table 1.

*Emotional Valence and Arousal Ratings on the Scale 1-9 for Each Gender and Emotion Type of Face images used in Experiments 1 and 2.*

| Gender | Emotion Type | Valence Rating | Arousal Rating |
|---|---|---|---|
| Male | Angry | 2.37 | 7.16 |
| | Happy | 7.29 | 6.22 |
| | Neutral | 4.81 | 4.33 |
| Female | Angry | 2.63 | 6.82 |
| | Happy | 7.36 | 6.27 |
| | Neutral | 4.81 | 4.35 |

Previous studies (e.g., Johansson et al., 2004) indicate that emotion during incidental learning can enhance recognition of the exact same face. At a minimum, the enhancement applies to specific emotional features. But, to establish that the enhancement also applies to general memory for facial identity, the effect needs to be shown for neutral faces at test. Most studies have not examined this issue and the one study that did (D'Argembeau et al., 2003) was inconclusive. The present study, therefore, examined whether the emotional valence of faces during incidental learning influences subsequent identity recognition.

Our study had three sequential phases: study, distraction, and then a recognition test. In Experiment 1, we first replicated the findings of Johansson et al. (2004) for the condition in which the exact same face is presented at study and test. Experiment 2, using nearly identical methods, examined whether emotion also enhances memory with emotional faces at study but neutral faces at test. This design allowed us to directly compare the effect of emotional valence on memory of facial identity when the same emotional expression at study was identical (Experiment 1) or different (Experiment 2), which has not been done in previous studies. If negative emotions enhance our memory and induce a recognition bias, then we should expect that angry faces would produce higher *d'* values than happy faces. For the sake of completion, we also reported the analyses with hit rate and false alarm rate.

## Experiment 1

In Experiment 1, we replicated Johansson et al.'s (2004) study using sensitivity, or *d',* as a measure of memory facilitation/enhancement. As in their study, both study and recognition test sessions contained emotional faces (angry and happy). Half of the faces in the recognition test were previously studied (same identity, same emotion; [Old]), whereas the other half were not (different identity; [New]).

### Method

Participants. Ninety-six undergraduate students from Oregon State University participated in a 1-hour session in exchange for extra course credit. Two participants' data were excluded from the final analyses (see the Results section below for details). For the remaining 94 participants (66 females, 28 males), the mean age was 20 years (range: 18-39 years). All reported having normal or corrected-to-normal visual acuity.

Apparatus, Stimuli, and Procedure. Stimuli were presented on IBM-compatible microcomputers. As described above, each participant received three sessions in order – study, distraction, and then recognition test. For the study session (the gender discrimination task), each trial started with the presentation of the fixation display for 800 ms, which was replaced with a single face in the center until the participant responded. Participants were asked to press the "z" key labeled as "M" with their left-index finger for male faces and the “m” key labeled as “F” with their right-index finger for female faces. They were asked to respond to the gender of the face image quickly and accurately. Immediately after a response was recorded, the next trial began with the 800-ms fixation display. They were not informed that they would later be tested on those faces. A total of 100 face images with different identities (25 male/angry, 25 male/happy, 25 female/angry, and 25 female/happy) were used in the study session. Each face was presented only once for each participant.

For the distraction session, they were given an iPad and played a matching pairs game for 20 minutes.

The recognition test session was similar to the study session with the exceptions noted. A total of 200 face images with an equal number for each emotion type (angry vs. happy) and gender (male vs. female) were used. Half of face images were the ones shown earlier in the study session and the other half were new identities. Participants were asked to press the “x” key labeled as “Y” with their left-index finger for “yes, it was shown earlier” responses (“old”) and the “m” key labeled as “N” with their right-index finger for “no, it wasn’t shown earlier” responses (“new”). Feedback (a tone for an incorrect response or a blank screen for a correct response) was presented for 100 ms.

Results

The overall accuracy for the gender discrimination task during the study session was 0.96, which was similar for angry faces (0.95±0.05 [SD]) and happy faces (0.96±0.05 [SD]), suggesting that participants were appropriately focused on the gender task. We next analyzed data from the recognition test session. We followed Grady et al. (2007) and included data from participants who demonstrated above-chance performance in the recognition test session with the overall corrected accuracy score (*hit rate – false alarm rate*) greater than or equal to 0.10. Two out of 96 participants did not meet this criterion, resulting in 94 participants' data included in the final analyses[3]. Analysis of variance (ANOVA) on hit rate, false alarm rate, and sensitivity *d'* as a function of emotion type (angry vs. happy; a within-subjects variable) and gender (male vs. female; a within-subjects variable) was conducted with an alpha level of .05 to ascertain statistical significance. Table 2 shows mean hit rate, false alarm rate, and *d'* in each condition.

Table 2.

*Hit Rate, False Alarm Rate, and Sensitivity (d') for each Gender and Emotion Type of Face images in Experiment 1.*

| Gender | Emotion Type | Hit Rate | False Alarm Rate | *d'* |
|---|---|---|---|---|
| Male | Angry | 0.60 | 0.23 | *1.13* |
| | Happy | 0.63 | 0.35 | *0.79* |
| Female | Angry | 0.66 | 0.24 | *1.25* |
| | Happy | 0.62 | 0.30 | *0.94* |

The overall hit rate (correctly identifying the previously shown face is "old") was 0.63. It was not significantly different between angry and happy faces (0.63 for both), $F < 1.0$. The hit rate was 0.04 higher for female-angry than female-happy faces (0.66 vs. 0.62, respectively) but was 0.03 lower for male-angry than male-happy faces (0.60 vs. 0.63, respectively), $F(1, 93) = 9.76$, $p < .01$, $\eta_p^2 = 0.10$. The overall false alarm rate

[3] Similar results were observed with all participants (N=96) included in the analyses. The hit rate was similar for angry and happy faces (0.62 for both), $F < 1.0$. The false alarm rate was significantly lower for angry faces (0.24) than happy faces (0.33), $F(1, 95) = 18.72$, $p < .0001$, $\eta_p^2 = 0.16$. The *d'* was larger for angry faces (1.17) than happy faces (0.85), $F(1, 95) = 12.59$, $p < .001$, $\eta_p^2 = 0.12$.

(incorrectly identified new faces as "old") was 0.28. Importantly, it was significantly lower for angry faces (0.24) than happy faces (0.33), $F(1, 93) = 18.40$, $p < .0001$, $\eta_p^2 = 0.17$, suggesting that angry faces were less likely to be falsely recognized as previously shown. The false alarm rate was 0.06 lower for female-angry than female-happy faces (0.24 vs. 0.30, respectively) but was 0.12 lower for male-angry than male-happy faces (0.23 vs. 0.35, respectively), $F(1, 93) = 14.51$, $p < .001$, $\eta_p^2 = 0.14$.

The overall sensitivity measure *d'* was 1.03. Importantly, *d'* was much larger for angry faces (1.19) than happy faces (0.87), $F(1, 93) = 12.23$, $p < .001$, $\eta_p^2 = 0.12$. In addition, the sensitivity *d'* was higher for female faces (1.09) than male faces (0.96), $F(1, 93) = 7.39$, $p < .01$, $\eta_p^2 = 0.12$. No other effects were significant for hit rate, false alarm rate, and *d'*.

Discussion

Experiment 1 examined whether the emotional valence of face images modulates recognition accuracy. As in Johansson et al. (2004), both study and recognition test sessions contained emotional faces (angry and happy). We found similar hits rates for angry and happy faces (0.63 for both), suggesting that participants correctly identified the face identity as shown earlier in the study session regardless of the emotional valence. However, participants were less likely to falsely identify the new face as one shown earlier in the study session when it contained angry emotional expression comparing to happy emotional expression (false alarm rate = 0.24 vs. 0.33 for angry and happy, respectively). The false alarm data indicate that participants were more reluctant to falsely respond that an angry face was "old" than that a happy face was "old"; given this reluctance, the hit rate for angry faces is more impressive than the hit rate for happy faces (even though they are roughly equal). This conclusion is supported by significantly higher *d'*, an overall measure of memory facilitation/enhancement, for angry faces than happy faces. Thus, using a much larger sample size (94 in our study and 16 in Johansson et al.), we were able to show that Johansson et al.'s conclusions based on ERP data alone also can be confirmed in recognition (Old/New faces) performance. In addition, we generalized their conclusion to a study with different face stimuli, twice as many face stimuli (102 in theirs vs. 200 in the present Experiment 1), and a much longer retention interval (30 seconds in theirs and 20 minutes in ours).

## Experiment 2

While Experiment 1 provided evidence, in line with Johansson et al. (2004), that negatively-valenced faces are remembered better than happy faces, note that the same exact face images were used in the study and recognition sessions. This finding does indicate an impact of emotion, but that impact could be restricted to registration of the emotional expression, rather than the registration of identity. To examine this issue, Experiment 2 tested whether angry emotion leads to a generally improved memory for that person's identity even when the emotional valence of the faces was absent during the recognition test. That is, does anger enhance a general representation of all features used to identify the face, or does it merely enhance memory of the specific features representing anger?

To make this determination, we used neutral faces in the recognition test session – half of these test faces were the same identity as the previously viewed faces ("old" but with a neutral rather than emotional expression) and half were different identities ("new"). If the emotional valence of the faces shown in the study session enhances the subsequent recognition of the facial identity, then we ought to once again observe memory enhancement: higher *d'* for previously shown angry faces than happy faces. But if anger merely enhances representation of anger-related features, then no such enhancement should be observed in this experiment, given that the neutral test faces did not have the angry expression.

Method

Participants. There were 117 participants, drawn from the same participant pool as in Experiment 1. None had participated in the previous experiment. Fifteen participants' data were excluded from the final data analyses due to their overall corrected accuracy score was smaller than the cutoff we used (0.10; see above)[4]. For the remaining 102 participants (69 females, 33 males), the mean age was 20 years (range: 18-33 years). All reported having normal or corrected-to-normal visual acuity.

Apparatus, Stimuli, and Procedure. The tasks, stimuli, and equipment were the same as in Experiment 1, except for the face images used in the recognition test session. Instead of using emotional faces, we used neutral faces – half of the faces were in the same identity as the previous shown and half were different identities. Participants were to determine whether the identity of the face image was shown earlier in the study session.

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[4] The data analyses including all participants (N=117) revealed similar patterns as the reported analyses excluding the 15 participants whose overall corrected accuracy score was smaller than the cutoff. The hit rate was identical for both angry and happy faces (0.58 for both), $F < 1.0$. The overall false alarm rate was 0.37; it was larger for male faces (0.38) than female faces (0.35), $F(1, 116) = 6.92$, $p < .01$, $\eta_p^2 = 0.06$. The *d'* was not significantly different for angry faces (0.57) and happy faces (0.60), $F < 1.0$.

<u>Results</u>

As in Experiment 1, the overall accuracy for the gender task during the study session was 0.96, which was similar for angry faces (0.95±0.05 [SD]) and happy face (0.96±0.04 [SD]). Again, this result indicated that participants were appropriately focused on the gender task. We next analyzed data from the recognition test session. The data analysis in Experiment 2 was similar to that of Experiment 1, except for the false alarm rates (incorrectly identify the identity of the neutral faces as shown earlier). The false alarm rates could not be analyzed as a function of emotional valence (angry vs. happy; i.e., all "new" neutral faces were shown in the recognition test session); therefore, they were analyzed only as a function of gender (male vs. female). Table 3 shows mean hit rate, false alarm rate, and *d'* in each condition.

Table 3.

*Hit Rate, False Alarm Rate, and Sensitivity (d') for Each Gender and Emotion Type of Face images in Experiment 2.*

| Gender | Emotion Type | Hit Rate | False Alarm Rate | *d*' |
|---|---|---|---|---|
| Male | Angry | 0.59 | 0.37 | *0.60* |
| | Happy | 0.61 | | *0.69* |
| Female | Angry | 0.60 | 0.33 | *0.72* |
| | Happy | 0.57 | | *0.66* |

The overall hit rate was 0.59, which was not significantly different between angry and happy faces (0.59 for both), $F < 1.0$. The hit rate was also 0.03 higher for female-angry than female-happy faces (0.60 vs. 0.57, respectively) but was 0.02 lower for male-angry than male-happy faces (0.59 vs. 0.61, respectively), $F(1, 101) = 6.87$, $p < .05$, $\eta_p^2 = 0.06$. The overall false alarm rate was 0.35, which was significantly higher for male faces (0.37) than female faces (0.33), *F*(1, 101) = 5.59, $p < .05$, $\eta_p^2 = 0.05$. Note that because test faces were always neutral, the happy and angry conditions necessarily have the exact same false alarm rate (i.e., emotion cannot influence false alarms at test, since no emotion was presented at test).

The overall *d'* was 0.66. In contrast to the findings of Experiment 1, the *d'* was similar for angry faces (0.66) and happy faces (0.67), $F < 1.0$. The *d'* was higher for female-angry faces (0.72) than female-happy faces (0.66), but was lower for male-angry faces (0.60) than male-happy faces (0.69), *F*(1, 101) = 7.66, $p < .01$, $\eta_p^2 = 0.07$. No other effects were significant for hit rate, false alarm rate, and *d'*.

<u>Discussion</u>

To assess whether angry emotion leads to a generally improved memory for that person's identity, Experiment 2 used neutral faces instead of the same emotional valence of faces as used in Experiment 1 in the recognition test session. The overall hit rate decreased from 0.63 in Experiment 1 to 0.59 in Experiment 2. A between-experiment comparison showed that this decrease was significant, *t*(194) = 2.68, $p < .01$, suggesting that participants were less able to correctly identify the previously shown facial identity when the emotional expression changed. Along with the decrease in hit rate, the overall false alarm rate significantly increased from 0.28 in Experiment 1 to 0.35 in Experiment 2, *t*(194) = -5.51, $p < .0001$. Participants were more likely to falsely identify the new identity of neutral faces as the previously shown facial identity. The overall *d'* decreased significantly from 1.03 in Experiment 1 to only 0.66 in Experiment 2, *t*(194) = 8.58, $p < .0001$.

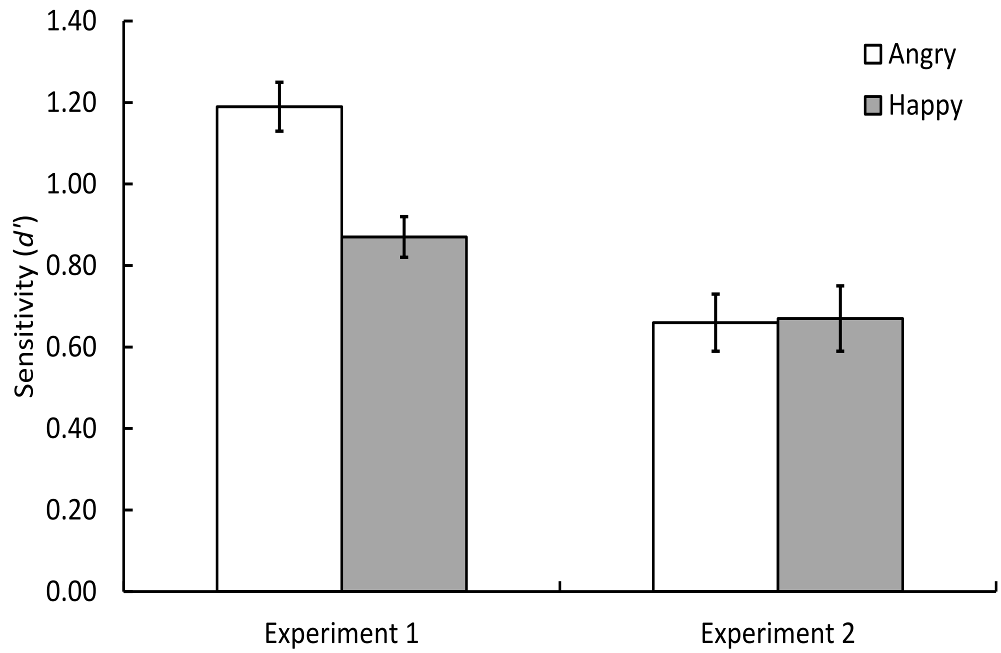


*Figure 2.* Overall sensitivity (*d'*) for face emotion at study (angry vs. happy) in Experiments 1 and 2. The error bar represents the standard error of the mean.

Although the overall hit rate decreased from Experiments 1 to 2, the hit rate was not modulated by emotional valence of the faces shown in the study session. Critically, the observed memory enhancement for angry faces over happy faces in Experiment 1 (*d'* = 1.19 vs. 0.87, respectively) was not evident in Experiment 2 (*d'* = 0.66 vs. 0.67, respectively), $F(1, 194) = 10.72$, $p < .01$, $\eta_p^2 = 0.05$. The difference in *d'* between angry and happy faces in Experiment 2 was only -0.01±0.09 (95% confident interval). Thus, our data allow us to argue against a *d'* difference larger than 0.08, which is quite small, especially when compared to the *d'* difference between angry and happy faces observed in Experiment 1 (0.32). The between-experiment comparison revealed that the decrease in *d'* from Experiment 1 to Experiment 2 was more pronounced for angry emotion (*d'* was 1.19 and 0.66, respectively) than happy emotion (0.87 and 0.67), $F(1, 194) = 10.73$, $p < .01$ (see Figure 2). Thus, with incidental learning, memory enhancement occurs only when the same expression is used at both study and test.

# GENERAL DISCUSSION

The present study examined whether emotional valence of faces during study leads to a generally improved memory for that person's identity in recognition even when the emotional valence was absent. Participants first performed a gender discrimination task on a face expressing either an angry or happy emotion, unaware that they would later be tested on their recognition of those faces (i.e., incidental learning). They then performed a 20-minute distraction task. Finally, they were given the recognition test, judging whether a face was shown earlier (old vs. new identity). Experiment 1 used the same emotionally-valenced faces in both the study and recognition test sessions, whereas Experiment 2 used the emotionally-valenced faces in the study session but neutral faces in the recognition test session. We used *d'* as an index of the ability to discriminate old-new face identity.

We found a higher *d'* for angry faces, relative to happy faces, when the exact same face picture – showing the same emotion – was used during the later recognition test (Experiment 1; 1.19±0.13 for angry faces vs. 0.87±0.10 for happy faces). This finding demonstrates memory enhancement even when participants have no reason to remember the faces and no reason to attend to emotion. This finding of emotion-induced memory enhancement for negative emotion is consistent with previous incidental learning studies suggesting more accurate recognition memory for negative faces than neutral (e.g., Johansson et al., 2004; Wang, 2013). Although Johansson et al. (2004) found little to no support for enhancement in their recognition (Old/New faces) data, which was disconcerting, we documented substantial enhancement using a much larger sample size (16 in Johansson et al. vs. 94 in the present study).

However, the emotion-induced memory enhancement for angry faces was abolished when neutral faces were used at test (Experiment 2), as indicated by similar *d'* for both previously shown angry and happy faces (0.66±0.07 vs. 0.67±0.08, respectively). This finding suggests that the automatic enhancement of face encoding caused by negative facial expressions is relatively shallow. Negative emotional expressions improve memory for that specific image (e.g., the expression of anger), without improving general memory for that person's identity.

**Response Bias Toward Negative Emotion**

In Johansson et al. (2004), negative emotion produced overall higher hit rate and false alarm rate than positive and neutral emotions, which led them to suggest the adoption of liberal response bias toward negative emotion. To critically evaluate this claim, we followed Stanislaw and Todorov (1999; see also Abdi, 2007) and quantified response bias for each participant using $\beta = d' \times -0.5 \times (Z(\mathit{Hit\ Rate}) + Z(\mathit{False\ Alarm\ Rate}))$, which was then analyzed as a function of emotion type and gender. We examined whether the emotional expression of faces during the recognition test induces a response bias in Experiment 1. Since there was no emotional expression on faces for the recognition test in Experiment 2, it is not possible to conduct the same analysis.

Results from Experiment 1 showed that $\beta$ was larger for angry faces (0.35) than happy faces (0.13), $F(1, 93) = 8.31$, $p < .01$, $\eta_p^2 = 0.08$, signifying a less likelihood of saying "yes, it was previously shown [Old]" for angry faces than happy faces. This conservative response bias is inconsistent with Johansson et al.'s (2004) finding of a liberal response bias toward negative emotion. The reasons for the discrepancy are not clear, though an obvious culprit would be methodological differences – differences in the face stimuli used (e.g., differences in strength of emotional expression), the number of face stimuli used (102 in their study vs. 200 in the present study), and the duration of the distraction task (30 seconds in their study vs. 20 minutes in the present study). In addition, we found that a much larger difference in response bias between angry and happy faces for males faces (0.42 vs. 0.04, respectively) than female faces (0.27 vs. 0.22), $F(1, 93) = 10.09$, $p < .01$, $\eta_p^2 = 0.10$. This gender difference might reflect gender profiling and stereotyping for potential threat; that is, females are believed to pose less of a social threat than their male counterparts (e.g., Niedenthal, Kauth-Gruber, & Ric, 2006).

**The Presence vs. Absence of Negative Emotion-Induced Memory Enhancement**

There are two main questions that arose from the present finding – why emotion-induced memory enhancement occurred only for the negatively-valenced emotion, and why it was observed only when the same emotional valence was used during study and recognition test.

With respect to the first question, some studies have shown an enhancement of visual processing of negative facial expressions over other expressions, including greater and even involuntary capture by negative emotion, perhaps reflecting survival value (anger signals a potentially dangerous situation; e.g., Byrne & Eysenck, 1995; Derakshan & Koster, 2010; Eastwood, Smilek, & Merikle, 2003; Ikeda, Sugiura, & Hasegawa, 2013; Öhman et al., 2001; Vuilleumier & Schwartz, 2001). For instance, Shaw et al. (2011) used a dual-task paradigm to examine whether processing of emotionally-valenced faces occurs automatically even when central attention is allocated to another non-emotional task (a tone task). Using ERP measures, they found that more pronounced N2pc effects (an index of the allocation of spatial attention) toward angry faces than happy faces under dual-task conditions. This trend occurred to some degree even when participants were told to look for happy faces. They argued that faces expressing a negative emotion have inherently high attentional priority because rapid recognition of negative facial emotions increases the odds of survival. The attentional priority for negative facial emotions might have enhanced subsequent recognition when those emotions were present again.

On the other hand, some studies have suggested that the negative emotion do not have the inherent power to capture attention involuntarily (see Lien, Taylor, & Ruthruff, 2013 for evidence that fearful faces capture attention but only when facial expressions were relevant to the task). However, they might delay the disengagement of spatial attention (e.g., Belopolsky, Devue, & Theeuwes, 2011; Fox et al., 2001; Georgiou et al., 2005). For instance, Belopolsky et al. (2011) showed that angry emotional faces elicited a large sustained posterior contralateral negativity, which has been associated with sustained attention and maintenance of visual information in short-term memory. Despite the subtle difference between the involuntary capture and delayed disengagement ideas, both views agree that negatively-valence expressions, especially angry ones, have an impact on spatial attention (e.g., Hansen & Hansen, 1988). Since attention plays a critical role in determining what to remember (see Chun & Turk-Browne, 2007), the anger superiority effect observed in attention literature would indicate that attention allocated to angry faces is sufficient to raise the likelihood of remembering that specific emotional face was studied.

With respect to the second question of why emotion-induced memory enhancement by negative emotion was observed only when the same emotional valence was used at both study and test, it is possible that emotion expression does not serve as the context/source to guide memory of a specific event, such as a face (e.g., Damasio, 2008). Rather, the to-be-remembered face is a combination of the facial emotion and the facial identity. Accordingly, the absence of the facial emotion during the recognition test would hinder face memory. Nevertheless, this explanation does not explain why emotion-induced memory enhancement occurs for negative but not positive emotion when the same emotionally-valenced faces were used at recognition test in Experiment 1. It is plausible that negative facial expressions are salient features that capture attention and disrupt processing of other local face features (e.g., D'Argembeau et al., 2003; Eastwood, Smilek, & Merikle, 2003). This disruption might hinder identity recognition when the negative emotion expression is absent at recognition test. Consistent with this argument, the decrease in *d'* from Experiment 1 to Experiment 2 was more noticeable for angry emotion (1.19±0.13 to 0.66±0.07, respectively) than happy emotion (0.87±0.10 to 0.67±0.08), $F(1, 194) = 10.73$, $p < .01$.

Alternatively, different levels of focus in processing positive vs. negative emotional faces during study may be responsible for the different degree in decline for recognition memory of face identity. Gasper and Clore (2002) have argued that negative emotion is typically processed in a local, analytical fashion (e.g., the trees rather than the forest) and is often remembered with specific local attributes. However, positive emotion is processed in a global manner (e.g., the forest) and is often remembered with less contextual detail. Thus, when local attributes of emotional expressions are removed from faces (i.e., from Experiment 1 to Experiment 2), the facilitation of local attributes associated with negative emotions for memory could have disappeared (see also

Kensinger, 2007).

## Relations to Previous Studies

There are few previous studies with incidental learning that directly compared the effect of emotional valence on the recognition of face identity when the same emotional faces versus neutral faces were used in the recognition test using the same face stimuli as in our present study (D’Argembeau et al., 2003; D’Argembeau & Van der Linden, 2004; D’Argembeau & Van der Linden, 2011; Shimamura et al., 2006). While there has been a trend showing an enhancement of memory for previously seen positive faces (D’Argembeau & Van der Linden, 2007; D’Argembeau & Van der Linden, 2011; Mather & Carstensen, 2003; Shimamura et al., 2006), the evidence is far from conclusive (D’Argembeau et al., 2003; D’Argembeau & Van der Linden, 2004). Our study further extended D’Argembeau et al.’s (2003) finding with a much larger sample size (e.g., 32 in theirs and average 98 between Experiments 1 and 2 in ours) and a larger set of face stimuli (24 face identities in theirs and 200 in ours) and found that memory enhancement by negative emotion did not occur when neutral faces were used during the recognition test.

The absence of a differential memory enhancement by either angry or happy emotions ($d'$ = 0.66±0.07 vs. 0.67±0.08, respectively) in our Experiment 2 contrasts with the findings of Shimamura et al.’s (2006) and D’Argembeau and Van der Linden’s (2007; 2011) incidental learning studies in which emotional faces were used during study and neutral faces were used during the recognition test. Shimamura et al. found that $d'$ was higher for happy emotion than for other emotions (1.39, 0.40, 0.34, and 0.36 for happy, angry, fear, and surprise, respectively, in their Experiment 1). While D’Argembeau and

Van der Linden did not use SDT in either of their analyses, they also found that positive facial expressions at test had a higher proportion of hits. It should be noted that Shimamura et al. used only 4 different faces for each emotion, which repeated twice for each participant during the study session, and D'Argembeau and Van der Linden only used a total of 16 faces (8 angry and 8 happy) at study in both of their studies. Such a small set of faces and the use of repetition might have increased the familiarity of faces with different emotions. Furthermore, Shimamura et al. administered the recognition test immediately following the study session without any distraction task in-between, whereas the present Experiments 1 and 2 inserted a 20-minute distraction task (note that there was a 5-minute retention interval without distractions in D'Argembeau et al., 2003). The distraction ensures that all recognition tests are based on long-term (not short-term) memory and also better simulates real-world conditions in which there can be a substantial delay before revisiting a face. It is possible that the impact of positive emotion in recognition of facial identity is a short-lived effect, which dissipates over a modest retention interval.

Righi et al. (2012) also used neutral faces at test and demonstrated a memory enhancement for fearful emotional faces with Pr and ERP measure, which is in line with our original hypothesis. Unlike the present study, study and test phases were alternated in a series of 10 blocks and the study task involved the identification of the emotion in the image. These conditions fostered intentional learning. The enhancement of formerly fearful faces at test, suggests that emotional valence can have a strong impact on the ability to discriminate faces when the observer is aware that the face will have to be identified in the future. The intermixed block design used in Righi et al. meant that individuals had to discriminate between fewer faces at each test (22 old faces from 12 new faces), which combined with the short time between study and test phases (3 minutes), may indicate that the emotional enhancement for facial identity disappears under circumstances of high difficulty, but the emotional enhancement of the image itself is still present. However, it is also possible that fearful and angry faces have differential effects on memory that prevent their comparison despite both being negatively valenced.

**Limitations & Future directions**

With 200 facial identities used, as well as a long distraction task of 20 minutes, the present study task can be noted to be of greater difficulty than the tasks found in much of the previous emotional face literature. Thus, one could argue that the disappearance of a difference in sensitivity in Experiment 2 is due to the additional difficulty increase of having to identify previously unseen faces, effectively creating a floor effect. However, our results suggest that this is not the case. Participants had a mean discrimination of 0.24 for angry faces and 0.24 for happy faces in Experiment 2, which was similar to the discrimination found in Johansson et al. (2005) Experiment 1 (0.26 for positive, negative and neutral). Participants in Experiment 2 also displayed a respectable overall *d'* (0.66 averaged across happy and angry faces) in comparison to Experiment 1 of Shimamura et al. (2006) which found *d'* of less than 0.50 for all conditions except happy, using only 20 facial images and repeated exposures. This suggests that the task, while challenging, is not so difficult that performance differences should be washed out. This leaves us with the possibility that our study is tapping into something different than studies that utilize smaller image sets and have shorter, less-involved distraction tasks. Grady et al. (2007) notes that studies showing enhancement of positive faces have typically used smaller image sets than those that find memory enhancement of negative faces, suggesting that set size is a moderating factor for emotional memory. Intuitively this makes sense, as the demands of interacting with a large crowd have significant differences than interacting with a smaller group of people. Under circumstances in which we are briefly presented with a large number of faces, there might be less incentive to encode facial identities, but we still have our attention captured by emotion laden features. Since the increase in sensitivity for angry faces is driven by a decreased false alarm rate in Experiment 1, it is possible that angry faces are scrutinized more closely at test.

In order to expand on this it would be beneficial to follow in the footsteps of Johansson et al. (2004) and include RKG judgments. It has been shown that emotional manipulations increase the contribution of recollection as opposed to familiarity, especially for negative emotions (e.g., Dolcos et al., 2005; Johansson et al., 2004; Ochsner, 2000; Sharot et al., 2004). Under the current study design it is possible that the increased sensitivity to the angry emotional faces in Experiment 1 is driven by recollection, with equal contributions to angry and happy faces from familiarity. In Experiment 2, the ability to effectively use recall is hampered by the fact that all of the images are different from those seen during study. Thus, one would expect the percentage of remembering responses to be higher for angry faces than happy faces in Experiment 1 but not in Experiment 2.

In addition to determining the contributions of recollection and familiarity, our study lacked the baseline that is provided by having neutral faces in the study phase. The neutral baseline would provide information regarding whether any emotion produces an encoding benefit over the absence of an emotion, in addition to which kind of emotional valence is superior. The power of the study could be further strengthened by making the test session manipulation a within-subjects design, so that each participant saw both emotional and neutral faces at study and at test. While this would greatly reduce the number of trials in each condition, the present study used many more identities than past studies (200 vs 24 in D'Argembeau et al., 2003), and the additional power of a within-subjects design should still allow for strong inferences to be made.

To additionally separate out the contribution of the face identity vs. the emotional expression at the test phase, it would be beneficial to add a comparison experiment in which the "old" faces contain a different emotion as in the study phase. If different images of faces with the same or similar emotion produce results similar to those found in Experiment 1, with the angry emotions allowing observers a greater sensitivity than happy emotion, then this would provide evidence that negative valence enhances at least some of the facial features used to identify an individual. However, if results replicate Experiment 2 with no difference in the sensitivity between happy and angry emotions, then our findings are likely due to the enhancement of the memory for the image, not the identity. This approach would further strengthen our conclusion and deserves further investigation.

The adjustments to the paradigms design would help answer the current question of interest with greater certainty, but we can also look to apply the paradigm to other questions. For example, it has been theorized that older adults respond to emotional stimuli differently than younger adults (D'Argembeau & Van der Linden, 2004; Grady et al., 2007). While some research has found minimal age-related differences in memory for emotional stimuli (Kensinger, Brierly, Medford, Growdon & Corkin, 2002), others have found that the enhancement of negative stimuli is absent in older adults and that positive stimuli have enhanced recollection (Charles, Mather, & Carstensen, 2003). This falls in line with the socioemotional selectivity theory, which posits that older adults are motivated to monitor and select their environment to maximize emotional meaningfulness and wellbeing, while younger adults are motivated to acquire information and monitor novelty to a greater extent (e.g., Carstensen, Isaacowitz, & Charles, 1999). Socioemotional selectivity theory predicts the improved emotional regulation found in older adults, and suggests that they do not have the relative advantage for negative emotional stimuli compared to younger adults, while still receiving a benefit for positive emotional stimuli. While most past research examining age differences has looked at emotional words or scenes, it seems likely that memory for emotional faces should follow a similar pattern, with happy faces producing a greater sensitivity. Previous research that has looked at emotional faces has been inconsistent, with some researchers finding no difference between older and younger adults (D'Argembeau & Van der Linden, 2004), while others have demonstrated worse performance on negative faces in older adults (Grady et al., 2007). The aforementioned lack of methodological consistency in studies of emotional faces is also found in aging studies for memories of emotional faces. Extending the present study to look at older adults would provide additional insight into this phenomenon.

# CONCLUSION

The main finding of the present study was that in an incidental learning setting, recognition of facial identities was modulated by the emotional valence of to-be-remembered faces only when the exact same image was presented at study and recognition test.  While negative emotional expressions improve subsequent recognition memory for that specific image (a relatively shallow effect), they do not necessarily improve general memory for that person's identity. This finding may be somewhat limited in its scope, given the methodological confines of the study, but it does speak to a common life experience. We are often in situations in which we encounter the faces of strangers that we may never see again, as we walk down a busy street or grab a drink at a coffee shop.  Faces carrying negative valence may signify danger or a threat and demand our attention, but in such passing encounters it is rarely important who the individual is unless we further interact with them.

One major real-world implication for eye-witness testimony is that it may be better to have individuals in a mugshot or police line-up adopt angry expressions than it would be to have them maintain a neutral expression. If a perpetrator committed the crime while expressing anger or threat, a negatively valenced lineup would reduce the rate of false accusations due to the greater sensitivity to features carrying negative emotions. Before implementation, further research will be needed, given that social circumstances are very different from the laboratory and it may not be practical to convince possible criminals to adopt an angry expression before being scrutinized. However, the findings do belie a need for awareness regarding the interaction between emotion and memory in situations where the identification of a face is significant.

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