

A Tale of Two Negatives: Differential Memory Modulation by Threat-Related Facial Expressions

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Facial expressions serve as cues that encourage viewers to learn about their immediate environment. In studies assessing the influence of emotional cues on behavior, fearful and angry faces are often combined into one category, such as “threat-related,” because they share similar emotional valence and arousal properties. However, these expressions convey different information to the viewer. Fearful faces indicate the increased probability of a threat, whereas angry expressions embody a certain and direct threat. This conceptualization predicts that a fearful face should facilitate processing of the environment to gather information to disambiguate the threat. Here, we tested whether fearful faces facilitated processing of neutral information presented in close temporal proximity to the faces. In Experiment 1, we demonstrated that, compared with neutral faces, fearful faces enhanced memory for neutral words presented in the experimental context, whereas angry faces did not. In Experiment 2, we directly compared the effects of fearful and angry faces on subsequent memory for emotional faces versus neutral words. We replicated the findings of Experiment 1 and extended them by showing that participants remembered more faces from the angry face condition relative to the fear condition, consistent with the notion that anger differs from fear in that it directs attention toward the angry individual. Because these effects cannot be attributed to differences in arousal or valence processing, we suggest they are best understood in terms of differences in the predictive information conveyed by fearful and angry facial expressions.

Keywords: facial expressions, memory, attention, emotion

A wealth of literature suggests that emotional cues can modulate memory by enhancing perception and attention during encoding (Christianson & Loftus, 1987; Easterbrook, 1959; McGaugh, 2004; Phelps, Ling, & Carrasco, 2006; Talmi, Anderson, Riggs, Caplan, & Moscovitch, 2008; Tulving, 2002). Although many experiments probing emotional enhancement of memory use

highly arousing negative stimuli that elicit strong emotional responses from viewers, other experiments demonstrate that subtle stimuli communicating emotional states, such as pictures of facial expressions, can also enhance memory (Sergerie, Lepage, & Armony, 2007; Vuilleumier, 2002). Many of these studies use a dimensional approach to assessing emotion (see Hamann, 2009), emphasizing the effects of either emotional valence (e.g., Maratos, Dolan, Morris, Henson, & Rugg, 2001; Sergerie et al., 2007) or emotional arousal (e.g., Anderson, Wais, & Gabrieli, 2006; Bradley, Greenwald, Petry, & Lang, 1992; Cahill & McGaugh, 1998) on memory.

Recent research has gone beyond examining the modulatory effects of valence and arousal on information processing, to consider the communicative value of specific emotions such as fear. Fearful facial expressions are social cues that signal to the viewer that there is a potential threat in the environment. Consistent with this notion, viewing pictures of fearful faces facilitates sensory processing by enhancing participants' ability to discriminate other visual stimuli present in the experimental context (Becker, 2009; Phelps et al., 2006). It is interesting that the act of displaying a fearful expression modulates an individual's sensory intake. Susskind et al. (2008) showed that the physical facial feature changes

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that constitute a fearful expression (i.e., expanding the eyes and nostrils) enhance one's ability to gather information from the environment.

Although fearful facial expressions serve as a warning signal to viewers, they provide no information about the source of threat, that is, what in the immediate environment may have elicited the expression. We have suggested previously that fearful expressions should facilitate processing of the immediate context (Whalen, 1998), defined broadly as information spatially or temporally proximal to the fearful expression. The present study evaluated the extent to which the communicative value of fear, beyond its negative and arousing qualities, facilitates contextual information processing. To do so, we compared the effects of fearful and angry facial expressions on memory for contextual information. Fearful and angry faces are equally negative and arousing but hold a divergent communicative signal. Specifically, in contrast to fearful faces, angry faces embody the very threat that they predict—an individual expressing anger communicates aggression toward the target of their gaze (e.g., the viewer). Previous research has shown that static pictures of fearful and angry facial expressions can be equated in terms of subjective reports of negative valence (Ekman, 1997; Johnsen, Thayer, & Hugdahl, 1995; Matsumoto, Kasri, & Kookan, 1999) and both subjective reports and objective measures (e.g., electrodermal activity) of emotional arousal elicited by the face presentations (Johnsen et al., 1995).

The present experiments evaluated the extent to which the presence of fearful and angry facial expressions would modulate information processing in accordance with the differential communicative signals they express to the viewer. To this end, neutral words were embedded within blocks of fearful and angry facial expressions. Although context is commonly manipulated in a concurrent, spatial domain (e.g., Easterbrook, 1959), contextual information presented immediately before and after the expression is consistent with the manner in which information gathering occurs in real life. For example, observing a fearful facial expression might lead to immediately surveying the environment, whereas observing an angry face might lead one to focus their attention on the individual producing the expression.

In Experiment 1, we assessed memory for neutral words presented within separate blocks of fearful, angry, and neutral faces. We hypothesized that, in comparison with neutral face blocks, memory for contextual words would be enhanced during fearful face blocks but not during angry face blocks. We had a clear prediction that angry faces would not facilitate memory for neutral words in the same way as fearful faces, and because previous research has shown that they capture attention (Fox, Russo, Bowles, & Dutton, 2001; Fox, Russo, & Dutton, 2002; Holmes, Bradley, Kragh Nielsen, & Mogg, 2009; Maratos et al., 2001; Mogg & Bradley, 1999; Schupp et al., 2004; Williams, Moss, Bradshaw, & Mattingley, 2005), we thought that their presence might even attenuate memory for neutral words. In Experiment 2, we directly tested this idea by comparing the effects of fearful and angry facial expressions on memory for the contextual words versus the faces themselves. We hypothesized that memory would be facilitated for information present in the temporal context (i.e., the neutral words) embedded in fearful face blocks and that memory would be facilitated for the faces in the angry face blocks.

Experiment 1

Method

Eighty healthy adults (ages 18–45; 40 male, 40 female) participated in this experiment. Participants were screened for psychiatric illness with an abbreviated version of the non-patient edition of the Structured Clinical Interview for the *DSM* (First, Spitzer, Gibbon, & Williams, 2002), which assessed for current and past history of major depressive disorder, dysthymia, hypomania, bipolar disorder, specific phobia, social anxiety disorder, generalized anxiety disorder, and obsessive–compulsive disorder. Informed consent was obtained in accordance with the guidelines of the Human Subjects Committee of the University of Wisconsin—Madison.

Stimuli

Face stimuli (Ekman & Friesen, 1976) consisted of 10 angry, 10 fearful, and 10 neutral faces as defined by high normative consensus ratings associated with this stimulus set. To control for gender, attractiveness, and other lower level aspects of the face stimuli, each of the emotion categories comprised the same 10 identities (50% male). Faces were aligned vertically with the middle of the pupils and horizontally with the nose in the center and matched on contrast and brightness.

Word stimuli were chosen from the MRC Psycholinguistic Database (www.psy.uwa.edu.au/MRCDataBase/mrc2.html#CONC) and consisted of 20 neutral words split into two lists of 10. Word lists were matched on concreteness, familiarity, imageability, written frequency, number of letters, and number of syllables (all $ps > 0.30$), and were counterbalanced with respect to face conditions across participants. Stimuli were presented in grayscale on a black background using MacStim software (<http://www.brainmapping.org/WhiteAnt/>).

Task Structure

An experimental block consisted of alternating presentations of face and word stimuli, with a given block containing a single emotion type. Modeled after previous neuroimaging studies by this group (Whalen et al., 2001), each block contained a 200-ms face presentation immediately followed by an 800-ms word presentation, with faces and words alternating continuously until each of the 10 word and face stimuli were displayed (duration: 10 s; see Figure 1). Emotion (angry or fearful) and neutral blocks each contained unique sets of words so that participants saw a particular word embedded only within one type of block, and word lists were counterbalanced so that all words appeared in both the emotional and neutral face blocks across participants. A 5-s fixation period was presented between each block. The type of emotion block (angry or fearful) was varied between participants so that half (40) of the participants viewed only angry and neutral face blocks, and the other half viewed only fearful and neutral face blocks. Each block was presented twice, meaning that participants viewed each face and word stimulus twice during the experiment. Thus, each participant viewed a total of four blocks of faces and words in an ABBA design that was counterbalanced across participants (i.e., emotion/neutral/neutral/emotion or neutral/emotion/emotion/neutral), where all stimuli were repeated in the final two blocks.

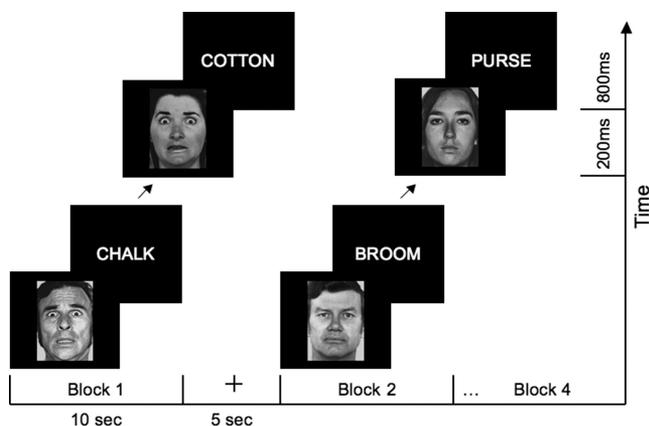


Figure 1. Experiment 1 paradigm design. In a between-participants design, 50% of participants viewed blocks of fearful faces alternating with neutral words and blocks of neutral faces alternating with neutral words. The other 50% of participants viewed blocks of angry faces alternating with neutral words and blocks of neutral faces alternating with neutral words. Faces were presented for 200 ms, and words were presented for 800 ms. A 5-s fixation period separated blocks. Images from *Pictures of Facial Affect*, by P. Ekman and W. V. Friesen, 1976, Palo Alto, CA: Consulting Psychologists Press. Copyright 1976 by P. Ekman and W. V. Friesen. Reprinted with permission from Paul Ekman, Ph.D./Paul Ekman Group, LLC.

Procedure

Participants were told that they would passively view a series of words and faces on a computer screen and that, after the task, they would be asked to complete some questionnaires. Participants then completed the Edinburgh Handedness Inventory (Oldfield, 1971) as a brief distracter. Finally, they were given a surprise free recall test, where they were asked to write down all of the words they remembered from the computer task. This recall task was self-paced, and the time that elapsed between the study and test phases was approximately 10 min.

On completion of the experiment, participants rated explicit valence (“How positive or negative is the expression on this face?”) on a scale ranging from 1 (*very positive*) to 9 (*very negative*) and rated arousal (“How much emotional arousal do you feel when looking at this face?”) on a scale ranging from 1 (*the least amount of emotional arousal I have ever felt*) to 9 (*the most emotional arousal I have ever felt*).

Data Analysis

Valence and arousal ratings were evaluated with a 2 (group: fear, anger; between) \times 2 (condition: emotional, neutral; within) analysis of variance (ANOVA). We predicted no main effect of group, indicating that participants who viewed the fearful face blocks did not rate any of the faces as more positive or negative than participants who viewed the angry face blocks. In contrast, we predicted a main effect of emotion, with participants rating the emotional faces as both more arousing and more negative than the neutral faces.

Recall data were corrected for intrusions by calculating (hits – false alarms)/(10, which is the total number of old words). A 2

(group: fear, anger; between) \times 2 (condition: emotional, neutral; within) ANOVA was computed to evaluate differences in recall for words. Directionality of significant interactions was evaluated with post hoc paired-samples *t* tests (one-tailed). We predicted an interaction where word recall would be enhanced for fearful, compared with neutral, face blocks but not in angry, compared with neutral, face blocks.

Results

Stimulus Ratings

There was a main effect of condition (emotional vs. neutral faces) for both the valence ratings, $F(1, 78) = 529.712, p < .001$; and the arousal ratings, $F(1, 78) = 156.411, p < .001$; but no interaction between group and condition for either the valence ratings, $F(1, 78) = 0.967, p = .328$; or the arousal ratings, $F(1, 78) = 2.722, p = .103$. On average, participants rated the emotional faces more negatively and more emotionally arousing than the neutral faces: For fearful faces, the mean valence rating = 6.692 ($SD = 0.110$) and the mean arousal rating = 3.995 ($SD = 0.217$); for angry faces, the mean valence rating = 6.813 ($SD = 0.107$) and the mean arousal rating = 4.153 ($SD = 0.261$). For neutral faces (for participants who saw fearful and neutral faces), the mean valence rating = 4.873 ($SD = 0.053$) and the mean arousal rating = 2.256 ($SD = 0.167$); for neutral faces (for participants who saw angry and neutral faces), the mean valence rating = 4.830 ($SD = 0.078$) and the mean arousal rating = 2.820 ($SD = 0.177$).

Consistent with fearful and angry faces being equated on valence and arousal, there was no main effect of group (fear vs. angry) for valence ratings, $F(1, 78) = 0.161, p = .689$; or arousal ratings, $F(1, 78) = 1.797, p = .184$. Direct comparison of valence and arousal ratings of fearful and angry faces further supported that the stimuli were matched on valence, $t(78) = -0.783, p = .436$; and arousal level, $t(78) = -0.464, p = .644$. The variability of ratings was also comparable for fearful and angry stimuli as indicated by nonsignificant results of Levene’s tests for equality of variance (valence: $p > .9$; arousal: $p > .12$).

Memory

See Table 1 for the full descriptive statistics of Experiment 1’s memory findings. A 2 (group: fear, anger) \times 2 (condition: emotional, neutral) ANOVA revealed a significant interaction between group and condition, $F(1, 78) = 4.189, p = .044, \eta^2 = 0.050$. (This interaction was equivalently significant when we used hits uncorrected for false alarms as the dependent variable.) There was no main effect of group, $F(1, 78) = 0.774, p = .382, \eta^2 = 0.010$; and no main effect of condition, $F(1, 78) = 0.792, p = .376, \eta^2 = 0.010$; on corrected word recall. Paired-samples *t* tests indicated that participants recalled more words from the fearful blocks, compared with the neutral blocks, $t(39) = 2.196, p = .018, d_z = 0.343$; and that there was no difference in the number of words recalled in the angry blocks, compared with the neutral blocks, $t(39) = -0.786, p = .219, d_z = -0.124$ (see Figure 2).

Experiment 2

Experiment 1 provided initial evidence supporting the prediction that fearful faces enhance processing of contextual informa-

Table 1
Raw Proportion of Words Recalled by Block Type in Experiment 1

<i>M</i> and <i>SD</i>	Fear sample			Anger sample		
	Fear	Neutral	No. of false alarms	Anger	Neutral	No. of false alarms
<i>M</i>	.34	.26	.33	.27	.30	.5
<i>SD</i>	.17	.21	.53	.18	.21	.78

Note. Mean values for fear, neutral, and anger represent proportions correctly recalled. Mean values for false alarm represent mean number of false alarms.

tion. It is interesting that, compared with neutral faces, angry faces did not facilitate memory for contextual information although they were rated equally with fearful faces on emotional valence and arousal. Indeed, because angry faces provide direct information about the source of threat (i.e., the person making the facial expression), they might call for more direct attention toward the threatening information itself, compared with the diffuse attention for contextual information called for by fearful expressions. This pattern of results motivates the hypothesis that angry faces should encourage people to attend to and learn about the faces themselves, whereas fearful expressions should encourage people to learn about the immediate context.

In Experiment 2, we expanded the number of face identities in a within-participant design to directly address word and face memory in fearful, compared with angry, face blocks. We predicted that participants would recognize more words in the fearful, compared with angry, face blocks but more faces in the angry, compared with fearful, face blocks.

Method

Twenty-seven healthy adults (11 male, 16 female; ages 18–25) participated in this experiment. Participants were screened for psychiatric illness as in Experiment 1. Of these, 24 completed the valence and arousal ratings. Informed consent was obtained in accordance with the guidelines of the Committee for Protection of Human Subjects at Dartmouth College.

Stimuli. Face stimuli consisted of 20 angry (10 targets, 10 foils) and 20 fearful (10 targets, 10 foils) faces with unique identities compiled from four stimulus sets (Ekman & Friesen, 1976; Lundqvist, Flykt, & Öhman, 1998; Matsumoto & Ekman, 1988; Tottenham et al., 2009)¹ and counterbalanced so that identity was not repeated between conditions (i.e., fear/angry). Gender of faces was equal (50% male) within and across conditions. Word stimuli consisted of 40 neutral words split into four groups of 10 (20 targets and 20 foils). Word lists were matched on concreteness, familiarity, imageability, written frequency, number of letters, and number of syllables as in Experiment 1 (all $ps > .30$) and were counterbalanced across conditions. Stimuli were presented in the center of the screen in grayscale on a black background with E-Prime software (Psychology Software Tools, Pittsburgh, PA).

Procedure. During a block of trials, participants viewed 10 fearful or angry faces (200 ms) interleaved with 10 neutral words (800 ms), as described in Experiment 1, with the following key differences. In contrast to Experiment 1, the face identities in the fearful and angry conditions were different (the words presented in the fearful and angry face blocks were also different, as in Experiment 1). Each block was repeated once, so that participants

viewed each stimulus twice during the experiment (see Figure 3). Thus, each participant viewed four blocks of faces (10 faces per condition) and words that were counterbalanced across participants (fear/angry/angry/fear or angry/fear/fear/angry). Participants then completed the State-Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1988) as a brief distracter, followed by surprise word and face recognition tasks. In the recognition test, participants were presented with 20 pseudorandomly intermixed target stimuli and 20 foils and were asked to indicate whether they had seen the stimulus earlier in the experiment. Face stimuli were presented one at a time in the center of the screen in grayscale on a black background with E-Prime software (Psychology Software Tools, Pittsburgh, PA), and participants pressed one of two keys indicating whether the face was “old” or “new.” Word stimuli were all presented on one sheet of paper, and participants were asked to circle the words they saw during the experiment. Both the face and word recognition tasks were self-paced. Order of the recognition tasks was counterbalanced across participants, and no feedback was provided. The time that elapsed between the study and test phases was approximately 10 min.

On completion of the experiment, participants rated explicit valence (“How positive or negative is the expression on this face?”) on a scale ranging from 1 (*very positive*) to 9 (*very negative*) and rated arousal (“How much emotional arousal do you feel when looking at this face?”) on a scale ranging from 1 (*the least amount of emotional arousal I have ever felt*) to 9 (*the most emotional arousal I have ever felt*).

Data analysis. Recognition data were corrected for false alarms by calculating $(\text{hits} - \text{false alarms}) / (\text{total number of old stimuli, whether words or faces})$. We computed a 2 (stimulus: faces, words) \times 2 (emotion: fear, anger) within-participant ANOVA to evaluate the predicted interaction, and we evaluated post hoc contrasts using paired-samples t tests (one-tailed). Valence and arousal ratings were evaluated with paired-samples t tests.

Results

Stimulus ratings. As predicted, there were no significant differences in valence ratings, $t(23) = -0.017$, $p = .987$; or arousal ratings, $t(23) = -0.230$, $p = .820$. For fearful faces, the average valence rating = 5.583 ($SD = 0.161$), and the average

¹ Development of the MacBrain Face Stimulus Set was overseen by Nim Tottenham and supported by the John D. and Catherine T. MacArthur Foundation Research Network on Early Experience and Brain Development. Please contact Nim Tottenham at tott0006@tc.umn.edu for more information concerning the stimulus set.

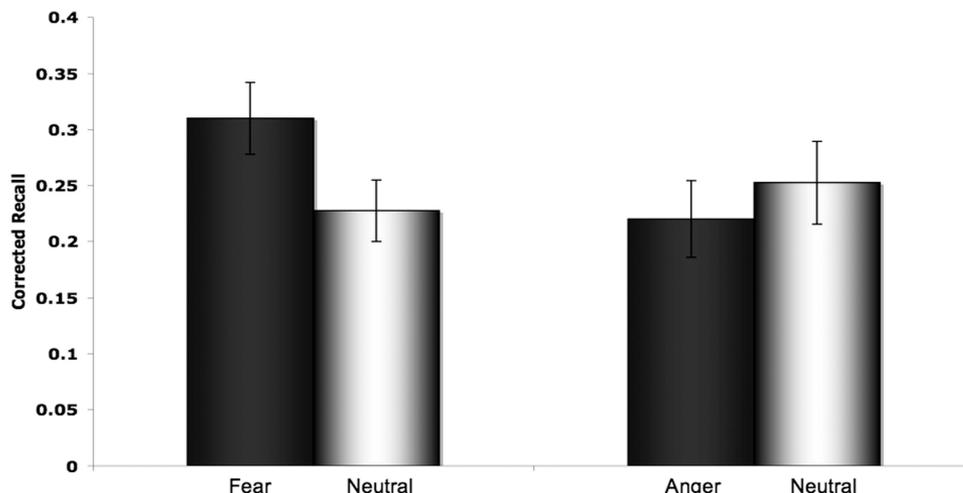


Figure 2. Experiment 1. Participants recalled more words from the fearful face blocks, compared with the neutral face blocks, and there was no difference in number of words recalled in the angry face blocks, compared with the neutral face blocks. Error bars represent standard error of the mean.

arousal rating = 3.60 ($SD = 0.303$). For angry faces, the average valence rating = 5.585 ($SD = 0.153$), and the average arousal rating = 3.565 ($SD = 0.293$). The variability of ratings was also comparable for fearful and angry stimuli, as indicated by nonsignificant results of Pitman tests for equality of variance among correlated samples (valence: $p > .6$; arousal: $p > .6$). Note that the magnitude of both the valence and arousal ratings for fearful and

angry faces decreased compared with Experiment 1, perhaps because of a lack of neutral faces in the present paradigm, thereby rendering these expressions less distinctive (see Dewhurst & Parry, 2000; Rajaram, 1996).

See Table 2 for descriptive recognition and error rate data. A 2 (stimulus: word, face) \times 2 (emotion: fear, anger) within-participant ANOVA revealed a significant main effect of stimulus, $F(1, 26) = 23.982, p < .001, \eta^2 = 0.332$; where words were better remembered than faces and revealed no main effect of emotion, $F(1, 26) = 0.109, p = .743, \eta^2 = 0.0004$. The Stimulus \times Emotion interaction was significant, $F(1, 26) = 6.371, p = .015, \eta^2 = 0.038$. Paired-samples t tests indicated that participants recognized more faces from the anger blocks, compared with the fear blocks, $t(26) = 2.076, p = .024, d_z = 0.399$; and more words from the fear blocks, compared with the anger blocks, $t(26) = 1.749, p = .046, d_z = 0.337$ (see Figure 4).

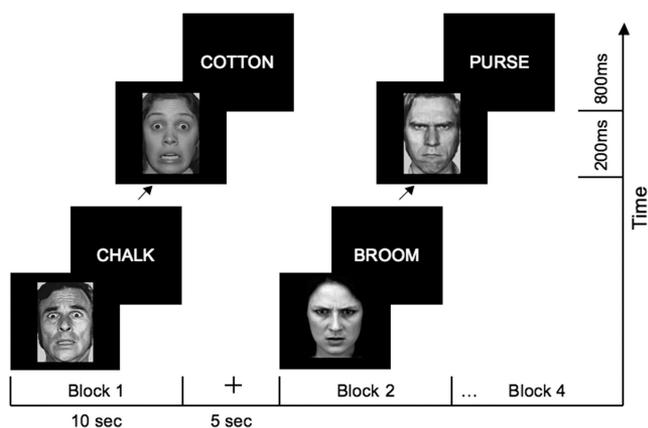


Figure 3. Experiment 2 design. In a within-participant design, participants viewed blocks of fearful faces alternating with neutral words and blocks of angry faces alternating with neutral words. Faces were presented for 200 ms, and words were presented for 800 ms. A 5-s fixation period separated blocks. Images from *Pictures of Facial Affect*, by P. Ekman and W. V. Friesen, 1976, Palo Alto, CA: Consulting Psychologists Press. Copyright 1976 by P. Ekman and W. V. Friesen. Reprinted with permission from Paul Ekman, Ph.D./Paul Ekman Group, LLC; and from The NimStim set of facial expressions: Judgments from untrained research participants, by N. Tottenham, J. Tanaka, A. C. Leon, T. McCarry, M. Nurse, T. A. Hare, D. J. Marcus, A. Westerlund, B. J. Casey, and C. A. Nelson, 2009, *Psychiatry Research*, 168, pp. 242–249. Copyright 2009 by N. Tottenham, J. Tanaka, A. C. Leon, T. McCarry, M. Nurse, T. A. Hare, D. J. Marcus, A. Westerlund, B. J. Casey, and C. A. Nelson.

General Discussion

Although fearful and angry facial expressions both convey negative valence and elicit equivalent levels of emotional arousal from viewers, their communicative signals vary in terms of the source of threat they imply. The studies presented here tested the hypothesis that fearful and angry facial expressions would differentially modulate memory in accordance with their ecological signal value. Whereas fearful expressions call for diffuse attentional modulation to quickly and nonspecifically gather information to identify the source of threat, angry facial expressions communicate a clear threat signal and draw focused attention to the individual expressing anger. In Experiment 1, fearful faces facilitated memory for information in the immediate temporal context (i.e., words), whereas angry faces did not. In Experiment 2, we extended these findings by directly comparing the effects of fearful and angry expressions on memory for the expressor's identities as well as words in the temporal context. Our results replicated the initial finding that fearful expressions enhanced memory for contextual word information and additionally demon-

Table 2
Raw Recognition Rates by Block Type in Experiment 2

<i>M</i> and <i>SD</i>	Fear blocks			Anger blocks			
	Face hits	Face FA	Word hits	Face hits	Face FA	Word hits	Word FA
<i>M</i>	.25	.15	.34	.27	.13	.30	1.59
<i>SD</i>	.11	.11	.09	.09	.08	.11	1.62

Note. Mean values for hits represent proportion correctly recalled. Mean values for false alarms (FA) represent mean number of false alarms.

stated that angry facial expressions enhanced memory for the faces themselves. Moreover, we observed a reduction in false alarms for angry versus fearful face recognition, suggesting that participants more accurately encoded the angry faces. Given that these expression categories were matched for emotional valence and arousal, we propose that these subtle but significant effects on memory resulted from the fact that fearful and angry facial expressions promote different foci of attention within the environment in accordance with their communicative value.

Fearful and angry facial expressions both predict negative outcomes but differ in the amount of information they provide regarding the source of threat in the environment. Specifically, angry facial expressions provide certain information about the source of threat, whereas the context dependence of fearful expressions leaves the source of threat more uncertain. The dimensions of emotional valence and arousal traditionally used to categorize facial expressions do not capture these differences in predictive information conveyed by fearful and angry expressions. Instead, a certainty–uncertainty dimension might prove useful in characterizing such differences and in making predictions about differential behaviors encouraged by these expressions.

The idea that the fearful expressions of others call for greater contextual monitoring (Whalen, 1998) is consistent with previous studies showing that fearful expressions enhance contextual perceptual discrimination (Phelps et al., 2006; see also Bocanegra & Zeelenberg, 2009) and contextual target detection (Becker, 2009). Whereas most experiments manipulate context in the spatial do-

main comparing centrally versus peripherally presented information, the present work considers context in a temporal domain, that is information (i.e., words) presented immediately before or after the facial expressions. Temporal context is a meaningful manipulation because in the real world, it is likely that individuals look to the environment *after* encountering an emotional expression to disambiguate its source. Therefore, the present data, showing that fearful faces also produce better memory for information within a close temporal context, are consistent with the idea that fear calls for greater attention to the environment, perhaps to gather clues about the source of threat. Conversely, better memory for the angry faces themselves is consistent with the idea that, relative to fear, these expressions call for greater attention to the individual producing the expression (Whalen, 1998; Whalen et al., 2001) because the source of the threat is clear and localized to that individual.

Previous research has demonstrated differential brain response patterns elicited by viewing fearful and angry faces, despite their uniformly negative and arousing properties. In one study, a ventral portion of the amygdala showed responses of equal magnitude to fearful and angry faces when compared with neutral faces, consistent with their equal negative valence. In contrast, a more dorsal portion of the amygdala showed greater responses to fearful faces when directly compared with angry faces, potentially consistent with their uncertain versus certain information value (Whalen et al., 2001). Given that the amygdala has also been consistently implicated in orchestrating modulatory influences on perception,

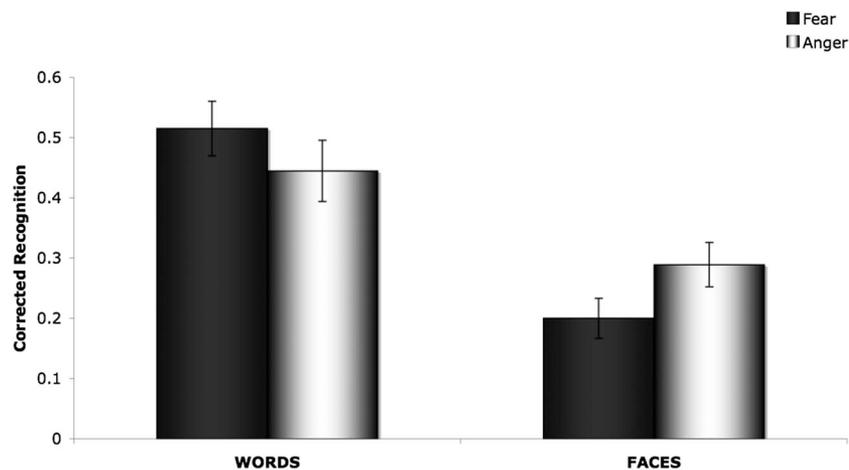


Figure 4. Experiment 2. Participants recognized more words from the fearful face blocks and more faces from the angry face blocks. Error bars represent standard error of the mean.

attention, and memory (Cahill & McGaugh, 1998; Phelps et al., 2006; Vuilleumier, 2005), we predicted that the differences in amygdala response to fearful and angry faces observed by Whalen et al. (2001) would manifest as different behavioral responses to these faces.

Although the reported effects were observed in memory performance, the mechanism underlying these effects could potentially lie at numerous stages in the information-processing stream. One interesting possibility is that the information conveyed by angry and fearful faces directs attention toward different aspects of the environment, differentially modulating the focus of attentional networks on expression (i.e., focused) versus contextual (i.e., diffuse) features of the environment.

Although the neural systems supporting emotion and attention can act independently, they are also interactive. It has been suggested that one function of emotion is to direct our attention in a way that shapes perception rather than simply imbuing our experiences with meaning (Vuilleumier, 2009). Several lines of evidence suggest that emotional stimuli, and threat stimuli in particular, preferentially capture visual attention. For example, in visual search tasks, participants are faster at detecting negative targets compared with positive or emotionally neutral targets (Eastwood, Smilek, & Merikle, 2001; Fox et al., 2000; Fox et al., 2002; Hansen & Hansen, 1988; Lucas & Vuilleumier, 2008; Öhman, Flykt, & Esteves, 2001; Tipples, Atkinson, & Young, 2002; Williams et al., 2005). Emotional versions of the Stroop paradigm also support the idea that emotional stimuli capture attention preferentially (Algom, Chajut, & Lev, 2004; Mathews & MacLeod, 1985; Pratto & John, 1991; Watts, McKenna, Sharrock, & Trezise, 1986). Visual search and continuous flash suppression tasks indicate that negative facial expressions of emotion, particularly fearful faces, capture early attention (Öhman et al., 2001; West, Anderson, & Pratt, 2009; Yang, Zald, & Blake, 2007), and an emotional go-no go task suggests that this capture of early attention has important influences on top-down control of behavior (Hare et al., 2008). Additional research suggests that physiological arousal associated with viewing positive and negative emotional stimuli plays a large role in emotional capture of attention (Anderson, 2005; Bradley et al., 2003; Keil & Ihssen, 2004; Schimack & Derryberry, 2005; Schupp et al., 2004) and that in some cases emotional capture of attention can disrupt encoding of neutral stimuli (Angelini, Capozzoli, Lepore, Grossi, & Orsini, 1994; Detterman, 1975; Hurlmann et al., 2005; Strange, Hurlmann, & Dolan, 2003; Tulving, 1969). Here, we extend this body of work to show that, although threat-related facial expressions capture early attention (Öhman et al., 2001; West et al., 2009; Yang et al., 2007), different expressions may subsequently modulate attention and memory in ways consistent with their ecological meaning.

The present study garners its strength from the a priori nature of these predictions (Whalen, 1998), but such a finding also calls for further experimentation. Future behavioral and neuroimaging studies could shed light on whether differential brain activations to fearful versus angry faces implicate perceptual, attentional, encoding and/or memory consolidation circuitries. Such studies might lead to alternative explanations for the present effects including (a) differential habituation rates for fearful versus angry faces, (b) differential attentional blink effects for anger and neutral faces compared with fear, and/or (c) differential sensory intake for angry versus fearful faces (Susskind & Anderson, 2008; Susskind et al.,

2008). Moreover, previous research shows that changeable aspects of the facial expressions themselves, such as eye gaze, can affect behavioral and neural responses to facial expressions (Adams, Gordon, Baird, Ambady, & Kleck, 2003; Adams & Kleck, 2003) and may have important influences on the way that information is encoded or remembered.

Conclusion

The facial expressions of fear and anger, although matched here for intensity of negative valence and arousal ratings, are social cues that communicate divergent messages. Although fearful expressions signal that the expressor has detected something threatening in the surrounding environment, an angry face suggests that the expressor himself or herself is the direct source of threat. Here we demonstrated that fearful and angry facial expressions influence memory differentially, in a manner consistent with this characterization. Fearful expressions enhanced memory for contextual information, whereas angry expressions enhanced memory for the faces themselves. We propose that these differential effects on memory result from the fact that the information conveyed by angry and fearful facial expressions differs on a certainty (i.e., angry)–uncertainty (i.e., fear) dimension, eliciting focused versus diffuse attention from viewers, respectively.

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