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More Than Mere Mimicry? The Influence of Emotion on Rapid Facial Reactions to Faces

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Within a second of seeing an emotional facial expression, people typically match that expression. These *rapid facial reactions* (RFRs), often termed mimicry, are implicated in emotional contagion, social perception, and embodied affect, yet ambiguity remains regarding the mechanism(s) involved. Two studies evaluated whether RFRs to faces are solely nonaffective motor responses or whether emotional processes are involved. Brow (corrugator, related to anger) and forehead (frontalis, related to fear) activity were recorded using facial electromyography (EMG) while undergraduates in two conditions (fear induction vs. neutral) viewed fear, anger, and neutral facial expressions. As predicted, fear induction increased fear expressions to angry faces within 1000 ms of exposure, demonstrating an emotional component of RFRs. This did not merely reflect increased fear from the induction, because responses to neutral faces were unaffected. Considering RFRs to be merely nonaffective automatic reactions is inaccurate. RFRs are not purely motor mimicry; emotion influences early facial responses to faces. The relevance of these data to emotional contagion, autism, and the mirror system-based perspectives on imitation is discussed.

Keywords: mimicry, EMG, facial expression

When a stranger quickly smiles in response to your smile, is it mere automatic motor mimicry, or does it reflect happiness at seeing your smiling face? Observers often produce facial movements similar to the emotional facial expression of the person being observed (Bush, Barr, McHugo, & Lanzetta, 1989; Dimberg, 1982; McIntosh, 2006; McIntosh, Druckman, & Zajonc, 1994). For example, when a person observes someone scowl, the observer's muscles that produce scowls often activate. The facial reactions in the observer may be overt; however, they are often subperceptual and very rapid (within 1000 ms) (Dimberg, 1982; Dimberg, Thunberg, & Elmehed, 2000).

Although these reactions have received much attention as important aspects of social and emotional processes, a number of theories are presented to account for these reactions (e.g., Dimberg, 1997; Hess, Philippot, & Blairy, 1998). There is still ambiguity regarding the nature of these reactions, and the psychological mechanism(s) that underlie them are not well understood (Hess et al., 1998; Moody & McIntosh, 2006). More specifically, how they are affected by situational factors such as the emotional climate, and whether they extend beyond simple positive/negative reactions to more complex and specific emotions have not been fully explored. Matching phenomena can vary along several dimensions. such as the intentionality of the observer, the underlying mechanism of the response, and the time frame of the response (Moody & McIntosh, 2006; Tomasello, 1990). The focus of the studies reported here is to identify factors influencing the quickest of these responses (within 1000 ms), which we term *rapid facial reactions* (RFRs) to faces.

Causes and Consequences of RFRs

Importance of RFRs

Discovering what leads to and influences RFRs is especially important because they are implicated in a number of social-emotional processes. For example, they may influence empathy and emotional contagion (Bavelas, Black, Lemery, & Mullett, 1987; Hatfield, Cacioppo, & Rapson, 1993, 1994; McIntosh et al., 1994). They are linked with helping and generosity (van Baaren, Holland, Kawakami, & van Knippenberg, 2004). Furthermore, embodiment theory suggests that cognitions are influenced by bodily referents, which may include RFRs (Barsalou, 1999; Thompson & Varela, 2001). Perception of emotional expressions also appears influenced by the ability of observers to match the other's facial expression (Neidenthal, Brauer, Halberstadt, & Innes-Ker, 2001). RFRs are important enough to social-emotional functioning that deficits in such matching reactions have been proposed as core problems in autism (Hepburn & Stone, 2006; Moody & McIntosh, 2006; Rogers, 1999, 2006; Rogers & Pennington, 1991) and schizophrenia (Abashev-Konstantinovsky, 1937). Indeed, individuals with autism spectrum disorders show an absence of quick, automatic facial matching of others' emotional expressions (McIntosh, Reichmann-Decker, Winkielman, & Wilbarger, 2006), and having individuals with schizophrenia

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match observed facial expressions can improve their ability to identify facial affect (Penn & Combs, 2000).

Most researchers that study RFRs use the term *mimicry* to describe these reactions (e.g., Hess & Blairy, 2001; McIntosh et al., 2006). We use the term here with caution, however, because it may imply that the action is merely a matching of the observed expression and not related to an independent response to that expression. Indeed, much of this research makes tacit or explicit assumptions regarding the mechanism(s) leading to the reactions of the observer. For example Hatfield et al. (1993, 1994) base their theory of emotional contagion on an assumed automatic and nonemotional rapid facial matching of observed emotional expressions. On the other hand, Dimberg (1997) suggests that these rapid reactions are the result of emotional processes rather than simple reflexive processes. The understanding of what these rapid facial reactions represent varies across studies and theoretical perspectives. That there are several untested assumptions regarding the underlying mechanism(s) of RFRs underscores the need for a focused approach to understanding and documenting the nature of these reactions and what influences them.

RFRs as Motor Responses

As noted earlier, some researchers consider RFRs to be automatic, nonaffective responses (Chartrand & Bargh, 1999), or posit a direct perception-action neural link that bypasses emotional systems and may be mediated by the mirror system (Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005). For example, Buccino, Binkofski, and Riggio (2004) posit that we can "recognize a large variety of actions performed by other individuals, including those belonging to other species, simply by matching the observed actions onto our own motor system" (p. 374). Chartrand and Bargh (1999) describe a perception-behavior link in which they "posit a direct causal sequence: Perception causes similar behavior, and the perception of the similar behavior in the other creates shared feeling of empathy and rapport" (p. 897). Recently, the mirror system has been used to explain this phenomenon as well as other, more complex matching behaviors, such as imitation. For example, Williams, Whiten, Suddendorf, and Perrett (2001) suggest that the mirror system may explain RFRs; their perspective sees RFRs as automatic nonemotional motor reactions. Common to these perspectives is that rapid motor matching is not an outcome of emotional processes but is rather a simple motor reaction or reflex often referred to as mimicry. By this account, RFRs to faces may precede and even cause emotion through facial feedback (McIntosh, 1996), thus generating emotional contagion (Hatfield et al., 1993, 1994; McIntosh, 2006; McIntosh et al., 1994).

RFRs as Emotional

Other researchers focus on RFRs as markers of subtle affective states in response to presented stimuli (Cacioppo, Martzke, Petty, & Tassinary, 1988; Dimberg, 1997; Winkielman & Cacioppo, 2001). In this literature, RFRs are typically used to assess output of *affective*, not motor mimetic, processes. That is, this perspective views RFRs as the result of the observer's emotional state rather than a nonemotional reflex. For example, Dimberg (1997) has demonstrated that RFRs occur in response to observed nonfacial emotional stimuli such as snakes. A standard understanding of emotions is that they include a broad set of action tendencies, cognitive appraisal, attentional mechanisms, and physiological changes that are related to the appraisal of environment (Cacioppo & Gardner, 1999). Such action tendencies may include increasing physiological arousal, increasing attention to the environment, and specific configurations of facial muscles (e.g., baring the teeth in preparation for fighting). If RFRs are wholly or partly the result of emotions, we would expect the facial reaction to be in line with or influenced by the action tendencies rather than simply matching the facial configuration of the observed face. In other words, the motor perspective suggests the facial action should be congruent with the observed face, and the emotion perspective suggests that facial action should be related to the action tendencies associated with an emotional reaction to the stimulus.

Exploring Causes of and Influences on RFRs

Despite these differing assumptions in the literature about the underlying mechanism(s) of RFRs, current data do not establish what processes lead to RFR outputs, or whether different mechanisms operate in different time frames or situations. Determining what processes contribute to this phenomenon or how different processes interact is important for several reasons. First, given that theories such as Hatfield et al.'s (1993, 1994) of emotional contagion are based on particular assumptions about what underlies RFRs, these assumptions need to be tested to validate the proposed mechanism(s) involved. In some cases, this may necessitate reformulation of theories. Alternatively, these assumptions may be correct, but how multiple mechanisms interact may make studying this phenomenon more complicated. Second, by identifying processes that give rise to, or influence, this phenomenon, we will better understand typical social development and certain psychopathologies (Moody & McIntosh, 2006).

We, therefore, address the assumption that RFRs are merely the behavioral output of an exact matching system that is relatively uninfluenced by emotional factors. The question of the role of motor and emotional processes in RFRs has been addressed in the past, but has proven difficult to answer. An indication that facial responses to faces are not entirely motor mimetic is provided by Hess, Philippot, and Blairy (1998). Individuals in their study not only smiled at pictures of smiling people and scowled at angry faces, they scowled in response to difficult to decode pictures. Moreover, judgment demands across tasks appeared to influence facial response. Their findings indicate involvement of a cognitive, nonmimetic process within five seconds of stimulus exposure and suggest influences of task contexts on these facial responses. Although these data implicate a nonmimetic process, they do not directly assess what influence participants' emotions had on RFRs, thus leaving the question of the role of emotion in RFRs unanswered.

Other research has examined the effects of various individual and situational factors on expressions at much longer time frames. For example, several researchers have demonstrated that a positive previous political attitude can enhance electromyography (EMG) responses to positive facial displays from a liked political leader (Bourgeois & Hess, 1999; Bush, McHugo, & Lanzetta, 1986). Similarly, McIntosh (2006) found that observers who liked the people they were observing showed stronger matching of smiles.

That liking the stimulus may enhance smiling suggests an emotional component to facial reactions to seeing others' faces.

However, the findings regarding previous attitudinal or affective influences on matching facial responses are not definitive for two reasons. First, the effects of attitude on facial reactions to emotional displays is not entirely consistent. For example, Lanzetta, Sullivan, Masters, and McHugo (1985), and McHugo (1985) found that attitude only affected EMG responses when attitudes were most extreme. Second, the supportive findings examine responses over a much longer time window (ranging from 5–15 seconds to 2 minutes) after stimulus presentation; whether the attitudinal and emotional influences occur for the most rapid muscle movements examined in much current mimicry research (e.g., Dimberg, 1997; Dimberg et al., 2000; McIntosh et al., 2006) is unknown. Establishing the nature of truly rapid facial responses is important to identifying the role of facial responses in emotional and social processes. The conflicting results and longer response windows examined beg the question of whether emotion influences the most rapid facial responses to faces.

Part of the difficulty in determining whether affect plays a role in RFRs to faces in this early time frame is that the view that RFRs are solely mimetic responses in most cases makes the same predictions as the view that RFRs represent output of emotional reactions to the faces. For example, when a person observes someone smiling at her or him, the mimicry perspective predicts that the observer's face will display a similar (smiling) pattern of muscular activation due to motor-mimetic processes. If, on the other hand, RFRs are the result of internal emotional states, a similar outcome is predicted, although for a different reason. From this perspective, the observer responds with positive affect to the positive stimulus of the smiling face. Likewise, in the case of a fear expression, the mimicry perspective predicts that the fear expression would be produced due to motor-mimetic reactions, whereas the emotion perspective predicts that the observer would match the fear expression because he or she is afraid, as the other's fear expression indicates danger in the shared environment. Similar predictions are made for many other emotional facial expressions.

There is at least one facial expression, however, for which differing predictions can be made. When an observer is presented with an *anger face* directed at the observer, the view that RFRs are an exact motor matching response would predict that the observer would generate a similar facial reaction regardless of the observer's felt emotions. That is, facial expressions of anger should elicit *only* anger expressions because the observer is simply reflexively mimicking the facial expression. In contrast, if RFRs are in whole or in part a display of the observer's emotional state, at least two potential reactions can be predicted. Because anger faces indicate a potential threat, the observer may become angry *or* afraid. Becoming angry in response to a threat may be adaptive if the observer is going to remain in the situation to contend with the threat. On the other hand, fear may facilitate removal from the threatening situation and would therefore be more adaptive in more threatening situations. In either event, because the RFR is related to emotional responses, the reaction would be in line with the observer's emotional state. Therefore, from this perspective anger faces could lead to early RFRs of anger *or* fear.

Given this reasoning, if individuals respond with a fear expression to the presentation of anger faces, this would suggest that RFR outputs are driven, at least in part, by emotion processes and not solely motor mimicry. More generally, if emotion plays a role in RFRs, either as a fundamental mechanism or by interacting with other processes, then one's emotional state when shown an angry face will influence one's facial responses. This is what we evaluated here.

The Present Study

To determine whether emotion influences RFRs, we assessed the effect of manipulating participants' emotions on RFRs. Given that observers who see nonfacial affective stimuli, such as snakes, have emotion-appropriate facial responses within 2000 ms after stimulus onset (Dimberg, Hansson, & Thunberg, 1998; Winkielman & Cacioppo, 2001), and that individual differences such as previous attitudes alter felt and expressed emotions at longer time frames (Bourgeois & Hess, 1999; McHugo, Lanzetta, & Bush, 1991; McIntosh, 2006), we hypothesized that the emotional state of the observer will influence RFRs at an early stage in patterns that suggest rapid emotionally specific reactions. The present study extends the earlier work on affective influences on facial reactions to faces by focusing on the earliest response window, and by looking at whether specific emotional reactions exist (e.g., fear vs. anger) to specific expressions, beyond just valence.

We examined the effect of induced fear on RFRs to anger, fear, and neutral faces in two experiments. The presence of an influence of emotion on RFRs would be supported if a fear induction causes an increase of RFRs consistent with a fear expression in response to anger faces and a decrease in RFRs consistent with an anger expression in response to anger faces. We thus predicted that the fear induction would change the type of RFR from an anger to a fear expression from a very early point in the process. This contrasts with the assumption that early RFRs are merely a motor mimetic reaction and regardless of the emotion induced in the participant a matching expression will be observed. We also examined the influence of fear induction on RFRs to fear and neutral faces to evaluate whether fear induction merely increased fear responses to all stimuli, or whether the induction changed specific reactions to anger.

Experiment 1

The first experiment was run in the context of a larger study to assess the viability of our approach and to gather preliminary data.

Method

Participants. Participants (N = 48, 42 female, mean age = 20.5, SD = 2.1 years) were recruited through undergraduate psychology courses and given extra credit for their time.

Stimuli. Participants viewed a series of 25 digitized photographs of fear faces (10), anger faces (10), and neutral faces (5) from the Pictures of Facial Affect (Ekman & Friesen, 1976) and the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1997). Photos were selected based on pilot testing in which several undergraduate psychology classes (N = 115 students) rated the photos for their emotional valence and arousal. In the pilot testing participants were shown 75 photos from the IAPS and Ekman sets that included emotional facial expressions, negative nonface images, and neutral images. Photos that were rated the most consistently for both valence and arousal were used in the present study.

Procedures. In a completely within-subjects design, facial reactions to fear, anger, and neutral faces were recorded first under a neutral and then a fear induction condition. In the neutral condition participants read ten phrases out loud. The phrases consisted of neutral "I am" statements, such as "I am sitting down," "I am at a desk," and other nonaffective phrases. For the fear induction, participants listened to two audio clips over headphones. Audio stimuli are effective at inducing emotions (Kenealy, 1988). The clips were the soundtracks of the film segments from *Silence of the Lambs* and *The Shining* shown by Gross and Levenson (1995) to reliably induce fear in participants. The use of clips from movies to induce emotion is commonly used in emotions research (e.g., Jakobs, Manstead, & Fischer, 2001). For this initial study, we used only the soundtracks to decrease the likelihood that nontarget emotions would be induced from the images (e.g., disgust from a scene of a decaying body).

Participants viewed the same 25 facial stimuli in each condition, with presentation order randomized by the computer. Each photograph was displayed for 5 seconds on a 21-inch Cathode Ray Tube (CRT) computer monitor 1 m from the participant. A large asterisk displayed for one second as a fixation point immediately before each stimulus face was displayed. The screen was blank for 6 seconds between each stimulus. Facial muscle activity was recorded continuously during presentation. After data collection, participants were fully debriefed and given an opportunity to ask questions.

Measures

Facial muscle movement. EMG was used to record levels of muscle activity over the *corrugator supercilli* (knits brow), the medial *frontalis* (raises inner eyebrow), and *levator labii* (elevates and everts upper lip). Activity over the corrugator muscle has been shown to be a marker of negative emotions such as anger (Cacioppo, Petty, Losch, & Kim, 1986) and we, therefore, used this as a marker of anger expressions. Activity over the medial portion of the frontalis has been associated with fear (Darwin, 1998; Ekman & Friesen, 1978; Frois-Wittman, 1930; Smith, 1989), as when one is afraid, the brow often raises. We thus used activity here to measure fear expressions. Disgust expressions have been associated with activity over the levator muscle (Vrana, 1993); therefore, we measured activity over this muscle group to check for disgust responses.

Standard EMG site preparation and electrode placement procedures were followed (Tassinary, Cacioppo, & Geen, 1989). Before electrode placement, the skin over the muscle group was cleansed with rubbing alcohol and gently abraded with NuPrep Gel. Electrodes were Med Associates 4 mm Ag-AgCl, cup-style electrodes. Muscle activity was continuously recorded using a NeuroScan Labs, SynAmps Model 5083 electroencephalograph amplifier. Activity over each muscle group was recorded using two electrodes placed approximately 1.25 cm apart from center to center, roughly parallel to the length of the muscle. Activity over each muscle was continuously recorded at a sampling rate of 2000 Hz with a 10-Hz to 500-Hz bandpass filter and a 60-Hz notch filter. The EMG signals were immediately amplified at the headbox by a factor of 150 and again by the main amplifier by a factor of 500.

To analyze EMG, each continuous file was first visually inspected for noise and artifacts. Next, the waveform around each stimulus presentation was visually inspected by a research assistant, blind to condition and hypotheses, to look for artifacts and anomalous waveforms. Sweeps that contained clearly anomalous waveforms were dropped from the analyses. No more than 10% of the sweeps for each individual were dropped, although the levator data for 13 participants were removed because of experimenter error resulting in electrical noise on that channel.

Following visual inspection, EMG data were used to calculate facial responses to the stimuli. The prestimulus window was the 500 ms before the onset of the orienting stimulus (asterisk). We averaged the poststimulus muscle activity in 100-ms chunks to better visualize the progression of change in activity; for analysis purposes, the poststimulus windows were the first and second half of the first second directly after stimulus onset (i.e., 0 to 500 ms and 500 to 1000 ms post stimulus onset (see Dimberg, 1982; Dimberg & Petterson, 2000). These data were smoothed and rectified, and the integral under the curve for each time window was calculated using CNS Analysis Suite, version 5.51 (1999). The integral values were next $\log_{10}$ transformed. This is a standard procedure in this (e.g., McIntosh et al., 2006) and other labs (e.g., Winkielman & Cacioppo, 2001) to reduce the impact of extreme values. These values were then standardized within participant and within muscle so meaningful comparisons could be made across muscles and participants. We next subtracted the prestimulus value from the poststimulus activity to measure the level of activity caused by viewing each facial stimulus (i.e., to calculate the change from baseline). Finally, we computed mean levels of activity for corrugator, frontalis, and levator for each type of stimulus face.

Manipulation check. The effect of the induction was evaluated after the presentation of stimuli to avoid interrupting the flow from manipulation to assessment of the dependent variables. After assessment of muscle movement in response to viewing the emotional facial stimuli, participants completed a self-report measure of how much they felt happiness, fear, anger, surprise, sadness, and disgust. The measure consisted of one Visual Analogue Scale (VAS) for each emotion. Participants made a single vertical mark along a 100-mm horizontal line to indicate the level of felt emotion (the far left of each line was anchored to indicate no felt emotion and the far right was anchored to indicate extreme felt emotion). The distance of each mark from the left-most anchor was measured in millimeters to provide a metric of each emotion, so that higher values indicate more subjective experience of the given emotion.

Results

Manipulation check. We first used a paired-sample t test to evaluate whether the fear induction altered the emotions of the participants (all t tests are two-tailed). There was a trend toward greater levels of fear in the fear induction condition ($M = 14.72$ mm; $SD = 19.5$) compared to the neutral condition ($M = 9.7$ mm; $SD = 14.95$), $t(47) = 1.83$, $p = .07$. To evaluate whether fear was induced to a greater extent than other emotions, difference scores for each emotion were calculated such that positive difference scores represent an increase in the emotion in the fear condition and negative scores represent a decrease. Paired-sample t tests were then calculated comparing the change in fear to change in each of the other emotions after the induction. The change in reported fear ($M = 5.02$ mm; $SD = 20.17$) was significantly higher than the change in happiness, which decreased ($M = -9.22$ mm; $SD = 15.50$), $t(47) = 3.45$, $p = .001$. No other comparisons were significant.

Preliminary analyses. Dimberg (1982, 1997) indicates that the clearest and strongest facial responses are seen in the second half of the first second post stimulus onset. To evaluate the effect of time, the data were analyzed with 2 (condition: fear vs. neutral induction) $\times$ 2 (time: first 500 ms vs. second 500 ms post stimulus onset) $\times$ 3 (stimuli: angry vs. fear vs. neutral face) repeated measures analysis of variance (ANOVA) for each muscle, in a fashion similar to Dimberg (1997). For the frontalis, there was a significant main effect for time, $F(1, 40) = 6.57$, $p = .014$, partial $\eta^2 = 0.14$, and for both frontalis and corrugator there were significant time $\times$ condition interactions, $F(1, 40) = 7.39$, $p = .01$, partial $\eta^2 = .016$, and $F(1, 37) = 7.49$, $p = .009$, partial $\eta^2 = 0.17$, respectively. As can be seen from Figure 1, this interaction appears to be due to the increased muscle activity beginning around 400-ms post stimulus onset, becoming most pronounced in the second 500-ms post stimulus onset. To verify that this is the case, paired-sample t tests were run to look for simple effects in the first 500 ms. No significant differences between conditions were found for any of the muscles to any of the stimuli. Therefore, given that the second 500 ms shows the greatest change in activity and following Dimberg (1997), further analyses focused on the second 500 ms only.

Primary analyses. To evaluate the effect of the fear induction on muscle responses to the facial expressions, a 2 (condition: fear vs. neutral induction) $\times$ 3 (muscle: frontalis vs. corrugator vs. levator) $\times$ 3 (stimuli: angry vs. fear vs. neutral face) repeated measures ANOVA for the second 500 ms was run. If the fear induction had an effect, there should be a main effect or interaction involving condition. Indeed, there was a main effect for condition, $F(1, 31) = 4.45$, $p = .043$, partial $\eta^2 = 0.13$, with more activation after fear induction ($M = 0.08$; $SD = 0.28$) than in the neutral induction condition ($M = 0.03$, $SD = 0.22$). There was also a significant muscle by condition interaction, $F(2, 62) = 3.87$, $p = .026$, partial $\eta^2 = 0.11$.

To better understand the effects of the induction, follow up paired sample t tests were run. As predicted by an emotions view of RFRs, there was significantly higher activation of the frontalis to anger faces in the fear condition ($M = 0.15$; $SD = 0.23$)

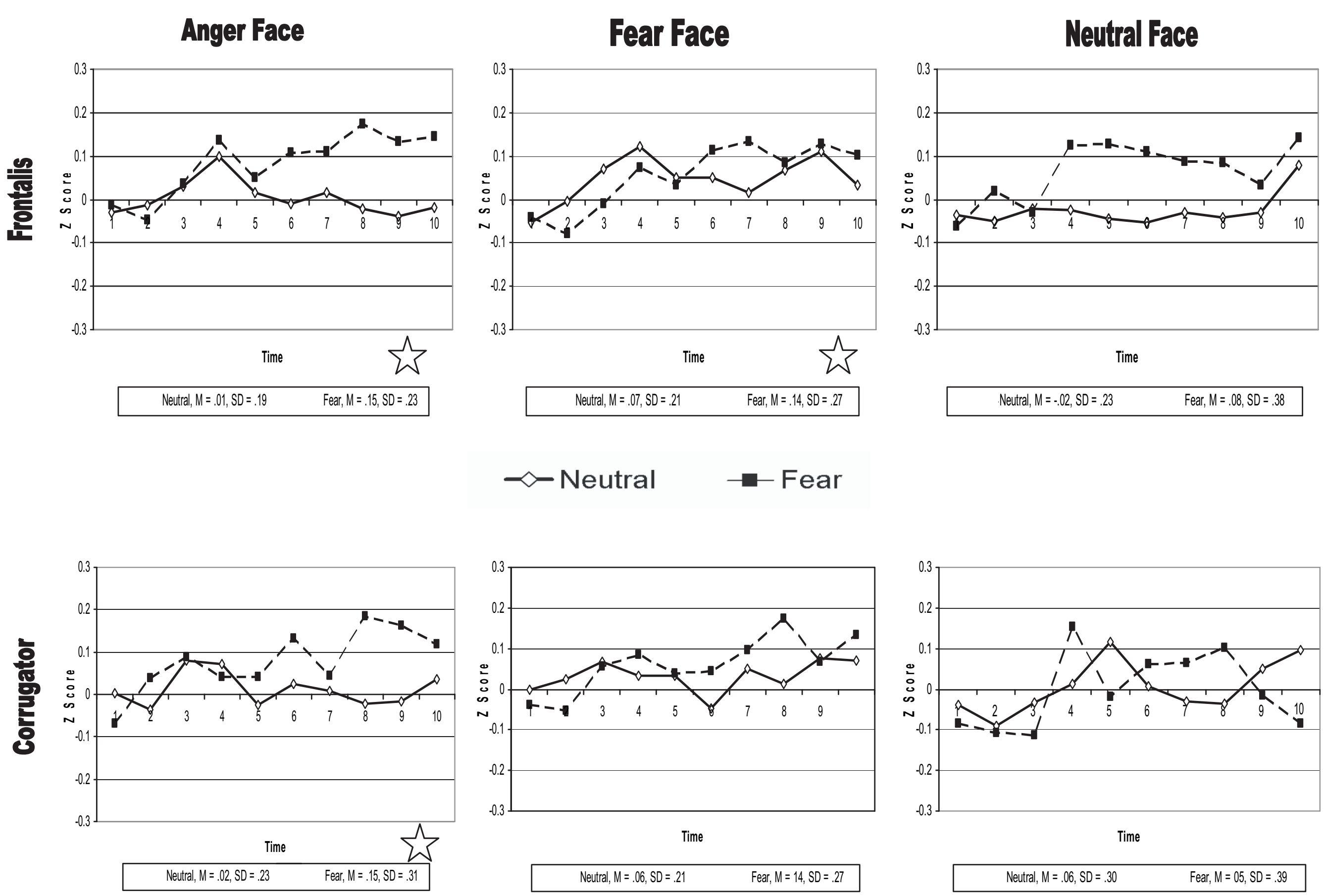

Figure 1. Experiment 1: First 1,000 ms of activity over each muscle to each facial expression after neutral and fear inductions. Activity reflects average activation during each 100-ms block, with the prestimulus baseline subtracted out. Graphs that are starred show significant differences between conditions. Means and standard deviations are for the second 500 ms only.

compared to the neutral condition ($M = 0.01$, $SD = 0.19$), $t(31) = 3.5$, $p = 0.001$.[1] In addition, there was significantly higher frontalis activation to fear faces in the fear condition ($M = 0.14$; $SD = 0.27$) than in the neutral condition ($M = 0.07$; $SD = 0.21$), $t(40) = 2.28$, $p = .028$. There were also significantly higher corrugator reactions to angry faces in the fear condition ($M = 0.15$; $SD = 0.31$) than in the neutral condition ($M = 0.02$; $SD = 0.23$), $t(40) = 2.74$, $p = .009$. There were no significant differences between the RFRs in neutral and induction conditions to neutral faces for any of the muscles, although, activity over the frontalis approached a trend, $t(40) = 1.73$, $p = .12$. The p values for corrugator and levator were very large (.89 and .64, respectively). There were no significant differences for the activity over the levator to any stimulus type or across conditions (p values range from .1 to .69).

Discussion

As predicted, the induction of emotion influenced the types of facial expressions rapidly produced in response to anger faces. More specifically, greater expressions of fear to anger faces and fear faces were observed when participants were in a heightened state of fear. The frontalis change appears to be related specifically to responses to relevant emotional stimuli (fear and anger) and not to a generalized change in status (e.g., simple increased arousal from the induction film). This finding is consistent with our assumption that the induction alters emotion. Furthermore, there were no significant differences in activity over the levator, which suggests that there were no nontarget emotions such as disgust induced. Rather, the pattern of findings suggests that as a result of the participants' emotional state, their RFRs to faces relevant to the induced emotion were altered.

These data provide evidence that early RFRs do not represent just exact motor matching of observed facial expressions. Instead, these rapid reactions are influenced by emotion induced in the observer in predictable ways. The pattern of results suggests that emotions may be part of these very rapid reactions, or may modulate, interact with, or cover up the output of reflexive motor responses very early in the process. Despite suggesting that emotion plays a role in early RFRs, these data cannot confirm or rule out the presence of nonaffective motor processes. Specifically, several alternative hypotheses may plausibly account for these results. For example, emotional processes may overlap with lower level motor reactions such that nonemotional reflexes are obscured by the emotional reaction, or emotional reactions may interact with existing motor processes. For example, the increased corrugator response to anger faces in the fear induction condition may reflect enhancement of motor mimicry. Nonetheless, this is the first demonstration that induction of an emotion causes changes in specific emotional responses (i.e., fear to anger faces) to observed faces within 1000 ms. The data point out that early RFRs may be more complex than suggested by approaches describing them as mere motor mimicry.

There were, however, several limitations to this experiment. First, the emotion induction was relatively weak, perhaps due to the lack of visual information in the induction clips. Alternatively, the marginal effect as measured by the manipulation check may be an artifact of unreliability of the VAS in measuring the emotions; because there were no midscale anchor points on the scale, it may have been difficult for the participants to give consistent scores or for them to conceptualize ranges of emotions in a consistent manner. Therefore, although the overall pattern of findings suggests that emotional processes influence RFRs at a very early stage, additional evidence with a stronger induction of fear would help clarify the findings. Second, the neutral induction used a different method than the fear induction. The use of phrases as a neutral induction may be sufficiently different from the audio fear induction procedure as to make comparison difficult. Further, to evaluate the overall consistency of these results (e.g., increased corrugator to anger expression in the fear condition) a second experiment was conducted. The second experiment will also correct for these problems and establish the replicability of the findings.

Experiment 2

Method

Participants. Participants ($N = 39$; 27 female; mean age = 22.67 years; $SD = 7.99$) were recruited through undergraduate psychology courses and given extra credit for their time.

Stimuli. Participants observed a series of randomly presented photographs (10 fear faces, 10 anger faces, and 10 neutral faces) from Pictures of Facial Affect (Ekman & Friesen, 1976). IAPS photos were not used in this study so that there was more consistency between stimuli and added control for extraneous content such as facial hair and averted gaze direction, which may increase the ambiguity of the stimuli (Adams, Gordon, Baird, Ambady, & Kleck, 2003).

Procedures. After each counterbalanced neutral and fear induction procedure, participants' reactions to the facial stimuli were evaluated. A stronger fear induction was desired for this study, and findings from our lab suggested that use of both audio and visual information has a significantly stronger effect than audio alone and that nontarget emotions are not a concern with the clips used here (Weisser, Moody, & McIntosh, 2004). Therefore, both the audio and visual of the fear induction clips used in Experiment 1 were used. These clips showed frightened individuals in various situations, and at no time were there displays of expressions other than fear. Also, to match the type of fear induction used, a short neutral video clip was used for the neutral condition. The clip was of a

[1] Because the perspective that emotions influence RFRs makes a specific prediction that it is the fear generated by the condition manipulation that causes the increased frontalis activation to anger faces, we evaluated whether self reported fear mediated the effects of emotion on frontalis activation to anger faces. Following the logic in Baron and Kenny (1986), we ran the analysis comparing activation of frontalis to anger faces with self-reported fear after the fear induction as a covariate. Because this experiment was not designed to directly test mediation, these results should be interpreted cautiously. Consistent with the idea that fear mediated the effect, the effect of condition decreased from $F(1, 40) = 12.3$, $p = .001$, partial $\eta^2 = 0.24$ to $F(1, 39) = 8.79$, $p = .005$, partial $\eta^2 = 0.18$. However, using Cohen's (1977) criteria, the effect sizes are medium in both cases; moreover, condition remains significantly associated with frontalis movement even with fear controlled. This pattern indicates that the fear measure did not fully assess the component of the manipulation that caused the condition effect. This may be because fear was not the only influential change, or that measuring fear with the visual analogue scale and after the outcome measures were taken reduced reliable measurement of fear from the induction. Similar tests for Experiment 2 are reported in footnote 3.

statue in a courtyard with several people seated on the ground next to it reading and talking, with an individual occasionally walking past the field of view. The clip was approximately 5.1 minutes in length. Stimulus pictures were presented for the same length of time as in Experiment 1 but were preceded by a short orienting tone rather than an asterisk. The remaining procedures were the same as Experiment 1. As with Experiment 1, all participants were fully debriefed after the procedures and given an opportunity to ask questions.

Measures. The same muscle groups were measured using the same standardized collection and data reduction procedures as in Experiment 1. Although there were no significant findings for levator in Experiment 1, we included this muscle to check for the presence of induced nontarget emotions such as disgust.

To check the emotion manipulation, a self-report measure of the participants' level of happiness, fear, anger, surprise, sadness, and disgust after each clip was taken at the end of the experiment. Participants retrospectively rated their emotions so that the manipulation check did not interrupt the flow from the manipulation to assessment of RFRs. Participants indicated on a 1 to 7 scale how much of each emotion they felt while watching each movie clip.

Results

Manipulation check. We used a paired-sample t test to evaluate whehter the fear induction altered the emotions of the participants. The level of fear in the fear induction condition was significantly higher ($M = 5.53$; $SD = 2.58$) than in the neutral condition ($M = 1.00$; $SD = 1.64$), $t(38) = 10.70$, $p < .0001$. To see whether this change was more pronounced than for other emotions, we compared change from baseline for fear versus change in the other emotions. Fear increased significantly more than all other emotions (p values $= .002$ to $<.00001$). Fear was generated via the induction procedure and more fear was generated than any other emotion. As with Experiment 1, there was no change in levator activation to any faces in any condition. This suggests that the inductions did not lead to disgust reactions. Also, therefore, further discussion of the results will not include levator.

Primary analyses. To evaluate the effect of the fear induction, we analyzed these data in the same manner as Experiment 1. As before, the primary activity appeared to be in the second 500 ms post stimulus onset.[2] Therefore, further analyses focused on that time window by using a 2 (condition: fear vs. neutral induction) $\times$ 3 (muscle: frontalis vs. corrugator vs. levator) $\times$ 3 (stimulus: angry vs. fear vs. neutral face) repeated measures ANOVA. Figure 2 shows frontalis and corrugator activity to each muscle by stimuli type across the first second post stimulus onset. Supporting the influence of the fear induction, condition had both a significant main effect (activation was higher in the fear [$M = 0.058$; $SD = 0.21$] than the neutral condition [$M = -0.0006$; $SD = 0.22$]), and interacted with the effects of muscle and stimulus (see Table 1 for the results of this analysis). To characterize the differences in these data, follow up paired-sample t tests were run. As with Experiment 1, there was significantly higher activation relative to baseline over the frontalis muscle to anger faces in the fear condition ($M = 0.12$; $SD = 0.26$) than in the neutral condition ($M = -0.10$; $SD = 0.25$), $t(38) = 3.39$, $p = .002$.[3] In addition, there were significantly higher levels of activity over the frontalis in response to fear faces in the fear condition ($M = 0.15$; $SD = 0.28$) versus the neutral condition ($M = -0.03$; $SD = 0.27$), $t(38) = 2.90$, $p = .006$, and the corrugator in response to fear faces in the fear condition ($M = -0.0001$, $SD = 0.21$) versus the neutral condition ($M = -0.12$, $SD = 0.27$), $t(38) = 3.53$, $p = .001$). Also, there were higher levels of activity recorded over the corrugator in response to neutral faces in the neutral condition ($M = 0.02$, $SD = 0.20$) compared with the induction condition ($M = -0.04$, $SD = 0.20$), $t(38) = 2.33$, $p = .025$). However, as in Experiment 1, there was no significant difference for the frontalis between conditions in response to neutral faces.

Discussion

As with Experiment 1, this experiment revealed that participants' RFRs were influenced by the prior induction of fear. Participants showed greater expression of fear to anger faces and to fear faces when they were in a heightened state of fear. Moreover, these reactions were not generalized reactions to all stimuli or a generalized fear response, as there was no increased frontalis activation seen in response to neutral faces. These findings further suggest that emotions may partly lead to or interact with other processes that lead to RFRs. Participants did not directly match the stimulus expressions, but rather made a context-relevant expression consistent with their emotional state and the significance of the stimuli seen.

There was also increased activity over the corrugator to fear faces in the fear induction condition and decreased activity over the corrugator to neutral faces in the fear induction condition. There are several possible explanations for these changes. First, the increase in activity over the corrugator to fear faces when participants are more afraid may reflect actual or anticipated cognitive effort (Hess et al., 1998; Smith, 1989) related to the fear response. The emotion of fear represents a grouping of action tendencies, attentional readiness, felt emotions and communicative facial expressions (Cacioppo & Gardner, 1999) that may have caused the participants to use more cognitive resources to understand the situational meaning of a fear face directed at him or her. On the other hand, the decrease in activity over the corrugator to

[2] The only significant difference found in the first 500 ms post stimulus onset for Experiment 2 was for frontalis in response to angry faces, $t(38) = 2.72$, $p = .01$. Visual analysis of Figure 2, upper left panel indicates that this may be the result of a strong and rapid onset of frontalis activation. Despite this early onset, as all effects seem to be clearly present by 500 ms post onset, and that Dimberg (1982, 1997) suggests that most activation occurs in the second 500 ms post stimulus onset, further analyses focus on the second 500 ms post stimulus onset.

[3] Similar to Experiment 1 (see footnote 1), we tested whether fear mediated the effects of emotion induction on both the three-way interaction and the effects on frontalis in response to anger faces across condition. As with the test of mediation for Experiment 1, these results should be interpreted cautiously. With self-reported fear after fear induction as a covariate, the three-way interaction went from $F(4, 152) = 2.59$, $p = .04$, partial $\eta^2 = 0.064$ (medium effect, Cohen, 1977) to $F(4, 148) = 1.07$, $p = .37$, partial $\eta^2 = 0.028$ (small effect). Furthermore, when comparing the effect of the fear induction on frontalis activation to fear faces, the effect of the fear induction went from $F(1, 38) = 11.46$, $p = .002$, partial $\eta^2 = 0.23$ (large effect) to $F(1, 37) = .40$, $p = .53$, partial $\eta^2 = .01$ (small effect). These findings are all consistent with fear mediating the effect of the induction on RFRs.

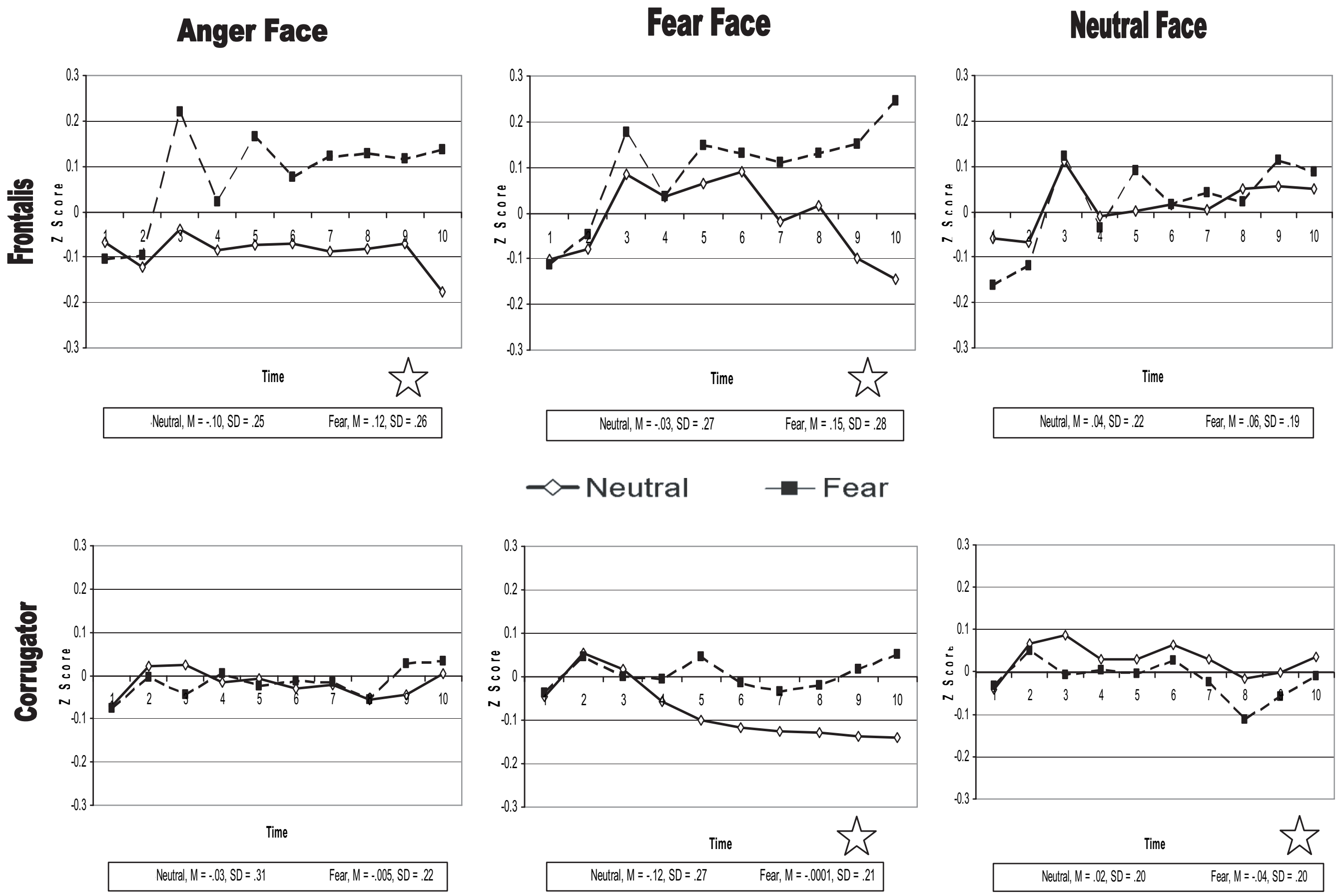

Figure 2. Experiment 2: First 1,000 ms of activity over each muscle to each facial expression after neutral and fear inductions. Activity reflects average activation during each 100-ms block, with the prestimulus baseline subtracted out. Graphs that are starred show significant differences between conditions. Means and standard deviations are for the second 500 ms, only.

neutral faces may reflect differences in how neutral faces are appraised and how such an appraisal interacts with induced emotions. For example, this phenomenon may be the result of a disambiguation effect. In any event, further research will need to be conducted to better reveal the underlying reason for this finding. More generally, the findings point to the importance of considering multiple influences on facial reactions to faces within this early time frame.

General Discussion

We found in two experiments that when fear is induced before viewing emotional facial expressions, the observers' facial responses to faces 500 to1000 ms after stimulus onset is changed in predictable ways. When in a heightened state of fear, participants did not match the expressions they saw exactly, but rather exhibited a context relevant facial expression. Most generally, these data indicate that RFRs to pictures of emotional facial expressions are at least partly the result of emotions or are influenced very rapidly by emotions.

These data indicate, at minimum, that very early facial responses measured by EMG cannot be interpreted as merely non-affective, automatic motor mimetic reactions uninfluenced by emotional processes. Contrary to the assumption that RFRs are simple motor matching reflexes of observed expression (Chartrand & Bargh, 1999; Hatfield et al., 1994; Niedenthal et al., 2005), participants did not exactly match the expressions presented. Discussions of the meaning and implications of RFRs, or "mimicry,"

Table 1
Result of Repeated Measures 2 (Condition: Fear vs. Neutral Induction) × 3 (Muscle: Frontalis vs. Corrugator vs. Levator) × 3 (Stimuli: Angry vs. Fear vs. Neutral Face) Analysis of Variance

Effects	*F* (*df*)	*p*	Partial η^2
Condition	6.61 (1,38)	.014	0.148
Muscle	7.72 (2,76)	.001	0.169
Stimuli	.047 (2,76)	.954	0.001
Condition × Muscle	4.54 (2,76)	.014	0.107
Condition × Stimuli	5.72 (2,76)	.005	0.131
Muscle × Stimuli	2.85 (4,152)	.026	0.070
Condition × Muscle × Stimuli	2.59 (4,152)	.039	0.064

should consider the influence of affective processes even at this early stage.

The effects of emotion appear to be more specific than a general increase in arousal or activation of the feeling. Participants did not just react with more fear to all stimuli after fear was induced. The heightened fear expressions were seen in response to anger and fear faces only, and not to neutral faces. This pattern of activation can be interpreted in several different ways. It may indicate that RFRs are simply the direct result of the emotional experience of the observer, as suggested by Dimberg (1997). However, these data may also be explained by positing two overlapping or interacting systems. For instance, a nonemotional matching response may exist, but the rapid emotional reactions generated by the appraisal of the stimulus influenced by the emotional context may lead to other expressions that obscure the nonemotional response. These separate systems may also interact in ways that change observed outputs. For example, an emotional system may heighten the attentional processes that direct one to look at facial stimuli thereby increasing the responses of the motor mimetic system; or, if one posits that RFRs are the result of mirror system activation (Williams et al., 2001), it may be that the observer's emotional experience alters the activation of that system. Whatever the case, this pattern suggests that fear reactions were not merely primed or activated by the induction, such that the participants indiscriminately responded with more fear to any sort of stimuli. Rather, participants, at some level, appear to have evaluated the stimuli rapidly enough that they could respond to anger stimuli with an emotion-appropriate reaction. Whatever the exact mechanism(s), emotional processes appear to be occurring quickly enough that they influence or drive these very quick facial responses.

From a more pragmatic standpoint, these data demonstrate the importance of emotional context of the situation when considering the meaning of RFRs to faces, as emotional states alter how people respond to faces in a very basic way. Individual differences in emotional state may add error variance to analyses of RFRs, and if different emotions are induced in different groups, it may be a confound affecting the ability to interpret group differences. Without being aware of individual or group differences in emotional state, researchers may have a hard time understanding what RFRs mean and how they function.

Beyond practical considerations, these data are relevant to several specific theories. For example, accounts of emotional contagion that theorize that it is the result of facial feedback from motor mimicry (Hatfield et al., 1993, 1994; McIntosh, 1996; McIntosh et al., 1994) may need to be revisited to account for emotional reactions causing the initial facial reactions, potentially covering up motor mimicry, or interacting with motor mimicry. As another example, there has been much interest in the neural substrate of imitative and empathic processes, especially regarding the mirror system (Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2005; Gallese, 2001, 2003). Given that one's emotional state can influence such rapid motor output as RFRs, it is worth considering that emotion may influence the activation of these neural sites very early in the process, especially when emotion relevant stimuli such as faces are used. Finally, because RFRs are important for social processes such as emotion perception (Neidenthal et al., 2001) the early influence of emotional state indicates that emotional state can influence social processes at even this low level.

Even though these data demonstrate that early RFRs outputs may not be merely motor mimetic reactions, it is important to note that they do not rule out the involvement of nonaffective, motor processes. That emotions have influence does not mean other processes are not involved in RFRs. Indeed, it seems likely that there are nonemotional motor mimetic reactions that may lead to or facilitate RFRs (Chartrand, Maddux, & Lakin, 2005) that are perhaps mediated by the mirror system (Gallese, 2001, 2003). If other mechanisms are involved, further research will be needed to understand how emotional processes interact with them to lead to differing patterns of responses. For example, how affect relates to RFRs may be similar to how affect influences startle responses (Lang, 1995). Lang has demonstrated that one's emotional state alters the degree of the startle response to a loud tone. When one is happy, the startle response is diminished; when one is in a negative emotional state, the startle response is enhanced. The startle response is suggested to be due to amygdala activation and the emotional state of the individual seems to change how the amygdala activates to the aversive stimulus. How emotions influence RFRs may be similar to this effect. That is, the emotional state of the observer may alter the activation of the neural substrate (perhaps the mirror system) responsible for RFRs.

Furthermore, these data cannot address other hypothesized causes of or influences on quick facial reactions. For example, several researchers (Bavelas, Black, Chovil, & Lemery, 1988; Fridlund, 1994) have suggested that emotional expressions are social/communicative acts. These rapid micro expressions may be partly socially determined—or the social context may alter the emotional state of the person, thus affecting these rapid reactions. More research is needed to better understand what nonaffective components are involved, how they interact with the affective components, and what components of the emotional response are represented by RFRs.

In addition to learning more about the basic mechanisms of this process, future research should more closely examine the precise meaning of RFRs and the functional significance of this phenomenon. Recent research has pointed to the importance of imitation for typical social functioning and has shown deficits in imitation in those with autism spectrum disorders (Rogers, 1999; Williams, Whiten, & Singh, 2004); RFRs have been proposed to be one link in the imitative process that is critical for social mechanisms to develop (Hepburn & Stone, 2006; Moody & McIntosh, 2006; Rogers, 2006) and appears to be deficient in those with autism (McIntosh et al., 2006). Facial reactions to the emotional facial actions of others may also be related to social functioning in schizophrenia (Penn & Combs, 2000). Discovering if and how RFRs are part of the imitative process may reveal how social and emotional development are relevant to psychopathology and may lead to better understanding of autism and other social-emotional dysfunctions. Further, exploring what factors influence RFRs may reveal much about what neural mechanisms are recruited in this process. For example, Adams et al. (2003) have demonstrated that anger and fear expressions with gaze directed either at the observer or away differentially activate the amygdala. Such factors may help uncover which mechanism(s) contribute to this phenomenon.

Conclusion

Rapid facial responses can be altered by one's emotional state, indicating that they may have some emotional component or influence on motor processes. Future research should examine participants' emotional states and traits more closely when using or evaluating RFRs to faces. Furthermore, additional work exploring the influence of quick emotional responses to social stimuli will help reveal what mechanisms are involved in matching phenomena such as RFRs and other, more complicated phenomena such as imitation and empathy. Most simply, considering RFRs to be only nonaffective automatic motor reactions is inaccurate. Early RFRs are not merely automatic matching of expressions; when someone flashes a smile in response to your smile, it may be more than mere mimicry.

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