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Garner Interference Reveals Dependencies Between Emotional Expression and Gaze in Face Perception

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The relationship between facial expression and gaze processing was investigated with the Garner selective attention paradigm. In Experiment 1, participants performed expression judgments without interference from gaze, but expression interfered with gaze judgments. Experiment 2 replicated these results across different emotions. In both experiments, expression judgments occurred faster than gaze judgments, suggesting that expression was processed before gaze could interfere. In Experiments 3 and 4, the difficulty of the emotion discrimination was increased in two different ways. In both cases, gaze interfered with emotion judgments and vice versa. Furthermore, increasing the difficulty of the emotion discrimination resulted in gaze and expression interactions. Results indicate that expression and gaze interactions are modulated by discriminability. Whereas expression generally interferes with gaze judgments, gaze direction modulates expression processing only when facial emotion is difficult to discriminate.

Keywords: face perception, facial affect, eye gaze, selective attention, amygdala

Given the wealth of information that co-occurs in the human face and its importance in social and emotional processing, considerable effort has been expended in understanding the cognitive and neural mechanisms that underlie face perception. Most face-processing models propose that after a common low-level stage of encoding, facial information is parsed into two distinct streams. One stream processes view-independent aspects of faces, such as gender and identity, and another stream processes view-dependent aspects of faces, such as facial expression and gaze direction (Bruce & Young, 1986). Experimental evidence supporting this independence has accumulated, converging from human behavioral studies (e.g., Prkachin & Prkachin, 1994; Young, McWeeny, Hay, & Ellis, 1986), human patient studies (e.g., Adolphs, Tranel, Damasio, & Damasio, 1994; Green, Turner, & Thompson, 2004; Parry, Young, Saul, & Moss, 1991), and single-cell studies in the macaque (e.g., Hasselmo, Rolls, & Baylis, 1989).

Incorporating evidence from functional neuroimaging and electrophysiology, Haxby, Hoffman, and Gobbini (2000, 2002) have proposed a similar model that emphasizes the distinction between invariant and variant facial information. Invariant facial information is processed in inferotemporal regions, whereas changeable aspects of faces are processed in superior temporal regions, specifically the superior temporal sulcus (STS). Furthermore, they propose that within each of these streams, processing more specific types of facial information involves interactions of the stream-specific temporal lobe areas with other brain regions. For example, both eye gaze and facial affect perception tasks engage the STS and involve the detection of deviance in changeable aspects of facial features. However, gaze perception tasks tend to elicit additional hemodynamic responses in the intraparietal sulcus, suggesting recruitment of the spatial attention system (Haxby, Hoffman, & Gobbini, 2000; Pelphrey, Singerman, Allison, & McCarthy, 2003; Puce, Allison, Bentin, Gore, & McCarthy, 1998), whereas facial affect perception tasks elicit greater activity in limbic structures, such as the amygdala and insula, according to the category of emotion expressed (Adolphs et al., 1994; Phillips et al., 1997; Morris et al., 1998; Whalen, 1998; Whalen et al., 2001).

In spite of these findings, the functional and anatomical distinction between the processes underlying gaze and expression perception is complicated by the fact that in addition to being sensitive to changes in facial expression, the amygdala also seems to be sensitive to gaze direction (e.g., Hooker et al., 2003; Kawashima et al., 1999). Electrophysiological studies with the macaque have also found evidence of face and gaze sensitive cells in the amygdala (Rolls, 1984). In a recent study with bilateral amygdala-damaged patient S.M., Adolphs et al. (2005) concluded that her well-documented deficits in recognizing fearful facial expressions stem from an inability to process information about the eye region. The sensitivity of the amygdala to the eye region is corroborated by the results of a recent neuroimaging study showing increased amygdala activation to the whites of the eyes (Whalen et al., 2004). Indeed, a growing body of evidence attests to the interactive or combined processing of these two types of variant facial information.

Neuroscientific studies of face processing suggest that processing dynamic facial information like expression and gaze involves

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both unique and shared neural mechanisms. However, the exact degree and nature of the interaction between gaze and expression processing remains uncertain. For example, neuroimaging studies have implicated the STS and amygdala in gaze and expression interactions, but evidence from transcranial magnetic stimulation suggests that these processes are independent at early stages of processing (Pourtois et al., 2004). Behavioral studies can have utility in examining gaze and expression interactions, yet recent behavioral studies and corroborating evidence from neuroimaging studies have yielded mixed results.

Adams & Kleck (2003, 2005) reported that gaze and emotional information are processed together such that direct gaze facilitates the processing of approach-oriented emotions (joy and anger), whereas averted gaze facilitates processing of avoidance-related emotions (sadness and fear). Results of a subsequent study suggest that the amygdala may play a role in this effect (Adams, Gordon, Baird, Ambady, & Kleck, 2003). In accordance with this view, Hooker et al. (2003) reported that STS activation to averted gaze was modulated by facial expression, being greater for angry faces than happy faces.

Although these results suggest that gaze direction modulates the perception of different facial expressions in different ways, other evidence argues for a more specialized role for direct gaze in the perception of facial expression: averted gaze signals the intention of the gazer away from the perceiver, whereas direct gaze toward the perceiver results in the feeling of being looked at. In turn, this feeling of being looked at causes an enhancement of all aspects of face processing, including the processing of facial expression (Senju & Hasegawa, 2005). For example, evidence suggests that direct gaze is processed more quickly than averted gaze and has an effect on judgments involving other aspects of face processing, including facial attractiveness (Kampe, Frith, Dolan, & Frith, 2001) and gender discrimination (McCrae, Hood, Milne, Rowe, & Mason, 2002). Notably, neuroimaging evidence suggests that direct gaze may engender privileged processing of emotional expressions, in that anterior STS activity is enhanced during the presentation of emotional faces with direct gaze (Wicker, Perrett, Baron-Cohen, & Decety, 2003).

Although these studies provide evidence for some integration of the processing of gaze and expression information, behavioral evidence on attentional orienting suggests otherwise (e.g., Hietanen & Leppänen, 2003). Individuals reflexively orient to eye gaze direction, as shown by Posner cueing studies where attentional targets are detected faster when placed in gazed-at locations (Friesen & Kingstone, 1998). The finding that averted gaze causes a reflexive shift of attention away from the face implies that attention should be allocated away from the face (and consequently away from facial expression) for faces with averted gaze, giving a relative advantage to processing emotion in faces with direct gaze. Despite this, some reflexive gaze-cueing experiments with emotional faces have not found convincing evidence of an interaction between gaze and emotion processing (Hietanen & Leppänen, 2003; Hori et al., 2005). Others have only found evidence of gaze and emotion interactions after individual differences in fearfulness or anxiety have been taken into account (e.g., Holmes, Richards, & Green, 2006; Mathews, Fox, Yiend, & Calder, 2003; Putman, Hermans, & van Honk, 2006; Tipples, 2006).

In summary, behavioral research examining gaze influences on emotion suggest that gaze and expression processing are integrated (e.g., Adams & Kleck, 2003; Senju & Hasegawa, 2005), but research examining emotional influences on reflexive orienting to gaze direction (e.g., Hietanen & Leppänen, 2003) suggests otherwise. However, few studies have simultaneously examined their mutual influence in the same experiment. The Garner two-choice speeded-classification task (Garner, 1974, 1976) is a behavioral task that allows for the determination of whether two stimulus dimensions interact and whether they are processed independently or in an integrated manner. The logic underlying the Garner paradigm is that if two stimulus dimensions are processed in an integral manner, then it will be impossible to attend to one dimension and ignore the other. Instead, variations in the irrelevant dimension should cause some interference that will be manifested as performance deficits, largely in reaction time.

Garner interference occurs when variations in the irrelevant dimension cause slowed responding or decreased accuracy along the relevant dimension and is supportive of the conclusion that two dimensions are processed in an integrated fashion. Garner interference is determined by comparing performance across two conditions: a control or baseline condition where only the relevant dimension varies and the irrelevant dimension is held constant, and an orthogonal or filtering condition where both dimensions vary. The original paradigm also included a correlated or redundant condition that has since been found to violate several assumptions and, hence, is not suitable for the determination of separability/integrality (see Ashby & Maddox, 1994; Maddox & Ashby, 1996, for a discussion of this issue). The Garner paradigm has been used to study the interdependence of various aspects of face processing, including the relationship between gender and identity (Ganel & Goshen-Gottstein, 2002), gender and emotional expression (Atkinson, Tipples, Burt, & Young, 2005; Le Gal & Bruce, 2002), identity and expression (Baudouin, Martin, Tiberghien, Verlut, & Franck, 2002; Schweinberger, Burton, & Kelly, 1999; Schweinberger & Soukoup, 1998), identity and speech information (Schweinberger et al., 1999; Schweinberger & Soukoup, 1998) and, most importantly for the present study, the relationship between gaze and expression (Ganel, Goshen-Gottstein, & Goodale, 2005).

In the first experiment by Ganel and colleagues (2005), participants classified faces either with respect to their gaze direction (direct vs. right or left vs. right) or their facial emotion (happy vs. angry) and ignored the irrelevant dimension. Overall, reaction times were slower for emotion judgments, suggesting that emotion was less discriminable than gaze (Algom, Dekel, & Pansky, 1996). They found Garner interference in both the gaze and emotion task as manifested by longer reaction times in the orthogonal condition relative to the control condition for both types of judgments. In their second set of experiments, Ganel et al. (2005) examined the effect of inversion on gaze and emotion judgments and, in addition to finding that emotion judgments were still more difficult than gaze, found that the interfering effect of gaze on emotion judgments disappeared with inversion, but the interference of emotion on gaze remained. Their third experiment increased the difficulty of the gaze task relative to the emotion task, equating them in discriminability (Algom et al., 1996) (direct vs. 20° left-averted, 20° vs. 40° left-averted gaze). This manipulation resulted in asymmetric interference effects for gaze and emotion: gaze interfered

more with emotion judgments than emotion with gaze judgments. The authors interpreted these effects in the context of configural versus featural processing whereby expression processing is configural, entailing an obligatory computation of gaze direction, whereas gaze processing is feature- or part-based and relies more on local features.

The findings of Ganel et al. (2005) are important because they suggest that the idea of a single, integrated system mediating gaze and expression is oversimplified. Instead, the fact that relationships between gaze and expression, as indexed by Garner interference, can be manipulated by inversion or discriminability implies that integrated processing of these two facial dimensions only occurs under certain circumstances. These findings are congruent with the Haxby et al. (2000, 2002) notion that the two types of processing share some common substrates but do have unique aspects associated with each.

Neural models of face processing, such as that proposed by Haxby et al. (2000, 2002), have implications for understanding behavior. For example, if it is indeed the case that gaze and expression processing share some common neural substrates but not others, then gaze and expression interactions should occur in different degrees under different circumstances. However, the conditions under which the two processes interact and the extent and nature of these interactions remain unclear. The goal of the present study was to provide behavioral evidence of gaze and expression interactions using the Garner selective attention paradigm, extending the results of Ganel et al. (2005) in three directions.

First, we sought to examine the generalizability of their findings with a different set of experimental stimuli that included different facial expressions and combinations of facial expressions. To this end, we used a well-normed database of faces thought to be panculturally representative of basic facial expressions of emotion (Ekman & Friesen, 1976) and used different combinations of facial expressions than those used in Ganel et al. (2005).

Second, we chose combinations of stimuli such that interactions between gaze and expression processing should be maximized. For example, according to Adams and Kleck (2003, 2005) the processing of happy and angry facial expressions should be facilitated when gaze is direct, whereas the processing of sad and fearful facial expressions should be facilitated when gaze is averted. Ganel et al. (2005) used happiness and anger, two emotions that should benefit from direct gaze; furthermore, they collapsed across emotions such that the effect of gaze was not assessed for each emotion separately. In the present study, we were interested in interactions between facial emotion and directness of gaze. In particular, we were interested in examining whether the relationships between directness of gaze and facial expressions reported by Adams and Kleck (2003, 2005) would still be observed using a different experimental paradigm. By pitting a facial expression that purportedly benefits from direct gaze against one that benefits from averted gaze, we can examine whether gaze and expression interactions reported in previous studies will be evidenced in a different experimental paradigm, providing a point of integration for our results with the existing literature. Specifically, in Experiment 1 we used sadness and happiness, whereas in Experiment 2 we used anger and fear. These combinations of stimuli were chosen in an attempt to maximize gaze and expression interactions.

Finally, we were interested in investigating the influence of stimulus discriminability on Garner interference. For example, in Ganel et al. (2005) Experiments 1 and 2, an overall reaction time advantage was observed for gaze judgments over emotion judgments, a finding that is indicative of differences in the discriminability of the two dimensions and that suggests that gaze is being processed more quickly than facial emotion (Algom et al., 1996). Baseline discriminability should be matched in the Garner paradigm; otherwise, differences in discriminability can give rise to asymmetries wherein the less discriminable dimension (in this case, emotion) may be affected more by the more discriminable dimension (gaze). In fact, when Ganel et al. (2005) made gaze judgments more difficult, interference effects that were previously symmetrical for the two tasks now became larger for emotion than for gaze (i.e., gaze now interfered more with emotion judgments than emotion did with gaze judgments). To examine the effect of discriminability on our Garner interference effect, in our Experiments 3 and 4 we varied the discriminability of facial expression. In Experiment 3, we increased the difficulty of the emotion discrimination by using morphed facial expressions of fear and anger, and compared these results to Experiment 2. In Experiment 4, we increased the difficulty of the emotion discrimination by using two facial emotions that are often confused with one another, fear and surprise (Ekman & Oster, 1982). The differences in performance attributable to discriminability could yield some insight into the nature and timing of the interaction between gaze and expression processing.

Experiment 1

Method

Participants. Participants consisted of a total of 22 students (9 women and 13 men) ranging from 18 to 26 years of age ($M = 20.8$ years). In all experiments, participants had no self-reported history of neurologic or psychiatric illness, and normal or corrected-to-normal vision. Similarly, all procedures for human participants were approved by the institutional review board at Duke University.

Stimuli and apparatus. Six digitized grey-scale photographs of the same individual were used as stimuli in this experiment, which constituted the factorial combination of facial expression (happy, sad) and gaze direction (direct, right, left). Left- and right-gazing photos were combined to comprise the averted gaze category (i.e., the averted gaze category consisted of ½ leftward gazing faces and ½ rightward gazing faces). The photographs were 2.5 in wide and 3.5 in high. Only one identity was utilized for two reasons. First, previous studies have established that facial identity modulates the perception of facial expression (Schweinberger et al., 1999). Second, we wanted our protocol to be comparable to that of Ganel et al. (2005) who also used one identity. One actor (M.O.) portraying emotional facial expressions that have been found to be panculturally representative of the basic emotions of happiness and sadness was chosen from the Ekman pictures of facial affect (Ekman & Friesen, 1976). To exclude extraneous cues such as hair, ears, and neckline, faces were cropped with an ovoid mask. Images were normalized for contrast and luminance and presented against a dark gray background. As pictured in Figure 1, all expressions were posed in full frontal orientations without changes in head orientation. The original stimuli had direct gaze. Adobe Photoshop was used to manipulate gaze direction so that

Figure 1. Facial stimuli employed in Experiment 1.

averted irises deviated between 0.37° and 0.4° from the centrally positioned irises in the faces with direct gaze. Stimuli were presented and responses recorded with Superlab Pro v. 2.0 experimental software for Windows (Cedrus, 1999).

Design and procedure. The experiment consisted of two main tasks, a gaze judgment task and a facial expression judgment task. For each task, the stimuli were combined in two different experimental conditions, a control condition and an orthogonal condition. For each of these conditions, two consecutive blocks were presented, each consisting of 64 trials. In both control conditions for both emotion and gaze judgments, the relevant task dimension (e.g., gaze directness for the gaze task) was varied while the irrelevant dimension (e.g., happiness or sadness for the gaze task) remained constant. In the second block, the other alternative of the irrelevant dimension remained constant while the relevant dimension varied. For example, for the gaze task, one control block kept facial emotion constant with happiness while gaze varied (direct, averted), and in the other control block, the emotion was held constant at sadness while the gaze directness varied.

In the orthogonal condition, both blocks contained all four possible combinations of the two dimensions (happy-direct, happy-averted, sad-direct, and sad-averted). In accordance with Schweinberger and Soukoup (1998), this blocking was conducted to ensure that all stimuli appeared with equal frequency in each condition, minimizing context effects (Ashby & Maddox, 1994; Maddox & Ashby, 1996). Thus, between both blocks, each of the four stimulus types (happy, sad, direct gaze, and averted gaze) was presented 32 times in each condition. As mentioned above, left- and right-gazing photos were each presented 16 times to comprise the 32 averted-gaze stimuli. Within blocks, trials were presented in randomized order, and the order of the tasks (gaze vs. emotion judgments) and the conditions (control vs. orthogonal) were counterbalanced across participants. Short breaks were permitted between blocks.

Depending on the task, in each block participants were asked to make two-alternative, forced-choice judgments of emotional expression (happy or sad) or gaze directness (direct or averted) with manual keyboard responses. Response keys were counterbalanced across participants. Each trial began with a fixation cross in the center of the screen for a duration of 400 ms, which was replaced by one of the stimulus faces that remained on the screen until a response was made. The next trial began immediately after the response was made. Responses were scored as correct if the appropriate response was made to the stimulus between 100 ms and 3000 ms after the onset of the face. Reaction time values outside of this range and those associated with incorrect responses were removed from the analysis.

Results

Incorrect responses accounted for 2.0% of the total data. Reaction time outliers accounted for 1.8% of the data points. These points were not included in the reaction time analyses.

Reaction time analyses. Median reaction times were subjected to a repeated-measures analysis of variance (RM-ANOVA), with task (gaze vs. emotion judgments), interference condition (control vs. orthogonal), gaze (direct vs. averted), and emotion (happy vs. sad) as within-subject variables.

The analysis of variance (ANOVA) revealed a main effect of task, $F(1, 21) = 82.52$, $p < .001$, reflecting the fact that emotion judgments ($M = 460$ ms) were made faster than gaze judgments ($M = 554$ ms). There was no significant main effect for condition;

instead, there was a task by interference condition interaction, $F(1, 21) = 6.72$, $p < .05$. This interaction is shown in Figure 2A, which indicates that the interference condition affected gaze judgments but not emotion judgments. Post hoc main effects analyses confirmed that when participants were required to judge gaze directness, they were slower in the orthogonal condition than the control condition ($M = 571$ ms vs. $M = 538$ ms, respectively), $t(21) = -2.21$, $p < .05$. There was no difference between the control and orthogonal conditions when participants were making emotion judgments ($M = 463$ ms vs. $M = 458$ ms, respectively), $t(21) = 0.86$, $p > .05$.

The initial omnibus ANOVA also indicated that there was a significant interaction between task and emotional expression, $F(1, 21) = 18.87$, $p < .01$, which is depicted in Figure 2B. Separate post hoc analyses for each task revealed that participants were faster to make judgments about the directness of gaze when the face was sad than when it was happy ($M = 547$ ms vs. $M = 561$ ms, respectively), $t(21) = -2.33$, $p < .05$. However, the reverse was true when participants were making emotion judgments—participants were faster to make emotion judgments when the face was happy than when it was sad ($M = 471$ ms vs. $M = 449$ ms, respectively), $t(21) = 3.72$, $p < .01$.

It was necessary to rule out the possibility that these results were attributable to inflated reaction times in the emotion control block with averted gaze. Although gaze was constantly averted, it did vary from left to right. Therefore, it was important to establish that results were not because of an overestimation of the emotion control condition mean driven by this particular block (i.e., that reaction times were significantly slower in the averted gaze control condition than in the direct condition). To ensure that these results were not because of slowed responses in the control block with averted gaze, reaction times for direct and averted gaze were compared for the emotion control condition only. Importantly, there were no significant differences between reaction times for the direct and averted gaze blocks of the emotion control conditions ($M = 465$ ms vs. $M = 461$ ms, for direct and averted gaze respectively), $t(21) < 1$, $p > .05$. In other words, the absence of an interference effect for gaze on emotion was not merely because of inflation of the control condition mean driven by the averted gaze emotion control block.

Errors. Despite the relatively small number of errors, a subsidiary RM-ANOVA was conducted on error rates, with task (gaze vs. emotion judgments), condition (control vs. orthogonal), gaze (direct vs. averted), and emotion (happiness vs. sadness) as within-subject variables. This analysis revealed a significant main effect of task, reflecting the fact that participants were more accurate at making emotion judgments (98.1% accuracy) than judgments about directness of gaze (97.8%), $F(1, 21) = 4.51$, $p < .05$. No other main effects or interactions achieved significance, although there was a trend for both emotion and gaze judgments to be more accurate when the gaze was direct rather than averted, $F(1, 21) = 4.08$, $p = .056$.

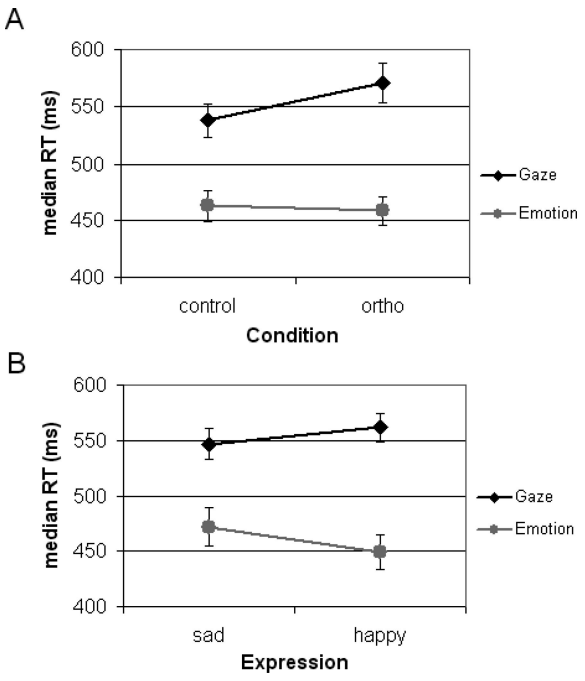

Figure 2. Means of the individual median reaction times (ms) obtained in Experiment 1 for the A) control and orthogonal (ortho) interference conditions for and B) to sad and happy faces for gaze and emotion judgments. Error bars show the SEM.

Discussion

The central finding in this experiment was an asymmetric pattern of Garner interference. Facial expression interfered with judgments of the directness of gaze (as indexed by longer reaction times in the orthogonal relative to the control condition), whereas gaze did not interfere with emotion judgments. This asymmetry was likely because of the relative discriminability of gaze and emotion, because our reaction time and error analyses indicated that participants were both faster and more accurate at making emotion judgments than directness of gaze judgments. In addition, we were able to rule out the possibility that the absence of any effect of gaze on emotion was because of an overestimation of the emotion control condition mean. Comparison of the happy faces used in this experiment and Ganel et al. (2005) by a certified Facial Action Coding System (FACS; Ekman & Friesen, 1978) coder (R.G.) confirmed that the happy face used in this experiment was more intense than those used in Ganel et al. (2005) and implies that baseline discriminability can indeed have an enormous impact on results (see Appendix). Therefore, the results of this experiment suggest that when emotional expression is easily discriminable, it is processed quickly and before gaze has time to interfere.

We also found a significant interaction between task and facial emotion such that although judgments for directness of gaze were slower when the face was happy, emotion judgments were facilitated when the face was smiling. The advantage for happy faces over sad faces in the emotion task may be because of the well-documented processing advantage for happy faces (Ekman & Oster, 1982; Kirita & Endo, 1995; Kirouac & Dore, 1983). The advantage for sad faces over happy faces when gaze judgments were made may be related to the relative importance of the eye region for these expressions (Adolphs et al., 2005). It is possible that the relative intensity of the happy facial expression in the lower face area drew attention away from the eye region and slowed down directness of gaze judgments for happy faces. It is

also possible that the eye aperture is slightly smaller because of the squint that accompanies a smiling face, and this decrease in aperture made the gaze discrimination faster for sad eyes, which were relatively larger.

We had hoped that the use of happy and sad facial expressions, whose processing purportedly benefits from direct gaze and averted gaze, respectively (Adams & Kleck, 2003, 2005), would allow for maximal interactions between gaze and expression. However, it is noteworthy that no gaze by expression or higher-order interactions involving gaze and expression approached significance in either the reaction time or the accuracy analyses. Instead, there was a trend for an accuracy advantage for direct gaze regardless of the task or attentional demands (i.e., a marginal main effect of gaze directness), more consistent with research supporting a processing advantage for faces with direct gaze (e.g., Senju & Hasegawa, 2005).

In summary, Experiment 1 demonstrated that when panculturally validated representations of happy and sad facial expressions are used, emotion is more discriminable than gaze, and an asymmetric pattern of Garner interference results such that irrelevant variations in facial emotion interfere with directness of gaze judgments, but gaze does not interfere with emotion judgments. The statistical analyses found no evidence of gaze by emotion interactions and only a trend for an accuracy advantage for direct gaze. We also found evidence that judgments about facial attributes can be modulated by emotion: directness of gaze is judged faster on sad than happy faces, whereas the opposite is true for emotion judgments (i.e., emotion is judged more quickly on happy than sad faces). Given that happiness may enjoy a processing advantage over other facial expressions of emotion, it was important to establish whether this pattern of results would also be evidenced if other facial expressions were used.

Experiment 2

Experiment 2 was motivated by the desire to establish whether the results of Experiment 1 were specific to happy and sad facial expressions. Given that facial expressions of happiness are detected and identified more quickly and accurately than any other facial expression (e.g., Kirita & Endo, 1995), it was important to ensure that our results did not arise because of the use of happy faces. Specifically, we wanted to know whether emotion would remain more discriminable than gaze, whether the asymmetric pattern of Garner interference would persist, and whether facial expression would have a differential effect on directness of gaze and emotion judgments when another set of facial expressions were used. To this end, we replicated Experiment 1 by using fearful and angry faces. These expressions were chosen to maximize the potential for gaze/expression interactions as predicted by Adams and Kleck (2003, 2005). In addition, a different actor from the one used in Experiment 1 was chosen from the Ekman face series.

Method

Participants. Participants consisted of a total of 21 students (11 women and 10 men) ranging from 18 to 22 years of age (M = 20.1 years).

Stimuli and procedure. Six digitized grey-scale photographs of the same individual (W.F.) from the Ekman face series were used as stimuli, which constituted the factorial combination of facial expression (fear, anger) and gaze directness (direct, averted—½ left, ½ right). Otherwise, the stimuli and design of Experiment 2 were identical to those used in Experiment 1. The stimuli used in this experiment are pictured in Figure 3.

Results

Incorrect responses accounted for 2.9% of the total data. Reaction time outliers accounted for 2.2% of the data points. These points were not included in the reaction time analyses.

Reaction time analyses. Median reaction times were subjected to an omnibus RM-ANOVA, with task (directness of gaze vs. emotion judgments), condition (control vs. orthogonal), gaze (direct vs. averted), and emotion (anger vs. fear) as within-subject variables. The ANOVA revealed a main effect of task, $F(1, 20) = 5.87$, $p < .05$, reflecting the fact that emotion judgments ($M = 540$ ms) were made faster than directness of gaze judgments ($M = 584$ ms). The ANOVA also revealed a main effect of gaze, $F(1, 20) = 15.10$, $p < .01$, reflecting the tendency for responses to direct-gazing faces ($M = 551$ ms) to be faster than those to averted-gazing faces ($M = 578$ ms), regardless of task or attentional demands. There was also a significant main effect of interference condition, $F(1, 20) = 7.99$, $p < .05$, indicating that responding during the orthogonal conditions was significantly slower than in the control condition ($M = 553$ ms vs. $M = 578$ ms, respectively). However, this effect was mitigated by a significant task by interference condition interaction, $F(1, 20) = 4.76$, $p < .05$. This interaction is shown in Figure 4A, which indicates that there was an effect of interference condition for gaze judgments but not for emotion judgments. Post hoc main effects analyses confirmed that when participants were required to judge the directness of gaze, they were slower in the orthogonal condition than the control condition ($M = 562$ ms vs. $M = 607$ ms, respectively), $t(20) = -4.42$, $p < .01$. There was no difference between the control and orthogonal conditions when participants were making emotion judgments ($M = 536$ ms vs. $M = 545$ ms, respectively), $t(20) = -0.61$, $p > .05$.

As in Experiment 1, it was necessary to rule out the possibility that these results were attributable to inflated reaction times in the emotion control block with averted gaze. To ensure that these results were not because of slowed responses in the control block with averted gaze, reaction times for direct and averted gaze were compared for the emotion control condition only. Importantly, there were no significant differences between reaction times for the direct and averted gaze blocks of the emotion control conditions ($M = 529$ ms vs. $M = 536$ ms, for direct and averted gaze respectively), $t(20) < 2$, $p > .05$. In other words, the absence of an interference effect for gaze on emotion was not merely because of inflation of the control condition mean driven by the averted gaze emotion control block.

The initial omnibus ANOVA also revealed a significant interaction between task and emotional expression, $F(1, 20) = 18.87$, $p < .01$, depicted in Figure 4B. Separate main effects analyses for each task revealed that this result was driven by the tendency for participants to be faster to make judgments about the directness of gaze when the face was scared than when it was angry ($M = 575$ ms vs. $M = 594$ ms, respectively), $t(20) = -2.65$, $p < .05$.

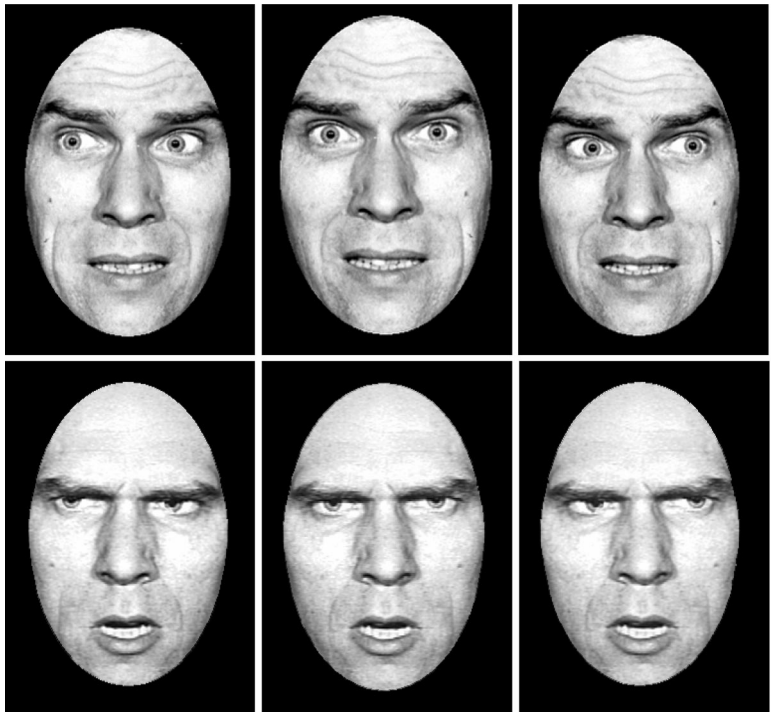

Figure 3. Facial stimuli employed in Experiment 2.

However, the specific expression posed did not affect the speed of emotion judgments, $t(20) < 1$.

Errors. Despite the small number of errors, a subsidiary RM-ANOVA was conducted on error rates, with task (gaze vs. emotion judgments), interference condition (control vs. orthogonal), gaze (direct vs. averted), and emotion (happiness vs. sadness) as within-subject variables. This analysis revealed a significant main effect of facial emotion, reflecting the fact that participants were more accurate at making both gaze and emotion judgments with fearful faces ($M = 97.5\%$) than with angry faces ($M = 96.7\%$), $F(1, 20) = 6.36$, $p < .05$. There was also a significant interaction between task and directness of gaze, $F(1, 20) = 10.95$, $p < .01$. When participants were asked to make gaze judgments, they were more accurate when gaze was direct ($M = 97.5\%$ vs. $M = 96.3\%$ for averted gaze); however, for emotion judgments, they were more accurate when gaze was averted ($M = 97.8\%$ vs. $M = 96.8\%$ for direct gaze).

Discussion

As in Experiment 1, the central finding was an asymmetric pattern of Garner interference. Whereas facial expression interfered with gaze judgments, gaze did not interfere with emotion judgments. This asymmetry was most likely because of the relative discriminability of gaze and emotion, because our reaction time analysis indicated that participants were faster at making emotion judgments than gaze judgments. Comparison of the angry faces used in this experiment and in Ganel et al. (2005) by a certified FACS coder (R.G.) confirmed that the angry face used in this experiment was more intense than those used in Ganel et al. (2005) and strengthens our previous finding that baseline discriminability can have an impact on results (see Appendix). Therefore, the results of this experiment corroborate those of Experiment 1 to suggest that when expression is easily discriminable, emotion is processed rapidly and before gaze has time to interfere.

This main finding was accompanied by other noteworthy results. First, there was an overall main effect of gaze on reaction time regardless of task and attentional demands, such that direct gaze facilitated both gaze judgments and emotion judgments, a finding which supports a privileged role for direct gaze. This finding was tempered by the task by gaze interaction in the error analysis, which indicated that participants were more accurate at judging emotion in faces with averted gaze. This suggests that the apparent advantage for direct gaze in the emotion judgment task could be because of speed/accuracy tradeoffs. Therefore, the advantage for direct gaze can only reasonably be attributed to gaze judgments, a finding that, in turn, could be attributable to context effects. Specifically, because there was only one instance of direct gaze and two of averted gaze (both left and right), making a direct gaze judgment may have been relatively easier than making an averted one. Another finding of note was that no gaze by emotion or higher-order gaze by emotion interactions approached significance. These results mirror those of Experiment 1 in failing to produce any support in favor of either gaze/emotion interactions or a processing advantage for direct gaze.

Finally, we found a significant interaction between task and facial emotion such that fearful faces engendered faster gaze judgments relative to angry faces, but there was no effect of the specific expression posed on emotion judgments. The most likely explanation for this result is that the eye aperture on a fearful face is much larger than eye aperture for angry faces, thereby facilitat-

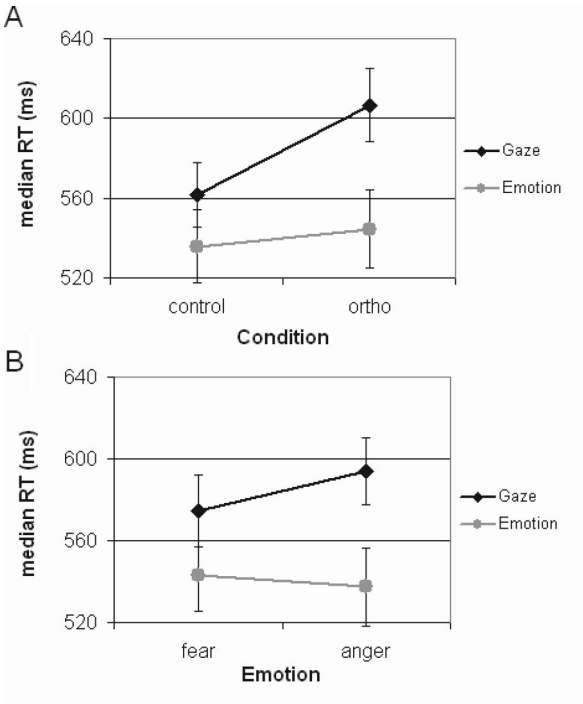

Figure 4. Means of the individual median reaction times (ms) obtained in Experiment 2 for A) the control and orthogonal (ortho) interference conditions and B) to fearful and angry faces for gaze and emotion judgments. Error bars show the SEM.

ing gaze judgments, an explanation similar to that for the gaze judgment advantage for sad faces over happy faces in Experiment 1. Increases in the amount of sclera or eye whites in fearful faces has been shown to elicit robust amygdala activity (Whalen et al., 2004), which may be at least partially responsible for this effect. Together, these experiments suggest that emotional effects on gaze judgments may be primarily attributable to upper face feature changes that affect eye aperture and, consequently, the discriminability of gaze. This finding is supported by the error analysis, which revealed an accuracy advantage for fearful faces, regardless of task. The fact that gaze judgments were more accurate with fearful faces corroborates our explanation that gaze is easier to discriminate when the eyes are wide. The increased accuracy for fearful faces in emotion judgments is somewhat harder to explain, but may be related to neuroimaging findings that fearful faces elicit greater activation in the amygdala and extrastriate regions than angry faces, which may yield perceptual advantages (LaBar, Crupain, Voyodic, & McCarthy, 2003; Whalen et al., 2001; but see Yang et al., 2002).

In summary, the results of Experiment 2 support those of Experiment 1 using different facial expressions and a different actor. With unambiguous facial expressions, emotion is more discriminable, is processed more quickly than gaze, and an asymmetric pattern of Garner interference results. Irrelevant variations in facial emotion interfere with gaze judgments, but gaze does not interfere with emotion judgments. This asymmetry seems to hold across different facial expressions. As in Experiment 1, we did not find any evidence of gaze/emotion interactions, suggesting that at least with these easily discriminable emotions, gaze does not modulate expression processing and vice versa. There was also evidence that judgments about gaze were modulated by emotion to the extent that different emotions vary in eye aperture—those that increase aperture (e.g., sadness, fear) make gaze more discriminable than those that decrease eye aperture (e.g., happiness, anger).

The issue of discriminability is critical to the Garner paradigm because differences in baseline discriminability can cause asymmetries in Garner interference between the two tasks (Algom et al., 1996). According to a speed-of-processing account (e.g., Atkinson et al., 2005; Schweinberger et al., 1999), mismatches in discriminability would cause asymmetric interference patterns because the more discriminable dimension (i.e., emotional facial expressions) is computed before the less discriminable dimension (i.e., gaze direction) has been fully processed. This would explain why our results differed from Ganel et al. (2005). Despite the intuitive appeal of this explanation, it was important to demonstrate that this was indeed the case, because asymmetric dependencies have been shown to persist even after differences in baseline discriminability have been redressed (Atkinson et al., 2005; Schweinberger et al., 1999).

In addition, the relative ease of discrimination of emotional expression in our first two experiments may also provide an explanation for why we did not find any evidence of gaze/emotion interactions. Adams and Kleck (2005) used both pure and morphed facial expressions of fear and anger to assess gaze and expression interactions. Although they did not use happy and sad facial expressions as in Experiment 2 of the present study, they did intermix several different identities in their design. The different actors may have posed the emotions so that they were expressed with differing degrees of intensity. This may have affected the discriminability of the emotion, because the intensity of a particular facial expression may have differed from actor to actor. Therefore, it is possible that gaze and emotion interactions will only occur if facial emotion is ambiguous or less discriminable.

Experiment 3

Experiment 3 was motivated by the desire to establish whether the results of Experiments 1 and 2 were caused by a mismatch in task difficulty. Given that in both experiments facial expressions were classified more quickly (and accurately in the case of Experiment 1), we were primarily interested in determining whether this pattern of asymmetric interference for gaze and not emotion would persist after increasing the difficulty of the emotion discrimination. We were also interested in whether this manipulation would promote gaze/emotion interactions. To this end, we attempted to extend the results of Experiment 2 by using fearful and angry faces that had been morphed with neutral expressions to provide less intense facial representations of fear and anger, thereby making emotion discrimination more difficult.

Method

Participants. Participants consisted of a total of 20 students (10 women and 10 men) ranging from 18 to 21 years of age (M = 18.9 years).

Stimuli and procedure. Six digitized grey-scale photographs of one actor (E.M.) from the Ekman face series were used as

stimuli, which constituted the factorial combination of facial expression (morphed fear, morphed anger) and gaze direction (direct, averted—½ left, ½ right). This actor was different from those used in Experiments 1 and 2. The morphs were created using the methods outlined in LaBar et al. (2003) using MorphMan, 2000 software (STOIK, Moscow). Morphs depicting 55% fear/45% neutral and 55% anger/45% neutral were chosen because our previous study indicated that morphs of this intensity were recognized just above threshold levels (Graham, Devinsky, & LaBar, in press). Thus, we were confident that this level of emotion intensity would be more difficult to discriminate. Otherwise, the stimuli and design of Experiment 3 were identical to those used in Experiments 1 and 2. The stimuli used in this experiment are pictured in Figure 5.

Results

Incorrect responses accounted for 2.8% of the total data. Reaction time outliers accounted for 2.5% of the data points. These points were not included in the reaction time analyses. Median reaction times were subjected to an omnibus RM-ANOVA, with task (directness of gaze vs. emotion judgments), interference condition (control vs. orthogonal), gaze (direct vs. averted), and emotion (anger vs. fear) as within-subject variables.

The ANOVA indicated that there was a main effect of condition, $F(1, 19) = 11.07$, $p < .01$, reflecting the fact that reaction times in the control conditions ($M = 592$ ms) were faster than those in the orthogonal conditions ($M = 622$ ms). Importantly, as shown in Figure 6A, this was not accompanied by a significant task by condition interaction, $F(1, 19) < 1$. The main effect of task was not significant, $F(1, 19) = 3.17$, $p = .09$, indicating that participants took equally long to make directness of gaze and expression judgments.

The omnibus ANOVA also revealed a main effect of emotion, $F(1, 19) = 7.17$, $p < .05$, indicative of the fact that, overall, fearful faces ($M = 600$ ms) were responded to more quickly than angry faces ($M = 614$ ms). This main effect was mitigated by a significant interaction between task and emotional expression, $F(1, 19) = 9.29$, $p < .01$, depicted in Figure 6B. Separate post hoc main effects analyses for each task revealed that this result was driven by the tendency for participants to be faster to make judgments about the directness of gaze when the face was scared than when it was angry ($M = 577$ ms vs. $M = 608$ ms, respectively), $t(19) = -4.46$, $p < .05$. In contrast, facial emotion did not affect the speed of emotional expression judgments, $t(19) < 1$.

The ANOVA also revealed a main effect of gaze directness, $F(1, 19) = 24.34$, $p < .01$, reflecting the tendency for responses to direct gazing faces ($M = 587$ ms) to be faster than those to averted gazing faces ($M = 627$ ms), regardless of task or attentional demands. The main effects of gaze and emotion were qualified by a significant interaction between gaze and facial emotion, $F(1, 19) = 22.13$, $p < .05$. This interaction is shown in Figure 6C. There were no differences between reaction times to classify fear and anger when gaze was direct, but when gaze was averted, participants were significantly slower to respond when the face was angry than when it was fearful. In other words, direct gaze facilitated judgments for angry faces but not fearful faces. This two-way interaction, in turn, was qualified by a three-way interaction among task, gaze, and emotion, $F(1, 19) = 7.08$, $p < .05$. Post hoc Bonferroni-corrected pairwise comparisons revealed that the slowed responding to angry faces with averted gaze (relative to

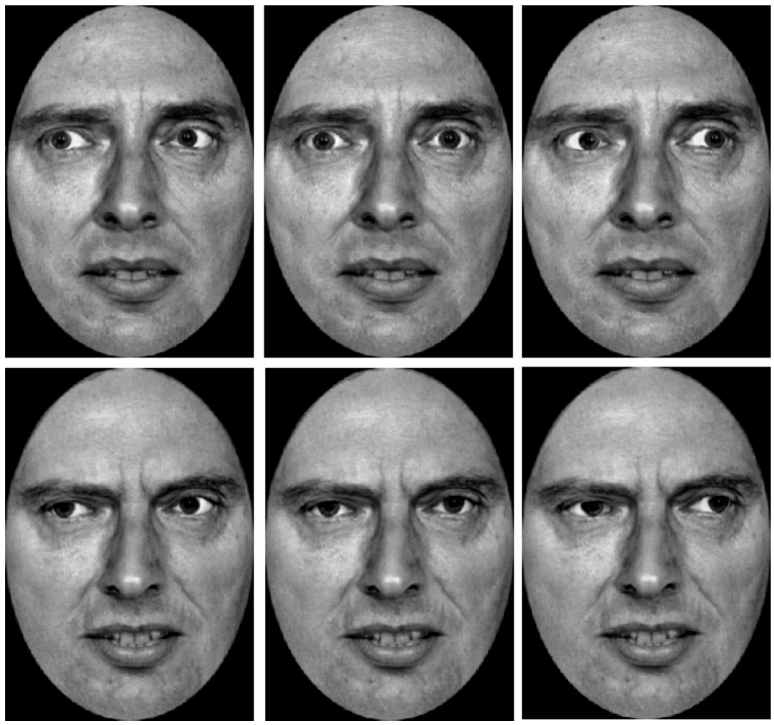

Figure 5. Facial stimuli employed in Experiment 3.

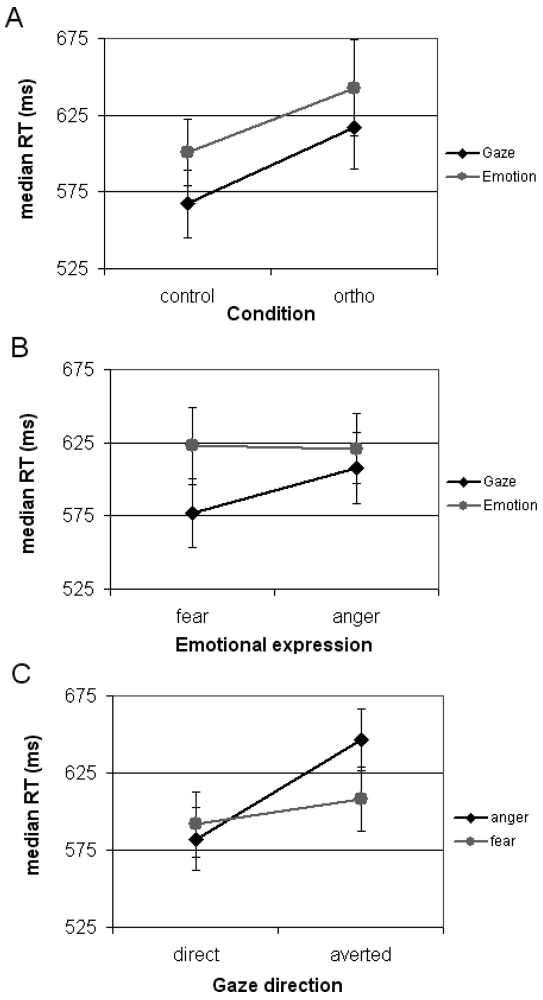

Figure 6. Means of the individual median reaction times (ms) obtained in Experiment 3 for A) the control and orthogonal (ortho) interference conditions, B) to fearful and angry faces and C) to faces with direct and averted gaze for gaze and emotion judgments. Error bars show the SEM.

fearful faces with averted gaze) was larger in the gaze task (M = 577 ms for averted fear vs. M = 646 ms for averted anger) than in the emotion task (M = 612 ms for averted fear vs. M = 661 ms for averted anger).

As in Experiments 1 and 2, we wanted to rule out the possibility that the emotion control condition was inflated because of slowed reaction times in the emotion control block with averted gaze. To this end, we compared reaction times for direct and averted gaze for the emotion control condition only. Importantly, there were no significant differences between reaction times for the direct and averted gaze blocks of the emotion control conditions (M = 634 ms vs. M = 645 ms, for direct and averted gaze respectively), $t(19) = -1.56$, $p > .05$. In other words, the interference effect for gaze on emotion was not attenuated because of inflation of the control condition mean driven by the averted gaze emotion control block.

Errors. A subsidiary RM-ANOVA was conducted on error rates, with task (gaze vs. emotion judgments), interference condition (control vs. orthogonal), gaze (direct vs. averted), and emotion (fearful vs. angry) as within-subject variables. This analysis revealed a significant main effect of facial emotion, reflecting the fact that participants were more accurate at making both gaze and emotion judgments with angry faces (M = 97.7% accuracy) than with fearful faces (M = 96.8%), $F(1, 19) = 5.63$, $p < .05$. There was also a significant main effect of gaze, $F(1, 19) = 11.70$, $p < .01$, which indicated that accuracy on both tasks was improved when gaze was direct (M = 97.7% vs. M = 96.8% for averted gaze), regardless of attentional demands. This finding was mitigated by a three-way interaction among task, interference condition, and gaze, $F(1, 19) = 6.44$, $p < .05$. Bonferroni-corrected post hoc comparisons indicated that the accuracy advantage for direct gaze was most marked in the gaze judgment task during the control condition.

Manipulation check. Differences in task difficulty attributable to discriminability were no longer present in Experiment 3, but to confirm that our manipulation succeeded in making emotion discriminations more difficult, we conducted a final ANOVA on the reaction time data across Experiments 2 and 3. In this analysis, experiment (Experiment 2 vs. Experiment 3) was a between-subjects variable and task (gaze vs. emotion judgments), interference condition (control vs. orthogonal), gaze (direct vs. averted), and emotion (anger vs. fear) were within-subject variables. This analysis yielded two results. First, there was a significant task by experiment interaction, $F(1, 20) = 10.95$, $p < .01$. Although reaction times for gaze judgments did not differ from Experiment 2 to Experiment 3 (M = 584 ms vs. M = 592 ms, respectively), reaction times for emotion judgments did (M = 540 ms vs. M = 622 ms, for Experiments 2 and 3, respectively). Second, there was a significant three-way interaction among experiment, gaze, and emotion, $F(1, 20) = 21.83$, $p < .01$. Post hoc tests showed that the gaze by emotion interaction was significant only in Experiment 3, as described previously.

Discussion

Using face morphs depicting threshold intensity expressions of fear and anger affected the difficulty of the emotion task, as indexed by slowed reaction times in the emotion judgment task relative to Experiment 2. Critically, using 55% intensity facial expression equated reaction times across the gaze and emotion judgment tasks. Unlike Experiments 1 and 2, the central finding in this experiment was a symmetric pattern of Garner interference: facial expression interfered with judgments about the directness of gaze and gaze interfered with emotion judgments. This pattern of interference is similar to that obtained by Ganel et al. (2005) and can be attributed to the fact that gaze and emotion had similar levels of discriminability, because our reaction time analysis indicated that participants were equally fast at making both kinds of judgments. Therefore, the results of this experiment extend those of Experiments 1 and 2, suggesting that when it is harder to discriminate, emotional expression processing is slowed, allowing gaze to interfere with emotion judgments.

This finding was accompanied by other noteworthy results. First, there was an overall main effect of directness of gaze on reaction time, such that direct gaze facilitated both gaze judgments and emotion judgments, a finding which supports a privileged role for direct gaze. However, this direct gaze advantage was mitigated by a significant gaze by emotion interaction, which was attribut-

able to the fact that the advantage for direct gaze was especially marked for angry faces, especially when gaze judgments were made. The reaction time advantage for direct gaze was also qualified by a three-way task by condition by gaze interaction in the error analysis, which indicated that the advantage for direct gaze was most marked for gaze judgments in the control condition. Together, these results suggest that the advantage for direct gaze was driven by gaze judgments for angry faces, a finding predicted by Adams and Kleck (2003, 2005). However, we did not find any evidence that fearful faces benefited from averted gaze. What is particularly interesting is that comparison of Experiments 2 and 3 indicated that gaze/emotion interactions emerged only when facial emotion became more difficult to discriminate.

Reaction time analyses revealed that judgments were made more quickly with fearful faces than with angry faces. However, this was accompanied by decreased accuracy, suggesting that speed/accuracy tradeoffs were responsible for the apparent reaction time advantage for fearful faces. Similar to Experiment 2, we found a significant interaction between task and facial emotion such that although judgments for gaze were faster for fearful faces relative to angry faces, there was no such advantage for fearful faces when emotion judgments were made. Together, these experiments suggest that emotional effects on gaze judgments may be primarily attributable to upper face feature changes that affect eye aperture and, consequently, the discriminability of gaze. This finding was supported by a main effect of emotion, which revealed an accuracy advantage for fearful faces, regardless of task. The fact that gaze judgments were more accurate with fearful faces further strengthens the conclusion that gaze discriminability can vary as a function of facial expression.

In summary, the results of Experiment 3 both extend and support those of Experiments 1 and 2. When unambiguous expressions are used, emotion is more discriminable than gaze and an asymmetric pattern of Garner interference results; irrelevant variations in facial emotion interfere with gaze judgments, but gaze does not interfere with emotion judgments. However, when gaze and emotion judgments are equated for difficulty, Garner interference becomes symmetric. Unlike Experiments 1 and 2, when emotion discrimination was more difficult, we did find evidence of gaze/emotion interactions, suggesting that with easily discriminable emotions, gaze does not modulate expression processing and vice versa. However, when emotional discrimination was more difficult, gaze/emotion interactions were observed, suggesting that gaze direction and emotional expression may modulate one another when they are hard to distinguish. This study also further supports evidence from the first two experiments that judgments about gaze can be modulated by emotion to the extent that different emotions vary eye aperture—those that increase eye aperture make gaze more discriminable than those that decrease it.

Experiment 4

The results of Experiment 3 suggested that using morphed facial expressions made the emotion discrimination more difficult, resulting in a symmetric pattern of Garner interference effects. However, it is possible that these results were because of the use of morphs and were not actually because of the difficulty of the emotion discrimination itself. The purpose of Experiment 4 was to rule out this possibility. Rather than using morphed facial expressions, we chose to use full intensity facial expressions of emotions that are naturally difficult to discriminate. Fear and surprise are commonly confused with one another (Ekman & Oster, 1982) and when fearful faces are presented briefly (less than 34 ms), they are more likely to be labeled as surprised rather than scared (Ogawa & Suzuki, 1999). Fear and surprise are similar in terms of feature displacement (Yamada, Matsuda, Watari, & Suenaga, 1993). Like fearful expressions, surprised expressions are typified by widened eye aperture, raised brows, and open mouths. We were interested in determining whether the symmetric pattern of interference for gaze and emotion would be evidenced if the difficulty of the emotion discrimination was increased using full intensity but easily confused facial expressions instead of threshold-intensity, morphed facial expressions. We were also interested in whether this manipulation would promote gaze and emotional expression interactions because, to our knowledge, the effect of gaze direction on the perception of surprised faces has not been examined.

Method

Participants. Participants consisted of a total of 20 students (13 females and 7 males ranging from 18 to 34 years of age (M = 20.5 years).

Stimuli and procedure. Six digitized grey-scale photographs of one actor (J.J.) from the Ekman face series were used as stimuli, which constituted the factorial combination of facial expression (surprise, fear) and gaze direction (direct, averted—½ left, ½ right). This actor was also different from those used in the previous experiments. Otherwise, the stimuli and design of Experiment 4 were identical to those used in the previously reported experiments. The stimuli used in this experiment are pictured in Figure 7.

Results

Incorrect responses accounted for 2.5% of the total data. Reaction time outliers accounted for 0.8% of the data points. These points were not included in the reaction time analyses. Median reaction times were subjected to an omnibus RM-ANOVA, with task (directness of gaze vs. emotion judgments), interference condition (control vs. orthogonal), gaze (direct vs. averted), and emotion (surprise vs. fear) as within-subject variables. The ANOVA indicated that there was a main effect of interference condition, $F(1, 19) = 5.95$, $p < .05$, reflecting the fact that reaction times in both control conditions (M = 481 ms) were faster than those in the orthogonal conditions (M = 502 ms). Importantly, replicating Experiment 3, this was not accompanied by a significant task by condition interaction, $F(1, 19) < 3$, $p > .05$.

The omnibus ANOVA also revealed a main effect of emotion, $F(1, 19) = 12.65$, $p < .01$, indicating that fearful faces (M = 487 ms) were responded to more quickly than surprised faces (M = 496 ms). There was also a main effect of gaze, $F(1, 19) = 13.43$, $p < .01$, reflecting the fact that faces with direct gaze (M = 484 ms) were responded to more quickly than faces with averted gaze (M = 499 ms), regardless of the task and attentional demands. Unlike previous experiments, there was no interaction between task and emotional expression, $F(1, 19) < 3$, $p > .05$.

These main effects were qualified by a significant three-way interaction between interference condition, directness of gaze and facial emotion, $F(1, 19) = 8.02$, $p < .05$. To characterize this

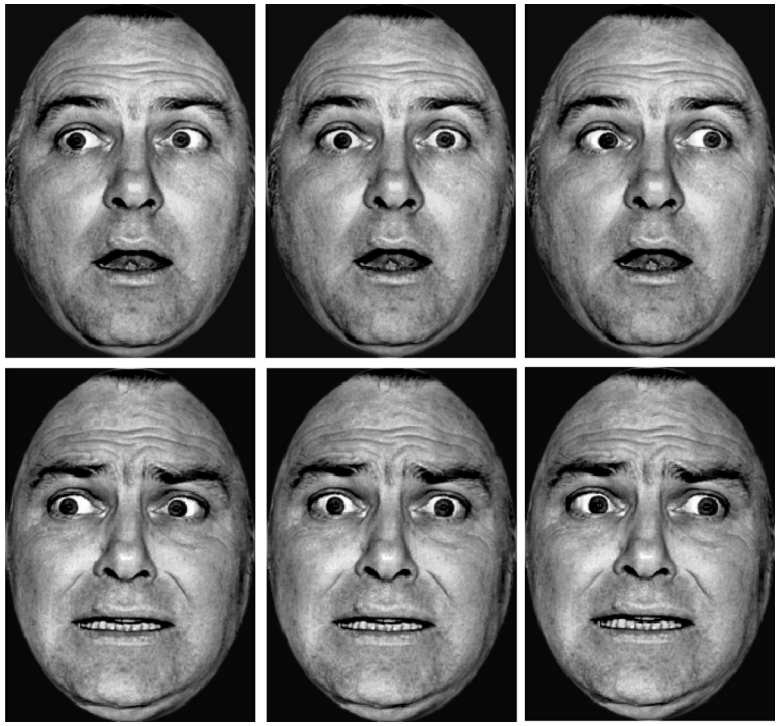

Figure 7. Facial stimuli employed in Experiment 4.

interaction, separate ANOVAs were performed for each interference condition. As shown in Figure 8, this interaction occurred because there was an overall main effect of directness of gaze in the control condition, $F(1, 19) = 9.40$, $p < .01$, which reflected the tendency for faces with direct gaze to be judged more quickly than faces with averted gaze. However, in the orthogonal condition, there was a gaze by emotion interaction, $F(1, 19) = 9.40$, $p < .01$. Post hoc Bonferroni-corrected pairwise comparisons indicated that the advantage for direct gaze only occurred for surprised faces ($M = 496$ ms for direct gaze and $M = 521$ ms for averted gaze), whereas there was no such difference for fearful faces ($M = 496$ ms for direct gaze and $M = 496$ ms for averted gaze).

As in the first three experiments, we wanted to rule out the possibility that the emotion control condition was inflated because of slowed reaction times in the emotion control block with averted gaze. To this end, we compared reaction times for direct and averted gaze for the emotion control condition only. As in the previous experiments, there were no significant differences between reaction times for the direct and averted gaze blocks of the emotion control conditions ($M = 463$ ms vs. $M = 471$ ms for direct and averted gaze, respectively), $t(19) = 1.0$, $p > .05$. In other words, the interference effect for gaze on emotion was not attenuated because of inflation of the control condition mean driven by the averted gaze emotion control block.

A subsidiary RM-ANOVA was conducted on error rates, with task (gaze vs. emotion judgments), interference condition (control vs. orthogonal), gaze (direct vs. averted), and emotion (surprised vs. fearful) as within-subject variables. This analysis revealed a significant interaction between task and gaze, $F(1, 19) = 7.76$, $p < .05$. Post hoc Bonferroni-corrected pairwise comparisons revealed that direct gaze was judged more accurately ($M = 97.9\%$ accuracy) than averted gaze ($M = 96.7\%$) in the gaze task, but there was no effect of gaze on the speed of the emotion judgments ($M = 97.6\%$ for direct gaze and $M = 98.0\%$ for averted gaze). There was also a significant gaze by emotion interaction, $F(1, 19) = 7.76$, $p < .05$. Post hoc comparisons (Bonferroni-corrected) revealed that this occurred because participants were less accurate at performing both kinds of judgments (emotion and gaze) when surprised faces had averted gaze ($M = 98.0\%$ for direct gaze and $M = 96.6\%$ for averted gaze), while no such difference was seen for fearful faces ($M = 97.5\%$ for direct gaze and $M = 98.1\%$ for averted gaze).

Discussion

Increasing the difficulty of the emotion discrimination by using facial emotions that are often confused with one another yielded similar results to Experiment 3, which increased the difficulty of the emotion discrimination by using morphed facial expressions. Most importantly, increasing the difficulty of the emotion discrimination by using surprised and fearful expressions equated the reaction times across the gaze and emotion task. In addition, there was also a symmetrical pattern of Garner interference: expression interfered with gaze directness judgments and gaze interfered with expression judgments. This pattern of interference converges with the results of Experiment 3 and suggests that when emotion and gaze discriminations are of equal difficulty, expression processing proceeds more slowly, allowing gaze to interfere with emotion judgments.

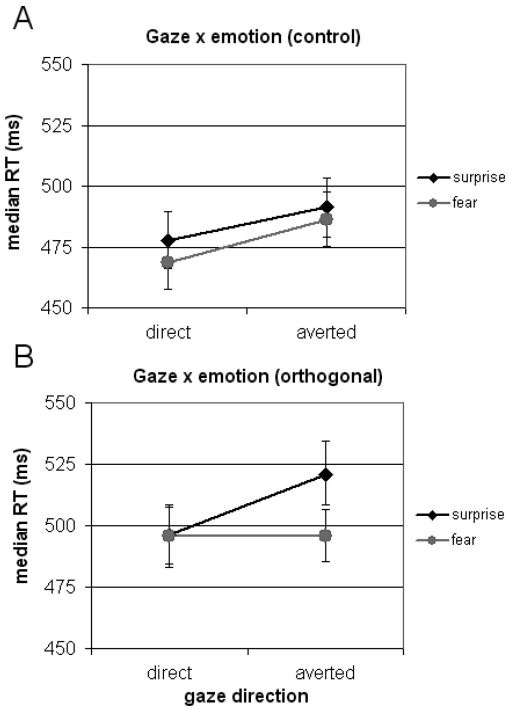

Figure 8. Means of the individual median reaction times (ms) obtained in Experiment 4 to surprised and fearful faces for gaze and emotion judgments in the A) control and the B) orthogonal interference condition.

Similar to the Experiment 3, we observed an overall main effect of gaze directness on reaction time. Direct gaze facilitated both gaze and emotion judgments, supporting the hypothesis that direct gaze is processed more quickly and efficiently than averted gaze. However, this advantage for direct gaze was mitigated by a gaze by emotion interaction in the accuracy data and a condition by gaze by emotion interaction in the reaction time data. The accuracy data suggests that the advantage for direct gaze is attributable primarily to the fact that averted gaze significantly slows judgments about surprised faces, whereas the three-way interaction observed with the reaction time data suggests that the reaction time advantage for direct gaze is only true for surprised faces in the orthogonal interference condition. Together, these results suggest that the direct gaze advantage observed in this experiment is driven largely by slower and less accurate processing for surprised faces with averted gaze, especially under high-interference conditions.

Given that less experimental evidence exists regarding the effect of gaze direction on the perception of surprised faces, these results are more difficult to interpret. The relative disadvantage for processing surprised faces with averted gaze could be attributed to a processing advantage for faces with direct gaze. However, this result could also provide indirect support for Adams and Kleck's (2003, 2005) theory that the processing of fearful faces is facilitated by averted gaze. The finding that surprised faces were processed more slowly and less accurately when gaze was averted could be indicative of participants misconstruing these faces as fearful rather than surprised. In other words, this result could be because of the fact that surprised faces with averted gaze are especially difficult to discriminate and are more likely to be perceived as fearful. It is possible that under conditions of stimulus ambiguity and divided attention, gaze direction may act as a context that is used to help resolve uncertainty. However, this explanation implies that the same, if not larger, effects should also be seen for fearful faces with averted gaze, which was not the case. These considerations suggest that the former explanation may be more valid. A potentially valuable avenue for future experiments would be to examine these possibilities regarding the role of gaze directness in the perception of surprised faces more pointedly. Nevertheless, the results of Experiment 4 converge with those of Experiment 3 in suggesting that gaze and emotion interactions are more likely to occur when facial emotion is more difficult to discriminate.

Unlike the previous experiments, we did not observe any interactions between task and facial emotion. In the previous experiments, task by emotion interactions were observed, which were thought to be because of differential eye apertures of the different emotion. It is important to note that both surprise and fear are characterized by widened eyes or similar eye aperture. Therefore, the lack of a task by emotion interaction lends credence to the hypothesis used to explain the results of previous experiments. The fact that the eye aperture of various emotional expressions can affect the discriminability of gaze is an important consideration for future experiments examining gaze and emotion interactions.

Experiment 4 also provided evidence that fearful faces are responded to more quickly than surprised faces, regardless of task or attentional demands. Together with Experiment 2, which showed a reaction time advantage for fearful faces over angry faces, these results suggest full intensity fearful faces have some processing advantage over other facial expressions. The explanation for this finding awaits clarification but converges with evidence that fearful faces elicit increased activation of the amygdala (e.g., LaBar et al., 2003; Whalen, 1998), which could provide processing advantages. However, both fear and surprise involve widened eye aperture, and increases in the amount of sclera or eye whites in fearful faces has been correlated with amygdala activation (Whalen et al., 2004). Amygdala activation has also been evidenced to surprised faces (Kim, Somerville, Johnstone, Polis, & Alexander, 2004; Kim, Somerville, Johnstone, Alexander & Whalen, 2003). In addition, surprise is ambiguous in terms of its valence, because it can be either positive or negative depending on the context (Kim et al., 2003, 2004). Ambiguity has also been linked to amygdala activation (Hsu, Bhatt, Adolphs, Tranel, & Camerer, 2005; Whalen, 1998). For example, Adams et al. (2003) reported enhanced amygdala activity for ambiguous expression/gaze combinations (e.g., direct gazing fearful faces and averted gazing angry faces). Therefore, the possibility that amygdala activation is responsible for this advantage for fearful faces seems unlikely, and future research on this topic is warranted.

In summary, Experiment 4 demonstrated that when the emotion discrimination is made more difficult by using two expressions that are often confused with one another, a symmetrical pattern of Garner interference emerges such that gaze interferes with emotion decisions and emotion interferes with gaze decisions. These results converge with those of Experiment 3 and suggest that when gaze and emotion judgments are equated for difficulty, either by using threshold intensities or emotions that are naturally confused with one another, emotion processing is slowed and gaze can interfere with emotion judgments. Because gaze and emotion interactions

were not evidenced in Experiments 1 and 2, but were observed in Experiments 3 and 4, these results suggest that such interactions emerge only when the emotion discrimination is made more difficult or under other conditions of ambiguity or uncertainty. Experiment 4 also supported the findings of Experiment 2, revealing a processing advantage for full intensity fearful faces.

General Discussion

The human face is a complex and salient stimulus that conveys a variety of critical information used in socioemotional communication. Face perception as a whole is thought to be accomplished via two processing streams, one that processes static or relatively invariant aspects of faces and another that processes more changeable aspects. Within these streams, individual face processing functions are achieved through the coordinated activity of different brain regions. Emotional expression and gaze direction are two types of variant information that are important signals of the internal states and intentions of others. Disruption of gaze and facial expression processing are thought to accompany socioaffective disorders such as schizophrenia (e.g., Baudouin et al., 2002) and autism (e.g., Pelphrey, Morris, & McCarthy, 2005; Pelphrey et al., 2002). By gaining an understanding of gaze and emotion processing and their interactions in a normal population, we can then determine how these processes are disrupted by development, disease or injury.

The Garner selective attention paradigm has proved to be a useful tool in elucidating how various aspects of face processing interact, which provides valuable insight into the organization of the face processing system. For example, the Garner paradigm has been used to demonstrate that within the static processing stream, gender and identity are processed integrally (Ganel & Goshen-Gottstein, 2002). Existing studies suggest that the interaction between the variant and invariant processing streams tends to be asymmetric. Whereas identity and gender judgments are not affected by variations in facial expression and speech, expression and speech judgments are affected by variations in identity and gender (Atkinson et al., 2005; Schweinberger et al., 1999; Schweinberger & Soukoup, 1998). Finally, Ganel et al. (2005) provided recent evidence that within the dynamic stream, interactions between gaze and expression processing can be manipulated by inversion and discriminabilty.

The present studies extended the results of Ganel et al. (2005) in three directions. First, we wanted to examine the generalizability of their findings with a different set of experimental stimuli that included different facial expressions and/or combinations of facial expressions. In their first experiment Ganel et al. (2005) reported a symmetric pattern of Garner interference for gaze and emotional expression, coupled with an overall reaction time advantage for gaze judgments. This pattern of interference was not replicated in Experiment 1 of the present study with happy and sad faces; instead, we found asymmetric interference effects such that although expression interfered with gaze judgments, gaze did not interfere with emotion judgments. This finding was accompanied by an overall reaction time advantage for emotion judgments. The asymmetric pattern of interference and the overall advantage for expression judgments were replicated in Experiment 2 with angry and fearful faces.

The divergence of our results from those of Ganel et al. (2005) is most likely because of differences in the baseline discriminabilities of the two stimulus dimensions. As shown in Experiments 3 and 4 of the present study, when the difficulty of the emotional expression discrimination is increased, a symmetrical pattern of interference results. Coupled with the results of Ganel et al. (2005), our findings support a speed-of-processing account of gaze and emotional expression interactions. When emotional expression is easily discriminable (Experiments 1 and 2), it occurs before gaze can interfere; however, when emotional expression is difficult to discriminate (Experiments 3 and 4), processing slows and gaze information interferes with emotion judgments. When gaze discrimination is easier than the emotion discrimination (as in Ganel et al., 2005), processing advantage for emotional expressions is reversed and a symmetric pattern of interference is also evidenced. Interestingly, when Ganel et al. (2005) made their gaze discrimination task more difficult (Ganel et al., 2005: Experiment 3), they observed an asymmetrical pattern of interference that was caused by emotion interfering with gaze judgments more than gaze interfered with emotion judgments. Together, these results suggest that the degree to which expression and gaze interact depends critically on the baseline discriminability of each dimension.

An alternative explanation for the asymmetric interference effects observed in our Experiments 1 and 2 is that the emotion judgment was easier than the gaze judgment because there were two alternatives for the emotion judgment but three (direct, left, right) for the gaze judgment. Although the discriminability of gaze per se should not change as a result (i.e., the discrimination of right or left gaze from direct gaze should have been equal because the pupil displacement from center was identical in both cases), the difficulty of the gaze judgments may have increased because there were more alternatives for gaze than emotion. In addition, the emotion control condition using averted gaze would have had two values for averted gaze that may have actually produced some unintended interference. This may have inflated reaction times in the emotion control block with averted gaze, resulting in an overestimation of the emotion control mean and obscuring differences between the control and orthogonal conditions for emotion judgments. However, we compared the emotion control conditions using direct and averted (left and right) gaze and were able to demonstrate that there were no differences between these two conditions in any of the experiments. Furthermore, the number of gaze values was kept constant across all four experiments. Therefore, if these results were entirely because of the unequal numbers of gaze and emotional expression stimuli, we would have expected to see asymmetries across all four experiments, regardless of true changes in discriminability. Increasing the difficulty of the emotion discriminations in Experiments 3 and 4 resulted in symmetrical interference effects, suggesting that this explanation alone could not have been responsible for the pattern of results seen across the four experiments.

A related explanation is that context effects were different across the gaze and emotion judgments. In other words, having more than two values for gaze should increase the number of contexts for emotion (direct, left, right—three contexts) relative to the number of contexts for gaze (e.g., fear, anger—two contexts). Having more than two levels of a particular stimulus dimension has the effect of reducing Garner interference when that dimension is irrelevant (Melara & Mounts, 1994). Therefore, it is possible

that the asymmetrical interference effects observed in Experiments 1 and 2 are because of unequal numbers of contexts across the two stimulus dimensions. However, similar to the argument above, if this was indeed the case, then one would expect that this pattern of results would persist even after discriminability manipulations because the number of levels of gaze was kept constant across all four experiments. Nevertheless, whether the results of these experiments would have been replicated with equal numbers of values in the two dimensions is an interesting question worthy of further examination.

The second way that the present studies extended the results of Ganel et al. (2005) was that we were interested in whether performance on the Garner selective attention task would produce gaze and emotional expression interactions similar to those found in recent studies of face processing. One theory predicts that only approach-related expressions (happiness and anger) benefit from direct gaze (e.g., Adams & Kleck, 2003), while another predicts that there is a processing advantage for all faces with direct gaze (e.g., Senju & Hasegawa, 2005). When emotional expressions were easily discriminable (Experiments 1 and 2), we found no evidence of gaze/expression interactions. However, when the emotion discrimination was made more difficult, gaze and emotion interactions emerged. In Experiment 3, when subtle facial expressions were used, there was an advantage for faces with direct gaze, especially angry ones. In Experiment 4, when commonly confused but prototypical facial expressions were used, a similar result was found—namely, a processing advantage for faces with direct gaze, especially surprised faces in the orthogonal interference condition.

These results provide partial support for both theories of gaze and expression interactions. Overall, our studies demonstrated an advantage for all faces with direct gaze. However, in Experiment 3 this was because angry faces with averted gaze were responded to more slowly than the other faces. This finding supports the assertion that the processing of angry faces is facilitated by direct gaze (Adams & Kleck, 2003, 2005). Similarly in Experiment 4, the advantage for faces with direct gaze was because of slower and less accurate responding for surprised faces with averted gaze, particularly under conditions of interference. This could support the assertion that the perception of fearful faces is facilitated by averted gaze (Adams & Kleck, 2003, 2005), because it is possible that surprised faces with averted gaze were more likely to be perceived as fearful. However, it is equally likely that these results are indicative of a general processing advantage for faces with direct gaze. Contrary to predictions that the processing of fearful faces should be facilitated by averted gaze, we were unable to find evidence of this in Experiments 3 and 4. Instead, Experiments 2 and 4 both found an overall processing advantage for full intensity fearful faces over other emotional faces.

One possibility for the divergence of our results from Adams and Kleck (2003, 2005) was that while our experiments used only a single identity within each experiment, Adams and Kleck (2003, 2005) intermixed several different identities. Our goal was to control for any identity-related effects on facial expression processing (e.g., Schweinberger et al., 1999) and to make our results comparable to those of Ganel et al. (2005), who also used single-identity exemplars. However, there is a possibility that the use of one identity per experiment may have encouraged strategies that were picture specific and not necessarily related to emotion processing per se. Because, to our knowledge, identity-related effects have not been reported for gaze processing, the use of one identity may have created a processing advantage for emotion that may have been responsible for the overall faster reaction times for emotion judgments and the asymmetrical interference observed in Experiments 1 and 2. This possibility may provide an alternate account for the lack of gaze and expression interactions observed in Experiments 1 and 2 and could explain why our results differed from those of Adams and Kleck (2003, 2005): Their use of many identities may have slowed down emotion processing, thus allowing for gaze and expression interactions. Nevertheless, the fact that we observed symmetrical interference effects when the emotion discrimination was made more difficult (despite having only one identity) suggests that picture-based strategies alone cannot be solely responsible for the results observed in this study. Furthermore, we reiterate that similar effects were observed across Experiments 1 and 2, as well as across Experiments 3 and 4, despite the use of different exemplar identities across experiments.

In addition, it is important to note that any main effects of gaze or emotion and any interactions between gaze and emotion are based on values that are collapsed across attentional demands. Because there is reason to believe that selective attention may change the way in which facial expressions are processed (see Vuilleumier, 2002, for a review), any main effects of emotion must be interpreted with caution. Similarly, main effects of gaze direction must be also be interpreted carefully because gaze is the attended dimension in some cases and to be ignored in others. Although our studies cannot resolve the nature of gaze and expression interactions, like the studies of Adams and Kleck (2005), they do imply that the emotional discriminability or ambiguity of facial expressions could be a critical factor in whether the two dimensions interact. The results of our study suggest that the role of stimulus ambiguity in gaze and expression interactions may be a potentially fruitful line of future inquiry.

Finally, we were interested in investigating the influence of stimulus discriminability on Garner interference and gaze and expression interactions. Discriminability had a significant impact on the nature and degree of Garner interference, a pattern of findings consistent with a speed-of-processing account of gaze and expression interactions. When emotional expression is unambiguous, emotional information is processed quickly and interferes with ongoing gaze processing. When emotion is more difficult to discriminate, processing slows. The role of gaze in resolving emotion becomes more important, and gaze information can interfere with emotion processing. If this speed-of-processing account is correct, it implies that the timing of gaze and expression processing are critical determinants of interactions between the two dimensions. Therefore, gaze-expression interactions should be susceptible to task-related variables that affect the timing of each processing channel.

Event-related potential (ERP) evidence indicates that gaze and expression are processed as separate streams until about 310 ms (Klucharev & Sams, 2004). This finding is supported by a study involving transcranial magnetic stimulation, which confirms that at 200 ms, these two streams of information are not yet integrated (Pourtois et al., 2004). However, ERP studies examining the timing of gaze and expression processing and modulation of these brain events by stimulus discriminability and task demands are lacking. Neuroimaging studies indicate that similar brain areas are involved in processing facial emotion and gaze direction, but the

temporal resolution of these studies is insufficient to determine the exact time-course of these processes. Our results suggest that even though these facial dimensions are processed at the same cortical sites, they may be computed at different times. This supposition provides some reconciliation between studies showing gaze and emotion interactions (e.g., Adams & Kleck, 2003, 2005) and studies showing independent effects of the two facial dimensions (e.g., Hietanen & Leppänen, 2003). It is possible that these studies are indexing processing at different temporal stages. Those that assess gaze and expression processing at later stages may be more likely to show gaze and expression interactions than those that index earlier stages. Future studies should examine how discriminability affects the time-course of ERPs associated with gaze and expression processing and the interaction between the two processing streams. In this way, it will be possible to clarify the temporal relationship between the processing of these two types of variant facial information.

In summary, the present study provides additional evidence that a single unitary system underlying gaze and expression processing is oversimplified. Factors such as task differences and baseline discriminability interact to determine the degree to which these two systems interact. Haxby et al.'s (2000, 2002) conception of a subsystem of face processing that selectively processes variant aspects of faces (the STS), with task-dependent recruitment from other brain areas, is consistent with our results. What remains to be delineated is an understanding of the contribution of different brain areas, including the amygdala and STS, and the nature and timing of their involvement in gaze and expression interactions.

References

Adams, R. B., Jr., Gordon, H. L., Baird, A. A., Ambady, N., & Kleck, R. E. (2003). Effects of gaze on amygdala sensitivity to anger and fear faces. *Science, 300,* 1536–1537.

Adams, R. B., Jr., & Kleck, R. E. (2003). Perceived gaze direction and the processing of facial displays of emotion. *Psychological Science, 14,* 644–647.

Adams, R. B., Jr., & Kleck, R. E. (2005). Effects of direct and averted gaze on the perception of facially communicated emotion. *Emotion, 5,* 3–11.

Adolphs, R., Gosselin, F., Buchanan, T. W., Tranel, D., Schyns, P., & Damasio, A. R. (2005). A mechanism for impaired fear recognition after amygdala damage. *Nature, 433,* 68–72.

Adolphs, R., Tranel, D., Damasio, H., & Damasio, A. (1994). Impaired recognition of emotion in facial expressions following bilateral damage to the human amygdala. *Nature, 372,* 669–672.

Algom, D., Dekel, A., & Pansky, A. (1996). The perception of number from the separability of the stimulus: The stroop effect revisited. *Memory & Cognition, 24,* 557–572.

Ashby, F. G., & Maddox, W. T. (1994). A response time theory of separability and integrality in speeded classification. *Journal of Mathematical Psychology, 38,* 423–466.

Atkinson, A. P. Tipples, J., Burt, D. M., & Young, A. W. (2005). Asymmetric interference between sex and emotion in face perception. *Perception & Psychophysics, 67,* 1199–1213.

Baudouin, J. Y., Martin, F., Tiberghien, G., Verlut, I., & Franck, N. (2002). Selective attention to facial emotion and identity in schizophrenia. *Neuropsychologia, 40,* 503–511.

Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology, 77,* 305–327.

Cedrus. (1999). SuperLab Pro for Windows (version 2.0.4) [Computer software]. San Pedro, CA: Cedrus Corporation.

Ekman, P., & Friesen, W. (1975). *Unmasking the face.* Englewood Cliffs, NJ: Prentice Hall, Inc.

Ekman, P., & Friesen, W. (1976). *Pictures of facial affect.* Palo Alto, CA: Consulting Psychologists Press.

Ekman, P., & Friesen, W. (1978). *The facial action coding system.* Palo Alto, CA: Consulting Psychologists Press.

Ekman, P., & Oster, H. (1982). Review of research: 1970–1980. In P. Ekman, W. Friesen, & P. Ellsworth (Eds.), *Emotion in the human face* (2nd ed., pp. 147–173). New York: Cambridge University Press.

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin and Review, 5,* 490–495.

Ganel, T., & Goshen-Gottstein, Y. (2002). Perceptual integrality of sex and identity of faces: Further evidence for the single-route hypothesis. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 854–867.

Ganel, T., Goshen-Gottstein, Y., & Goodale, M. (2005). Interactions between the processing of gaze direction and facial expression. *Vision Research, 49,* 1911–1200.

Garner, W. R. (1974). *The processing of information and structure.* Potomac, MD: Lawrence Erlbaum.

Garner, W. R. (1976). Interaction of stimulus dimensions in concept and choice processes. *Cognitive Psychology, 8,* 98–123.

Graham, R., Devinsky, O., & LaBar, K. S. (2007). Quantifying deficits in the perception of fear and anger in morphed facial expressions after bilateral amygdala damage. *Neuropsychologia, 45,* 42–54.

Green, R. E., Turner, G. R., & Thompson, W. F. (2004). Deficits in facial emotion perception in adults with recent traumatic brain injury. *Neuropsychologia, 42,* 133–141.

Hasselmo, M. E., Rolls, E. T., & Baylis, G. C. (1989). The role of expression and identity in the face-selective responses of neurons in the temporal visual cortex of the monkey. *Behavioural Brain Research, 32,* 203–218.

Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Sciences, 4,* 223–233.

Haxby, J. V., Hoffman, E. A., & Gobbini. M. I. (2002). Human neural systems for face recognition and social communication. *Biological Psychiatry, 51,* 59–67.

Hietanen, J. K., & Leppänen, J. M. (2003). Does facial expression affect attention orienting by gaze direction cues? *Journal of Experimental Psychology: Human Perception and Performance, 29,* 1228–1243.

Holmes, A., Richards, A., & Green, S. (2006). Anxiety and sensitivity to eye gaze in emotional faces. *Brain and Cognition, 60,* 282–294.

Hooker, C. I., Paller, K. A., Gitelman, D. R., Parrish, T. B., Mesulam, M-M., & Reber, P. J. (2003). Brain networks for analyzing eye gaze. *Cognitive Brain Research, 17,* 406–418.

Hori, E., Tazumi, T., Umeno, K., Kamachi, M., Kobayashi, T., Ono, T., et al. (2005). Effects of facial expression on shared attention mechanisms. *Physiology & Behavior, 84,* 397–405.

Hsu, M., Bhatt, M., Adolphs, R., Tranel, D., & Camerer, C. F. (2005). Neural systems responding to degrees of uncertainty in human decision-making. *Science, 310,* 1680–1683.

Kampe, K. K. W., Frith, C. D., Dolan, R. J., & Frith, U. (2001). Reward value of attractiveness and gaze. *Nature, 413,* 589.

Kawashima, R., Sugiura, M., Kato, T., Nakamura, A., Hatan, K., Ito, K., et al. (1999). The human amygdala plays an important role in gaze monitoring. *Brain, 122,* 779–783.

Kim, H., Somerville, L. H., Johnstone, T., Alexander, A. L., & Whalen, P. J. (2003). Inverse amygdala and medial prefrontal cortex responses to surprised faces. *Neuroreport, 14,* 2317–2322.

Kim, H., Somerville, L. H., Johnstone, T., Polis, S., & Alexander, A. L. (2004). Contextual modulation of amygdala responsivity to surprised faces. *Journal of Cognitive Neuroscience, 16,* 1730–1745.

Kirita, T., & Endo, M. (1995). Happy face advantage in recognizing facial expressions. *Acta Psychologica, 89,* 149–163.

Kirouac, G., & Dore, F. Y. (1983). Accuracy and latency of judgment of facial expressions of emotions. *Perceptual and Motor Skills, 57,* 683–686.

Klucharev, V., & Sams, M. (2004). Interaction of gaze direction and facial expressions processing: ERP study. *Neuroreport, 15,* 621–626.

LaBar, K. S., Crupain, M. J., Voyvodic, J. T., & McCarthy, G. (2003). Dynamic perception of facial affect and identity in the human brain. *Cerebral Cortex, 13,* 1023–1033.

Le Gal, P. M., & Bruce, V. (2002). Evaluating the independence of sex and expression in judgments of faces. *Perception and Psychophysics, 64,* 230–243.

Maddox, W. T., & Ashby, F. G. (1996). Perceptual separability, decisional separability, and the identification-speeded classification relationship. *Journal of Experimental Psychology: Human Perception and Performance, 22,* 795–817.

Mathews, A., Fox, E., Yiend, J., & Calder, A. (2003). The face of fear: Effects of eye gaze and emotion on visual attention. *Visual Cognition, 10,* 823–835.

McCrae, D. N., Hodd, B. M., Milne, A. B., Rowe, A. C., & Mason, M. F. (2002). Are you looking at me? Eye gaze and person perception. *Psychological Science, 13,* 460–464.

Melara, R. D., & Mounts, J. R. (1994). Contextual influence on interactive processing: Effects of discriminability, quantity and uncertainty. *Perception and Psychophysics, 56,* 73–90.

Morris, J. S., Friston, K. J., Buechel, C., Frith, C. D., Young, A. W., Calder, A. J., et al. (1998). A neuromodulatory role for the human amygdala in processing emotional facial expressions. *Brain, 121,* 47–57.

Ogawa, T., & Suzuki, N. (1999). Response differentiation to facial expression of emotion as increasing exposure duration. *Perceptual and Motor Skills, 89,* 557–563.

Parry, F. M., Young, A. W., Saul, J., & Moss, A. (1991). Dissociable face processing impairments after brain injury. *Journal of Clinical & Experimental Neuropsychology, 13,* 545–558.

Pelphrey, K., Singerman, J. D., Allison, T., & McCarthy, G. (2003). Brain activation evoked by perception of gaze shifts: The influence of context. *Neuropsychologia, 41,* 156–170.

Pelphrey, K. A., Morris, J. P., & McCarthy, G. (2005). Neural basis of eye gaze processing deficits in autism. *Brain, 128,* 1038–1048.

Pelphrey, K. A., Sasson, N. J., Reznick, J. S., Paul, G., Goldman, B., & Piven, J. (2002). Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders, 32,* 249–261.

Phillips, M. L., Young, A. W., Senior, C., Brammer, M., Andrew, C., Calder, A. J., et al. (1997). A specific neural substrate for perceiving facial expressions of disgust. *Nature, 389,* 495–498.

Pourtois, G., Sander, D., Andres, M., Grandjean, D., Reveret, L., Olivier, E., et al. (2004). Dissociable roles of the human somatosensory and superior temporal cortices for processing social face signals. *European Journal of Neuroscience, 20,* 3507–3515.

Prkachin, G. C., & Prkachin, K. M. (1994). Adaptation to facial expressions of emotion. *Cognition and Emotion, 8,* 55–64.

Puce, A., Allison, T., Bentin, S., Gore, J. C., & McCarthy, G. (1998). Temporal cortex activation in humans viewing eye and mouth movements. *Journal of Neuroscience, 18,* 2188–2199.

Putman, P., Hermans, E., & van Honk, J. (2006). Anxiety meets fear in perception of dynamic expressive gaze. *Emotion, 6,* 94–102.

Rolls, E. T. (1984). Neurons in the cortex of the temporal lobe and in the amygdala of the monkey with responses selective for faces. *Human Neurobiology, 3,* 209–222.

Schweinberger, S. R., Burton, A. M., & Kelly, S. W. (1999). Asymmetric dependencies in perceiving identity and emotion: Experiments with morphed faces. *Perception & Psychophysics, 61,* 1102–1115.

Schweinberger, S. R., & Soukup, G. R. (1998). Asymmetric relationships among perceptions of facial identity, emotion, and facial speech. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 1748–1765.

Senju, A., & Hasegawa, T. (2005). Direct gaze captures visuospatial attention. *Visual Cognition, 12,* 127–144.

Tipples, J. (2006). Fear and fearfulness potentiate automatic orienting to eye gaze. *Cognition and Emotion, 20,* 309–320.

Vuilleumier, P. (2002). Facial expression and selective attention. *Current Opinion in Psychiatry, 15,* 291–300.

Whalen, P. J. (1998). Fear, vigilance, and ambiguity: Initial neuroimaging studies of the human amygdala. *Current Directions in Psychological Science, 7,* 177–188.

Whalen, P. J., Kagan, J., Cook, R. G., Davis, F. C., Kim, H., Polis, S., et al. (2004). Human amygdala responsivity to masked fearful eye whites. *Science, 306,* 2061.

Whalen, P. J., Shin, L. M., McInerney, S. C., Fischer, H., Wright, C., & Rauch, S. L. (2001). A functional MRI study of human amygdala responses to facial expressions of fear versus anger. *Emotion, 1,* 70–83.

Wicker, B., Perrett, D. I., Baron-Cohen, S., & Decety, J. (2003). Being the target of another's emotion: A PET study. *Neuropsychologia, 41,* 139–146.

Yamada, H., Matsuda, T., Watari, C., & Suenaga, T. (1993). Dimensions of visual information for categorizing facial expressions of emotion. *Japanese Psychological Research, 35,* 172–181.

Yang, T. T., Menon, V., Eliez, S., Blasey, C., White, C. D., Reid, A. J., et al. (2002). Amygdalar activation associated with positive and negative facial expressions. *Neuroreport, 13,* 1737–1741.

Young, A. W., McWeeny, K. H., Hay, D. C., & Ellis, A. W. (1986). Matching familiar and unfamiliar faces on identity and expression. *Psychological Research, 48,* 63–68.

Appendix

FACS Coding of Faces Used in Experiments 1 and 2 and Those Used in Ganel et al. (2005)

The Facial Action Coding System (FACS) is a method for identifying and categorizing the displacement of different facial features based on the muscles that produce them. FACS measurements consist of Action Units (AUs), which are numeric labels. AUs describe feature displacement rather than the movement of discrete muscles for two reasons. First, it is often difficult to determine the unique contributions of different muscles to a particular displacement. Second, the feature changes produced by one large muscle were sometimes separated into different AUs to represent qualitative differences in the actions of different parts of that muscle. A FACS coder breaks a facial expression down into its constituent AUs. Duration, intensity, and asymmetry can also

Table 1
FACS Coding of Happy Faces Used in Experiment 1 and Those Used in Ganel et al. (2005)

	Action unit/Description		
Experiment	6/Cheek raiser	12/Lip corner puller	25/Lips part
Experiment 1	C	C	D
Ganel Experiment 1	A	D	—
Ganel Experiment 2	—	B	—

Note. Dashes indicate that the action unit was not present.

Table 2
FACS Coding of Angry Faces Used in Experiment 2 and Those Used in Ganel et al. (2005)

	Action unit/Description					
Experiment	4/Brow lowerer	5/Upper lid raiser	7/Lower lid tightener	17/Chin raiser	24 or 23/Lip pressor or tightener	26*/Jaw drop
Experiment 2	C	C	B	—	23C	C
Ganel Experiment 1	B	—	C	B	—	—
Ganel Experiment 2	D	—	B	C	24A	—

Note. Dashes indicate that the action unit was not present.
*AU is not a necessary component of an angry facial expression.

be recorded. Intensity is coded by letters, where A = feature displacement just noticeable feature displacement and E = maximum possible feature displacement.

FACS Coding of Happy Faces

The facial expression of happiness is shown in the lower face and the lower eyelids (Ekman & Friesen, 1975), specifically with the co-occurrence of AUs 6 and 12. AU 6 represents the action of the orbicularis oculi and pars orbitalis, whose action has the effect of raising the cheeks directly under the eye and lower eyelid (without tensing it), creating crow's-feet wrinkles that emanate outward from the corners of the eye. This is the AU that is most critical in determining whether a smile is genuine. This AU is also accompanied by AU 12, which represents the action of the zygomaticus major and has the effect further raising the cheeks caused by the raising of the lip corners. This AU creates a deepening in the nasolabial fold. These AUs may or may not be accompanied by parted lips and exposed teeth. As shown in Table 1, AU 6 was either absent or barely detectable in the Ganel et al. (2005) faces.

FACS Coding of Angry Faces

Angry facial expressions are associated with distinctive changes to three facial areas: the brows, the eyes and the mouth. For a face to be unambiguously angry, changes must be evident in all three areas (Ekman & Friesen, 1975). The angry brow is caused by AU 4, which represents movement of the corrugator supercilii and the depressor supercilii and draws the eyebrows in and together. This is evident in all stimuli, as shown in Table 2. In the eye region, anger is manifested as a tensed and raised lower lid, AU 7 (orbicularis oculi and pars palpebralis) and is accompanied by a lowering of the upper lid caused by the action of AU 4. This lowering of the upper lids can be mitigated by AU 5, the upper lid raiser that is caused by the levator palpebrae superioris, giving the eyes a hard, staring look. Both of the angry faces used in Ganel et al. (2005) show tensing of the lower lids (AU 7), but without the glaring quality caused by AU 5.

There are two ways in which the lower face displays anger depending on whether the mouth is open or closed. Closed-mouth feature changes associated with anger are caused by AU 17 (mentalis), which raises the chin and pushes the lips outward and AU 24 (orbicularis oris), which presses the lips together in a pout. Open-mouth feature changes associated with anger involve a tightening of the lips by AU 23 (caused by a different portion of the orbicularis oris). The stimuli used in Ganel et al. (2005) are attempts to model closed-mouth anger and as shown below, the tension in the mouth region caused by AU 24 is largely absent. In the Ekman face used in Experiment 2, AU 23 is clearly present.

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