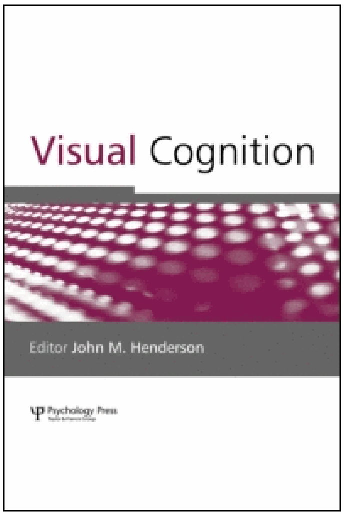

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Modulation of reflexive orienting to gaze direction by facial expressions

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Modulation of reflexive orienting to gaze direction by facial expressions

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Facial expression and gaze perception are thought to share brain mechanisms but behavioural interactions, especially from gaze-cueing paradigms, are inconsistent. We conducted a series of gaze-cueing studies using dynamic facial cues to examine orienting across different emotional expression and task conditions, including face inversion. Across experiments, at a short stimulus–onset asynchrony (SOA) we observed both an expression effect (i.e., faster responses when the face was emotional versus neutral) and a cue validity effect (i.e., faster responses when the target was gazed-at), but no interaction between validity and emotion. Results from face inversion suggest that the emotion effect may have been due to both facial expression and stimulus motion. At longer SOAs, validity and emotion interacted such that cueing by emotional faces, fearful faces in particular, was enhanced relative to neutral faces. These results converge with a growing body of evidence that suggests that gaze and expression are initially processed independently and interact at later stages to direct attentional orienting.

Keywords: Social attention; Eye gaze; Facial expression; Face processing.

Changeable aspects of faces, such as gaze shifts and facial expressions, provide humans with powerful social signals that permit inferences about the internal states and intentions of others. Gaze direction and emotional expression are

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often used conjointly to direct visuospatial attention to objects in the environment and inform others about the gazer's feelings towards those objects, even when they are out of another person's own field of view. Understanding how changes in facial expression and gaze direction are used in social situations is important for an observer to respond appropriately to the gazer, as well as to the gazed-at stimulus. The ability to interpret information from faces forms a cornerstone of higher level social cognitive processing such as Theory of Mind (Baron-Cohen, 1995) or mentalizing (Frith & Frith, 2003), and its disruption is associated with social and emotional deficits, such as those associated with autism (e.g., Campbell et al., 2006).

From a theoretical perspective, the integration of gaze and expression information is necessary for higher order social processing. Although gaze direction provides information about the spatial location of another person's attention, it does not provide information about the gazer's attitude towards the gazed-at object. In order for an observer to understand the emotional significance of that object, gaze direction information must be combined with emotional information such as facial expression, vocal affect, body gestures, and posture. Theories of face perception specify some integration of gaze and facial expression processing. For example, Haxby, Hoffman, and Gobbini (2000, 2002) have proposed a model of face processing wherein variant or changeable aspects of faces like facial expression and gaze direction are processed in superior temporal regions, in particular the superior temporal sulcus (STS). Specific types of dynamic facial information are processed via interactions between the STS and other, more task-specific brain areas. For example, both the STS (e.g., Hasselmo, Rolls, & Bayliss, 1989; Hooker et al., 2003) and amygdala (e.g., Adolphs, Tranel, Koenigs, & Damasio, 2005; Hooker et al., 2003; Kawashima et al., 1999; Rolls, 1984) appear to be involved in the perception of both eye gaze and facial expression. However, gaze elicits additional activity in the intraparietal sulcus, suggesting the recruitment of spatial attention (Hoffman & Haxby, 2000; Pelphrey, Singerman, Allison, & McCarthy, 2003; Puce, Allison, Bentin, Gore, & McCarthy, 1998).

These findings suggest that there is some overlap in the brain areas that subserve expression and gaze perception. Therefore, it is reasonable to expect that reflexive orienting to gaze would be modulated by facial expression. Reflexive orienting to gaze is indexed by gaze-cueing studies, which have reliably demonstrated that individuals automatically shift their attention to gazed-at locations, even if they are told that gaze direction does not predict where the target will appear (e.g., Friesen & Kingstone, 1998; see Frischen, Bayliss, & Tipper, 2007, for a review). Intuitively, it makes sense that if one were to encounter an individual who looked in a particular direction and then looked frightened, one would quickly shift attention to where he/she was looking, since a significant and potentially threatening event might be occurring in that location. Reacting adaptively to this sort of situation would require the integration of gaze and expression information, engaging brain areas like the STS and amygdala that are part of a processing stream that is sensitive to both gaze and expression information. Because fearful faces indicate the presence of a potential threat, one might expect that an object cued by a gazing fearful face would be detected and/or identified more quickly than an object cued by a neutral face or a happy face (in the absence of other motivating factors).

Studies examining the effect of facial expression on reflexive orienting to gaze have yielded mixed results regarding gaze and expression interactions. In a series of experiments, Hietanen and Leppänen (2003) examined the effects of facial expression (happy, angry, fearful, and neutral) and gaze direction on target detection. In spite of the wide range of facial expressions and cue-to-target stimulus–onset asynchronies (SOAs), they observed that although participants were consistently faster at detecting targets that appeared in a gazed-at location (the cueing effect), there was no evidence that the cueing effect was modulated by facial expression. A study by Hori et al. (2005) using happy, angry, and neutral faces found that the cueing effect of gaze was not consistently affected by facial expression, being larger for happy female faces only. Bayliss and colleagues (Bayliss, Frischen, Fenske, & Tipper, 2007) also did not observe any differences in reflexive orienting to targets (household objects) cued by disgusted and happy faces. However, they did find that the expression of the face cue affected participants' evaluations of the targets: Objects cued by happy faces were liked more than those cued by disgusted faces. Counter to intuition, these studies suggest that facial expression does not modulate reflexive orienting to gaze.

Other studies have reported modulation of the cueing effect by facial expression, but only after individual differences such as trait anxiety or fearfulness are taken into account. Mathews, Fox, Yiend, and Calder (2003) hypothesized that the effect of a fearful expression on the gaze cueing effect might only be observed in people who were particularly sensitive to fear-related stimuli. Accordingly, they found that the cueing effect did not differ in magnitude for neutral and fearful face cues in nonanxious participants, but it was significantly larger for fearful faces in anxious individuals. They concluded that gaze in fearful faces is a more powerful trigger for reflexive orienting than gaze in neutral faces, but only for highly anxious individuals. Enhanced orienting to fearful faces and attenuated orienting to angry faces in highly anxious individuals were also observed in a subsequent study (Fox, Mathews, Calder, & Yiend, 2007).

Tipples (2006) examined whether emotional faces (fearful and happy) enhanced orienting to gaze in a target identification task as well as the role of individual differences in trait fearfulness on the magnitude of the cueing effect. Unlike Mathews et al. (2003), Tipples found evidence of a gaze and expression interaction: When the face cue was fearful, the cueing effect was larger than it was for neutral faces, but the effect for happy and neutral faces was equivalent. Correlations between individual trait fearfulness scores and the magnitude of the cueing effect for each facial expression revealed a significant positive correlation between trait fearfulness and the cueing effect, especially for fearful faces. Putman, Hermans, and van Honk (2006) reported similar findings with dynamic displays of fearful and happy expressions: The cueing effect for fearful expressions was larger than that for happy expressions and the magnitude of this effect was correlated with state anxiety. Another study using fearful, angry, happy, and neutral face cues (Holmes, Richards, & Green, 2006, Exp. 3) found that the cueing effect was larger for fearful and angry faces relative to happy and neutral face cues; however, this was only true for high state-anxious participants.

As a whole, then, the results of behavioural studies examining the effect of emotional face cues on gaze-directed orienting lack consistency. In contrast, a growing body of neuroimaging and behavioural evidence attests to the interactive or combined processing of these two types of variant facial information. For example, Adams and Kleck (2003, 2005) reported interactions between expression and gaze information, which may have been mediated by amygdala activity (Adams, Gordon, Baird, Ambady, & Kleck, 2003), supporting the role of this structure in both gaze and expression processing. Similarly, Hooker et al. (2003) reported gaze and facial expression interactions in STS activation, supporting the role of this area in higher order social cognition (Allison, Puce, & McCarthy, 2000; Pelphrey, Viola, & McCarthy, 2004; Wicker, Perrett, Baron-Cohen, & Decety, 2003).

Behavioural evidence of gaze and emotional expression interactions has been observed with other experimental designs. Using the Garner selective attention paradigm, Ganel, Goshen-Gottstein, and Goodale (2005) and Graham and LaBar (2007) reported integrated processing of gaze and expression: Participants were unable to attend to one dimension without interference from the other. However, there were important differences between gaze and expression processing, since inversion interfered more with expression judgements than with gaze judgements (Ganel et al., 2005), and the nature of the interaction could be manipulated by the relative discriminability of gaze and expression (Graham & LaBar, 2007). Interactions between gaze direction and facial expression have also been reported in ratings of the intensity of expression (Sander, Grandjean, Kaiser, Wehrle, & Scherer, 2006), the attractiveness of gazing faces (Jones, DeBruine, Little, Conway, & Feinberg, 2006), and in affective ratings of gazed-at objects (Bayliss et al., 2007).

It is somewhat surprising that the evidence for emotional modulation of the cueing effect is mixed and is sometimes inconsistent with other research which suggests that gaze and emotion are processed in an integrated manner. One possibility is that methodological differences between gaze cueing studies are responsible for these inconsistencies; in particular, differences in how the face cue is presented. For example, Hietanen and Leppänen (2003, Exps. 1–4), Holmes et al. (2006, Exp. 3), and Hori et al. (2005) used static stimulus displays where the gaze cue and the emotional expression were presented simultaneously. Tipples (2006) first presented a neutral face with direct gaze, followed by expressive faces with averted gaze. One problem with presenting both expression and gaze information simultaneously is that it is impossible to rule out the possibility that low-level stimulus parameters were responsible for the larger cueing effects for fearful faces reported by Tipples rather than gaze and expression interactions per se. In other words, fearful faces have widened eyes that should facilitate gaze processing relative to neutral faces, or to faces with happy expressions where the eyes are squinting (Graham & LaBar, 2007). The fact that gaze may be easier to resolve in fearful eyes could explain why some studies have found larger cueing effects for only for fearful faces (Tipples, 2005).

Other studies have used dynamic gaze cues while emotion remained constant. Hietanen and Leppänen (2003, Exps. 5 and 6) and Mathews et al. (2003) first presented emotional faces with direct gaze and then shifted the gaze, such that the emotional expression remained constant and gaze direction changed. This may have created a processing advantage for gaze over expression since the gaze cue was dynamic but expression was not. Putman et al. (2006) addressed this potential confound by presenting the face cues dynamically where both the gaze shift and the emotional expression changed simultaneously and found that the gaze cueing effects were larger for fearful faces than for happy faces. However, similar to the argument above, simultaneous changes in expression and gaze make it difficult to rule out lower level stimulus-based explanations for this finding (i.e., differences in the ability to resolve gaze direction in happy vs. fearful eyes). Using still photos, Bayliss et al. (2007) addressed this issue by first presenting neutral faces with direct gaze and shifting gaze prior to the expression change. No differences in the magnitude of the cueing effects for happy and disgusted faces were observed. Importantly, however, no neutral faces were used in order to test for a main effect of emotion so there was no way to determine whether cueing with both emotional faces would have been larger than that with neutral faces. Given the variety of face cues used in these studies, it is possible that differences in the presentation sequences of the cue could account for the inconsistencies between studies.

The influence of local feature changes is important to the issue of expression effects on attentional orienting to gaze cues because facial expressions can affect eye aperture differentially, thereby enhancing or reducing the discriminability of gaze (Tipples, 2005). Therefore it is important to determine whether the modulation of the gaze cueing effect by emotion can be attributed to a stimulus-driven process (e.g., the ratio of pupil to sclera and the discriminability of gaze direction) or to expression perception per se. Presenting static stimulus displays where the gaze cue and the emotional expression were presented simultaneously, Tipples (2005) demonstrated that orienting to eye gaze was enhanced by increased pupil to sclera contrast (i.e., raised eyelids), regardless of the actual emotion on the face. In contrast, feature changes indicative of emotional expression (e.g., raised eyebrows) resulted in increases in reaction time that were not sensitive to gaze/target congruency. These findings suggest that in gaze cueing experiments that manipulate the emotional expression on the face, it is important to ensure that differences in the pupil to sclera contrast in the initial gaze direction cue are not confounded with differences in facial expression. If gaze is shifted just prior to the onset of emotion, the gaze shift is independent from eye aperture changes caused by facial expression. Hence, the discriminability of gaze should be equal regardless of the emotion on the face, allowing for the examination of attentional changes caused by the combined processing gaze direction and expression rather than local feature changes.

Another important consideration is that the use of different SOAs (cue to target intervals) may tap into gaze and emotion processing at different stages of integration. Behavioural and neuroimaging studies have provided an abundance of evidence that gaze and expression processing are subserved, at least in part, by the same brain areas (e.g., Engell & Haxby, 2007; Hasselmo et al., 1989; Hooker et al., 2003; Wicker et al., 2003) and are processed in an integral manner (e.g., Adams & Kleck, 2003, 2005; Ganel et al., 2005; Jones et al., 2006; Sander et al., 2006), at least at later stages of processing (Graham & LaBar, 2007). However, evidence has emerged suggesting that at early stages of processing, gaze and emotional expression may be processed in separate streams. A study involving transcranial magnetic stimulation demonstrated that at 200 ms, these two streams of information are not yet integrated (Pourtois et al., 2004), and electrophysiological evidence suggests that gaze and facial expression are not fully integrated until approximately 300 ms (Fichtenholtz, Hopfinger, Graham, Detwiler, & LaBar, 2007; Klucharev & Sams, 2004). Therefore, the length of time that intervenes between the face cue and the target may be an important determinant of whether or not gaze and expression interactions will be observed in behavioural cueing experiments.

The objectives of the present study were threefold. First, we were interested in examining the role of emotional face cues in modulating the cueing effect when dynamic stimulus presentation sequences of happy, fearful, and neutral faces were used. The stimulus presentation sequences employed across the experiments in this study were different from those used by Putman et al. (2006) in that the gaze shift always occurred before the expression change. This was done in order to rule out the possibility that eye aperture could be responsible for any differences in cueing effects to different emotional face cues, as well as to provide a more ecologically valid sequence of events (i.e., foveating a stimulus and then reacting to it). Therefore, the initial gaze cue was always the same, regardless of the subsequent emotional expression. Furthermore, the gaze shift and expression changes occurred more rapidly than in Putman et al. to yield a more natural-looking sequence and to maximize the chances of observing emotional modulation of the cueing effect, since expressions with faster rise times are perceived as more intense than those with slower rise times (Yoshikawa & Sato, 2008).

Our second objective was to characterize the time course of gaze and expression interactions. Given the evidence that expression and gaze are processed in separate streams at early stages of perceptual processing, we would not expect to see interactions between these two stimulus dimensions at short SOAs (i.e., before 310 ms; Klucharev & Sams, 2004), regardless of the emotion on the face or the type of task used (Experiments 1–3). In other words, with a short interval between the emotional gaze cue and target, we would expect separate effects for expression and gaze on target detection/identification speed and no interaction between the two dimensions. If separate expression effects were observed, it would be important to rule out that biological motion was not solely responsible (i.e., emotional faces moved more than neutral faces; Experiments 4 and 6). If gaze and expression information require time to become integrated, then expression and gaze should not interact to give rise to differential cueing effects at short SOAs, but interactions should be evidenced at longer SOAs (Experiments 5 and 6).

If gaze and expression interactions were observed, our final objective was to determine their exact nature in the context of gaze cueing. One possibility is that emotional gazing faces would serve as more effective cues than neutral faces, regardless of the emotion portrayed, since emotional faces signal the presence of an important event. In this case, the cueing effects for emotional faces should be greater than those to neutral faces. Another possibility is that the cueing effect would be smaller for fearful faces relative to happy and neutral faces. Studies have demonstrated that threatening stimuli capture attentional resources (e.g., Fox, Russo, Bowles, & Dutton, 2001; Fox, Russo, & Dutton, 2002; Koster, Crombez, van Damme, Verschuere, & de Houwer, 2004; van Honk, Peper, & Schutter, 2005), which may delay the allocation of attention to the target. The final and most ecologically plausible expectation is that the cueing effect for fearful faces will be larger relative to other emotional and neutral faces. Fearful faces may serve as more effective cues and elicit faster orienting to the gazed-at location because they act as signals of impending threat (Vuilleumier, 2005). The ability to orient quickly to the location of a potential danger should provide a significant survival advantage to the perceiver. However, this advantage might only occur if sufficient time is given to integrate the gaze and expression information in the cue.

EXPERIMENT 1

Method

Participants. Participants were 27 undergraduate and graduate students (14 females, 13 males) ranging from 18 to 29 years of age (mean 22.6 years) from Duke University. In all experiments, participants had no self-reported history of psychiatric or neurologic illness and had normal or corrected-to-normal vision. For all of the following experiments, procedures for human subjects were approved by the appropriate Institutional Review Board at either Duke University or Texas State University.

Apparatus and stimuli. Digitized greyscale photos of the same individual were used as stimuli in this experiment. The photographs were 8.3 cm wide × 12.0 cm high. One actor (PE) portraying a neutral expression and facial expressions of emotion that have found to be panculturally representative of the basic emotions of happiness and fear was chosen from the Ekman and Friesen (1976) pictures of facial affect. To omit extraneous cues such as the ears, hairline, and neck, the faces were cropped with an ovoid mask and placed on a 94% black background. The photos were normalized for contrast and luminance. All expressions were posed at full emotional intensity in full frontal orientations without changes in head orientation. Facial expressions of intermediate intensities were created using the methods outlined in LaBar, Crupain, Voyvodic, and McCarthy (2003) using MorphMan 2000 software (STOIK, Moscow, Russia). The original stimuli had direct gaze, and Photoshop™ was used to manipulate gaze direction so that averted irises deviated 0.4° of visual angle from the centrally presented irises in the faces with direct gaze.

The experimental stimuli were centrally presented on a 75% grey background on a 17-inch monitor. A 1 cm × 1 cm black cross presented at approximately the level of the eyes on the photographs (approximately 2.5 cm above the horizontal meridian) served as the fixation stimulus. The target was a 0.5 cm × 0.5 cm asterisk positioned with its centre at eye level (approximately 2.5 cm above the horizontal meridian) and approximately 8 cm from the vertical midline (as measured by the nearest edge of the target). Stimuli were presented and computer keyboard responses were recorded with Superlab Pro (Ver. 2.0) experimental software for Windows (Cedrus, 1999).

Design and procedure. Each experimental session was approximately 40 minutes in duration. Participants were seated approximately 57 cm from the monitor. Participants performed a target detection task, in which they were asked to press the spacebar on the computer keyboard as soon as the target appeared. Each trial began with the fixation stimulus. This was replaced after 600 ms by a face with a neutral expression and direct gaze that remained on the monitor for 600 ms. Then, on all trials, the gaze direction cue—a neutral face with gaze averted to the left or right—was presented. On neutral expression trials, this image remained on the monitor for another 225 ms (+ / − 50 ms). On fearful and happy expression trials, the neutral gaze cue remained on the monitor for 100 ms and was replaced with an intermediate facial expression with averted gaze for 50 ms, and then a full intensity facial expression with averted gaze for 75 ms (+ / − 50 ms). Therefore, the cue-to-target intervals or SOAs (i.e., the time that intervened between the gaze cue and the appearance of the target) were 175, 225, and 275 ms. This small latency jitter was used to prevent anticipatory responding. The trial sequence ended with the appearance of a target to the left or right of the face. Trials were separated with intertrial intervals of either 500 or 1000 ms; both intervals occurred randomly and with equal frequency. An example of a typical trial is shown in Figure 1.

Prior to the experiment, participants were told that the neither the expression nor the gaze direction of the face was predictive of where the target would appear. Nevertheless, they were asked to centre their attention on the information in the face and to avoid looking directly at the target when it occurred in the periphery. Participants were informed about the

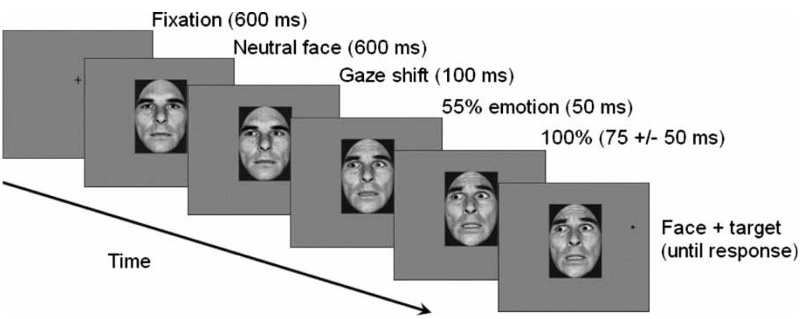

Figure 1. Schematic depiction of the sequence of events in an invalidly cued trial with fearful facial expressions. Each trial began with a fixation stimulus (600 ms) and then a face with a neutral expression and direct gaze. After 600 ms, the gaze direction cue (neutral face with averted gaze) was presented. On neutral expression trials, the cue remained on the monitor for another 225 ms (+/ −50 ms). On emotional trials, it remained on the monitor for 100 ms and was replaced with 55% intensity facial expressions with averted gaze for 50 ms, and then 100% intensity facial expressions with averted gaze for 75 ms (+/ −50 ms). The trial ended with the appearance of a target to the left or right of the face.

number of trials and blocks in the experiment and were encouraged to rest between blocks.

All participants completed 792 trials that were presented in six blocks of 132 trials. Of these, 720 trials were used as data trials. The other 72 trials were catch trials, in which no target was presented. This was done to discourage anticipatory responses. On the 720 data trials, facial expression (fearful, happy, neutral), gaze direction (left, right), target side (left, right), and SOAs (175, 225, 275 ms) were presented in random order and equally within the six blocks. Valid trials were those in which the target appeared on the side of the screen that the eyes were gazing toward; invalid trials were those in which the target appeared on the side opposite to where the eyes were gazing.

Data analysis. Responses were scored as correct if the spacebar was pressed within 100–1000 ms after target onset. Reaction time values outside of this range and those associated with incorrect keypresses (two subjects pushed undesignated keys during the experiment) were removed from the analysis. For the purposes of analysis, the three cue-to-target intervals were combined, as the small jitter was introduced solely to avoid anticipatory responses. Median reaction times were subjected to a repeated-measures analysis of variance (ANOVA) with facial expression (fearful, happy, or neutral) and validity (validly or invalidly cued) as within-subject variables. Where applicable (i.e., where the assumption of homogeneity was violated), degrees of freedom were adjusted with Greenhouse-Geisser corrections.

Results and discussion

On average, participants made false alarms on 2.7% of the catch trials (i.e., pressed the spacebar when no target appeared). Errors occurred on 2.15% of trials, with anticipations accounting for 1.63% of all responses and timed out trials accounting for 0.52%. Due to the low rate of errors (less than 1% in each trial category), they were not analysed further. The means of the median reaction times for each condition for Experiment 1 are shown in Table 1. Repeated measures analysis of variance revealed a main effect of validity, $F(1, 26) = 30.2$, $p < .01$, which was due to the fact that reaction times for validly cued trials were faster than those for invalidly cued trials. There was also a main effect of expression, $F(1, 26) = 54.8$, $p < .01$. Bonferroni-corrected post hoc pairwise comparisons revealed that participants detected the targets faster when the face was emotional (285 ms for both fearful and happy faces) than when the face was neutral (304 ms): Fearful vs. happy, $t(26) = 0.3$, $p > .05$; fearful vs. neutral, $t(26) = -8.6$, $p < .01$; happy vs. neutral, $t(26) = -7.5$, $p < .01$. No other results were

TABLE 1
Means of the individual median reaction times (ms) for the valid and invalid gaze cueing conditions and cueing effect for fearful, happy, and neutral faces in Experiment 1

	Valid		*Invalid*		*Cueing effect*	
Facial expression	*M*	*SD*	*M*	*SD*	*M*	*SD*
Fearful	280	29	291	29	11	11
Happy	282	33	288	30	6	11
Neutral	299	35	309	32	10	10

$N = 27$ (Experiment 1); SD = standard deviation (ms). The cueing effect for happy faces was not reliably different from those for neutral and fearful faces.

significant, although there was a trend for the cueing effect to be smaller with happy faces than with neutral or fearful faces; Validity × Expression interaction, $F(2, 46) = 3.0$, $p = .064$.

The results of Experiment 1 demonstrated two separate effects. First, there was a main effect of cue validity: When gaze validly cued the location of the target, participants were faster to detect the target. This result replicates the standard cueing effect that has been observed in many studies of reflexive orienting (e.g., Driver et al., 1999; Friesen & Kingstone, 1998; Hietanen & Leppänen, 2003). Second, there was a main effect of expression such that when the face was emotional (either fearful or happy); participants detected the target more quickly regardless of where gaze was directed. These results are consistent with Fichtenholtz et al. (2007), who also did not observe behavioural evidence of expression and gaze interactions when a short interval occurred between the gaze cue and the appearance of the target.

The interaction between validity and expression only approached significance, reflecting the tendency for the cueing effect to be smaller with happy faces relative to fearful and neutral faces. Smaller cueing effects for happy faces relative to angry and neutral faces have been reported by Hori et al. (2005), but only for female faces. An examination of our data on a case-by-case basis revealed that the attenuated cueing effect for happy faces was not observed in the majority of participants; only 13 of the 27 participants showed this pattern of reaction times and the effect size was small (partial $\eta^2 = .11$). Importantly, the cueing effect for fearful faces was not significantly different from that for neutral faces.

EXPERIMENT 2

The purpose of Experiment 2 was to examine whether the effects of facial expression and gaze cueing observed in Experiment 1 were expression specific. We were interested in determining whether the effects of facial emotion and gaze cueing would remain separate across different emotions, since the facial expressions of fear and happiness may both be special in terms of how they are processed. For example, there is a well-documented processing advantage for happy faces, which are recognized more quickly and accurately than any other facial expression (Ekman & Oster, 1982; Kirita & Endo, 1995; Kirouac & Dore, 1983). Similarly, fearful faces are hypothesized to engender rapid, automatic processing via subcortical inputs to the amygdala that do not involve the lateral geniculate nucleus or striate occipital cortex (Vuilleumier & Pourtois, 2007). Therefore, it was necessary to rule out the possibility that the results of Experiment 1 were specific to happy and fearful faces.

Rather than use facial expressions of opposite valence, we used two negative facial expressions: Fear and disgust. If the results of Experiment 1 were due to the privileged processing of both fearful and happy faces, then faster reaction times for fearful face cues should still remain, whereas reaction times for disgusted face cues might not differ from those for neutral faces cues. On the other hand, if the results of Experiment 1 were actually due to the facilitatory effects of facial emotion in general, then the same results should be observed (i.e., facilitation for both types of expressive faces, relative to neutral faces), even when different facial expressions are used.

Method

Participants. Participants were 29 graduate and undergraduate students (16 females and 13 males) ranging from 19 to 34 years of age (mean 24.6 years) at Duke University.

Stimuli and procedure. Cue stimuli consisted of the same photos of neutral and fearful expression that were used in Experiment 1, plus a set of photos of the same actor (PE) portraying the emotion of disgust. Image preparation of the disgust photos was the same as that for the photos in Experiment 1. The design, procedures, and data analysis were otherwise identical to those used in Experiment 1.

Results and discussion

On average, participants made false alarms on 1.9% of the catch trials. Errors occurred on 1.19% of trials, with anticipations accounting for 0.73% of all responses and timed out trials accounting for 0.46%. Due to the low rate of errors (less than 1% in each trial category), they were not analysed further. The means of individual median reaction times for Experiment 2 are shown in Table 2. A repeated measures analysis of variance revealed a main

TABLE 2
Means of the individual median reaction times (ms) for the valid and invalid gaze cueing conditions and cueing effect for fearful, disgusted, and neutral faces in Experiment 2

	Valid		*Invalid*		*Cueing effect*	
Facial expression	*M*	*SD*	*M*	*SD*	*M*	*SD*
Fearful	298	45	310	45	12	21
Disgusted	299	47	312	47	13	15
Neutral	311	50	327	50	16	17

$N = 29$ (Experiment 2); SD = standard deviation (ms). The cueing effect for neutral faces was not reliably different from those for fearful and disgusted faces.

effect of validity, $F(1, 28) = 27.2$, $p < .01$, which indicated that reaction times for validly cued trials were faster than those for invalidly cued trials. There was also a main effect of expression, $F(1, 28) = 21.9$, $p < .01$. Bonferroni-corrected post hoc pairwise comparisons revealed that participants detected the targets faster when the face was emotional (298 ms for fearful faces and 299 ms for disgusted faces) than when the face was neutral (311 ms): Fearful vs. disgust, $t(28) = -0.3$, $p > .05$; fearful vs. neutral, $t(28) = -4.9$, $p < .01$; disgust vs. neutral, $t(28) = -5.3$, $p < .01$. The expression by validity interaction was not significant ($F < 1$).

The results of Experiment 2 replicated the results of Experiment 1, showing separate effects for expression and gaze cueing. Targets whose locations were validly cued by gaze were responded to more quickly than targets that were invalidly cued. When the faces were emotional (fearful or disgusted), participants detected targets more quickly regardless of where they appeared or how they were cued. Together, the results of Experiments 1 and 2 suggest that at a short SOA, facial expression, and gaze cueing facilitate target detection but do not interact with one another.

Experiments 1 and 2 examined the effects of facial expression and gaze cueing on the ability of participants to detect targets. It is possible that these results are due to task demands. Target detection is typically faster than target identification (e.g., Friesen & Kingstone, 1998), suggesting that this task is less difficult and less attentionally demanding. It was important to establish that the results of the first two experiments were not due to the response characteristics of the detection task. Experiment 3 was designed to examine whether expression and gaze cueing effects would generalize across tasks, specifically if the task was more attentionally engaging. We wanted to rule out the possibility that interactions between gaze and expression might emerge with identification because task demands are more intensive than in detection.

EXPERIMENT 3

Experiment 3 was designed to rule out the possibility that the relative easiness of the target detection task was responsible for the results of Experiments 1 and 2. To this end, we replicated the design of Experiment 1 but instead of using the same target on every trial, we used two target letters and required that participants identify the targets. In order to examine whether the marginally smaller cueing effect for happy faces in Experiment 1 would also be evidenced when the task requirement were changed, we used the same facial expressions: Fearful, happy, and neutral expressions.

Method

Participants. Participants consisted of a total of 33 graduate and undergraduate students (16 females and 17 males) ranging from 18 to 35 years of age (mean 21.2 years) at Duke University.

Stimuli and procedure. Facial stimuli consisted of the photos used in Experiment 1. The two target stimuli were capital letters ("T" and "L") that were 1 cm wide and 1.5 cm high, positioned with their centre at eye level (approximately 2.5 cm above the horizontal meridian) and approximately 8 cm from the vertical midline (as measured by the nearest edge of the targets). Each participant completed six blocks of 120 trials, which consisted of equiprobable combinations of facial expressions (fearful, happy, and neutral), gaze direction (left, right), target direction (left, right), and target type ("T" or "L"). No catch trials were included. Otherwise, the stimuli and design were identical to Experiment 1.

Procedure and data analysis. Each experimental session was approximately 45 minutes in duration. Participants performed a target identification task in which they were required indicate whether the target letter was a T or an L by pressing a preassigned key. Keyboard presses were counterbalanced across subjects: for half of the subjects, the designated key for "T" was on the left and the key for "L" on the right; for the other half, the keys were reversed. Identification errors (incorrect keypress responses) were excluded from the analysis. Otherwise, the design, procedures, and data analysis were identical to those used in Experiment 1.

Results and discussion

Anticipations accounted for 0.32% of all trials, and timed out trials accounted for 0.81%. Due to the low percentage of these error types across the trial categories, these errors were not analysed further. On average, target identification performance approached ceiling; participants made commission errors on 4.4% of the total number of trials. Mean proportion correct obtained for the different trial types are shown on the bottom half of Table 3. In spite of the low error rates, identification accuracy was analysed by way of a repeated measures ANOVA with expression (fearful, happy, neutral) and validity (valid, invalid) as within-subject factors. The ANOVA revealed a main effect of validity, $F(1, 32) = 17.6$, $p < .01$, due to the fact that invalidly cued letters (96.5% accuracy) were identified more accurately than validly cued letters (94.7% accuracy). However, it is important to note that this accuracy difference amounts to less than 2 (out of 64) trials performance difference between validly and invalidly cued letters. In addition, given the skewed nature and restricted range of these data due to ceiling effects, the result of this analysis should be interpreted with caution.

Initial repeated measures ANOVA of the reaction time data did not detect a difference between reaction times to the different target letters (effect of target type, $F < 1$); therefore, the data were combined across targets. The mean of the individual median reaction times obtained in Experiment 3 are shown in the top portion of Table 3. A subsequent repeated measures ANOVA revealed a main effect of validity, $F(1, 32) = 7.7$, $p < .01$, which indicated that reaction times for validly cued trials were faster than those for invalidly cued trials. There was also a main effect of expression, $F(1, 32) = 22.5$, $p < .01$. Bonferroni-corrected post hoc pairwise comparisons revealed that participants identified the targets faster when the face was emotional (472 and 474 ms for fearful and happy faces, respectively) than when the face

TABLE 3
Means of the individual median reaction times (ms) and mean accuracy for the valid and invalid gaze cueing conditions and cueing effect for fearful, happy, and neutral faces in Experiment 3 (target identification)

	Valid		*Invalid*		*Cueing effect*	
Facial expression	*M*	*SD*	*M*	*SD*	*M*	*SD*
Mean of median reaction times (correct responses only)						
Fearful	468	76	476	74	7	18
Happy	471	74	476	76	5	18
Neutral	482	78	485	75	3	21
Mean proportion correct						
Fearful	.94	.03	.96	.02		
Happy	.95	.03	.97	.03		
Neutral	.95	.03	.96	.03		

$N = 33$ (Experiment 3); SD = standard deviation (ms). The cueing effect for neutral faces was not reliably different from those for fearful or happy faces.

was neutral (484 ms). The expression by validity interaction was not significant ($F < 1$).

Experiment 3 replicated the results of Experiments 1 and 2 in showing separate effects of expression and gaze cue validity. Participants identified letters more quickly when they appeared at a gazed-at location. Although this effect was quantitatively smaller than the effects observed in Experiments 1 and 2, it was consistent across subjects (25 of the 33 participants). Participants also identified letters more quickly when the face was emotional than when it had a neutral expression. Similar to the first two experiments, there was no significant interaction between gaze cue validity and facial expression. Together, the results of these three experiments suggest that at short SOAs facial expression and gaze cues produce independent effects and do not interact.

One possible interpretation of these results is that the effects that we have attributed to emotional expression are really due to motion, since emotional faces had facial features other than the eyes that moved and neutral faces did not. Therefore, it is possible that facial movement, and not emotion per se, was responsible for facilitating the detection and identification of the targets on trials with expressive faces. Experiment 4 was designed to evaluate this interpretation.

EXPERIMENT 4

The purpose of Experiment 4 was to rule out the possibility that biological motion alone was responsible for the expression effects observed in the first three experiments. In order to disrupt emotion processing, we chose to present inverted faces (e.g., Bartlett & Searcy, 1993; McKelvie, 1995; Valentine, 1988) because this has been shown to disrupt facial expression processing, regardless of whether the expressions are static or dynamic (Ambadar, Schooler, & Cohn, 2005). Although face inversion may also disrupt gaze processing (Jenkins & Langton, 2003), it affects expression judgements more than gaze judgements (Ganel et al., 2005). Whether the gaze cueing effect in dynamic facial displays would survive the inversion manipulation was uncertain. Using static displays of inverted faces, Hori et al. (2005) reported that gaze cueing in a small sample ($N = 10$) participants was disrupted, whereas Langton and Bruce (1999) and Tipples (2005) reported no attenuation of the cueing effect with inversion for targets appearing along the horizontal axis. Nevertheless, the main question of interest was whether we would see the overall advantage for expressive faces compared to neutral faces that we observed in Experiments 1–3 after inversion.

We reasoned that inverting the faces should impair facial expression processing without affecting motion processing. We reasoned further that gaze processing, being feature based, should not be affected by inversion because our targets appeared along the horizontal axis (Langton & Bruce, 1999; Tipples, 2005). The design and procedures in Experiment 4 were identical to those of Experiment 1, except that the face cues were inverted and the targets appeared below the horizontal meridian (so that they remained at eye level along the horizontal axis). This design allowed us to compare the results of the two experiments directly. If the results of the first three experiments were entirely due to motion, then the expression effect observed in Experiment 4 should be of the same magnitude as the expression effect in Experiment 1. However, if the reaction time advantage for expressive faces in the first three experiments was due to the actual evaluation of the affective features of the face, then the expression effect observed with inverted faces in Experiment 4 should be absent or significantly attenuated relative to Experiment 1.

Method

Participants. Participants were 27 undergraduate students (15 female, 12 male) ranging from 19 to 32 years of age (mean 23.1 years) from Texas State University.

Apparatus, stimuli, design, procedure, and data analysis. Each experimental session was approximately 40 minutes in duration. The stimuli consisted of the same facial photos and target asterisk used in Experiment 1, except that the face images were rotated by 180° and the target was positioned approximately 2.5 cm below the horizontal meridian (so that its centre was at eye level). Otherwise, the apparatus, design, procedure, and data analysis were identical to those described for Experiment 1.

Results and discussion

On average, participants made false alarms on 1.7% of the catch trials (i.e., pressed the spacebar when no target appeared). Errors occurred on 0.26% of trials, with anticipations accounting for 0.13% of all responses and timed out trials accounting for 0.13%. Due to the low rate of errors (less than 1% in each trial category), they were not analysed further. The results of Experiment 4 are shown in Table 4. Repeated measures analysis of variance revealed a main effect of validity, $F(1, 26) = 56.9$, $p < .01$, which was due to the fact that reaction times for validly cued trials were faster than those for invalidly cued trials. There was also a main effect of expression, $F(1, 26) = 20.4$, $p < .01$. Bonferroni-corrected post hoc pairwise comparisons revealed

TABLE 4
Means of the individual median reaction times (ms) for the valid and invalid gaze cueing conditions and cueing effect for inverted fearful, happy, and neutral faces in Experiment 4

	Valid		*Invalid*		*Cueing effect*	
Facial expression	*M*	*SD*	*M*	*SD*	*M*	*SD*
Fearful	331	59	343	58	12	11
Happy	337	62	344	62	8	11
Neutral	345	78	357	59	12	11

$N = 27$ (Experiment 4); SD = standard deviation (ms). The cueing effect for happy faces was not reliably different from those for fearful and neutral faces.

that participants detected the targets faster when the face was emotional (338 ms for fearful and 341 ms for happy faces) than when the face was neutral (351 ms). The Validity × Expression interaction was not significant, $F(2, 52) = 1.6$, $p > .05$.

To confirm that face inversion had succeeded in making expression discriminations more difficult and to compare the magnitude of the expression effect before and after inversion, we conducted a final ANOVA on the reaction time data across Experiments 1 and 4. In this analysis, experiment (Experiment 1 vs. 4) was a between-subjects variable and cue validity (valid, invalid) and facial expression (fearful, happy, neutral) were within-subject variables. Only the main effect of experiment and interactions of experiment with expression and with cue validity were examined.

A direct comparison of Experiments 1 and 4 yielded three results. First, there was a significant main effect of experiment, $F(1, 52) = 16.4$, $p < .01$, reflecting the fact that reaction times to detect targets with inverted faces were longer than those with upright faces. Second, reflexive orienting to gaze direction was not affected by inversion ($F < 1$). Finally, there was a significant interaction between experiment and expression, $F(2, 104) = 5.2$, $p < .05$. Figure 2 shows the reaction time advantage for fearful and happy faces relative to neutral faces (as indexed by reaction time for neutral face cues minus reaction time for the emotional expression), for each of the two experiments. As illustrated in Figure 2, the reaction time advantage for targets cued by emotional faces was larger for upright than for inverted faces, indicating that the expression effect was attenuated with inversion. This result was confirmed by comparing the sizes of the expression effects obtained Experiment 1 and Experiment 4: the effect size for upright faces (partial $\eta^2 = .68$) was considerably larger than that for inverted faces (partial $\eta^2 = .37$).

The results from Experiment 4 indicated that inversion had an overall slowing effect on reaction times and did not affect reflexive orienting to gaze

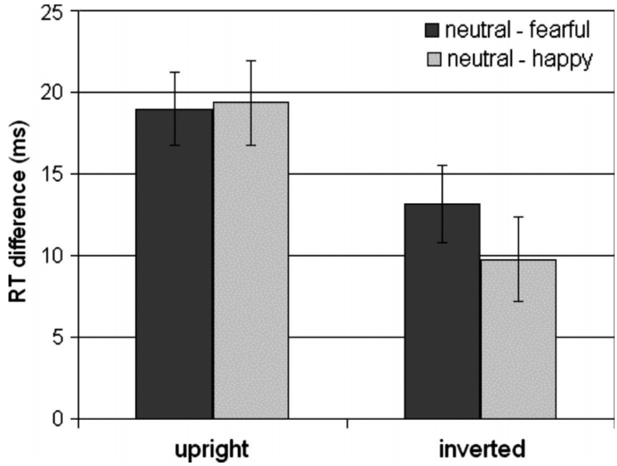

Figure 2. Reaction time (RT) advantage (collapsing across gaze cue validity) for targets cued by fearful and happy faces relative to neutral faces (RT neutral – RT emotional expression), for upright faces (Experiment 1) and inverted faces (Experiment 4). Error bars represent the standard error of the mean. To view this figure in colour, please see the online issue of the Journal.

direction. This finding is consistent with Ganel et al.'s (2005) finding that face inversion does not have as profound an effect on gaze processing as it has on expression processing. These results are also consistent with Langton and Bruce's (1999) observation that face inversion does not affect gaze cueing at short SOAs for targets presented along the horizontal axis. However, our results do contradict those of Hori et al. (2005), who found that reflexive orienting to gaze direction was disrupted by face inversion. Given that Hori and colleagues employed a much smaller sample size ($N = 10$) and used static stimulus presentations, the differences in results are most likely due to methodological issues.

With regard to the expression effect, participants were still faster to detect targets when the inverted faces were emotional. Given that inversion interferes with the efficiency of expression recognition but does not disrupt it entirely (e.g., Ganel et al., 2005), this result is not surprising. Nevertheless, the attenuation of the emotion effect with inverted faces compared with that for upright faces suggests that even if biological motion did play a role in facilitating responses to targets preceded by emotional faces in Experiment 1, it was not wholly responsible. Our findings suggest that the evaluation of the affective features of the face plays an important role in the detection advantage for targets signalled by emotional faces, and that this effect is augmented by biological motion.

The results from the first four experiments suggest that when a short SOA intervenes between the gaze cue and the target, expression and gaze direction do not interact to produce cueing effects that vary in magnitude depending on the emotional expression. Instead, there appear to be separate effects for expression and gaze. Individuals detected and identified targets more quickly if the face was emotional, regardless of whether the target appeared at the gazed-at location, and the magnitude of the cueing effect was the same across emotional and nonemotional faces. These results seem counter-intuitive, given that as signals of the location of potential threat, the gaze direction of fearful faces was expected to be a stronger cue than the gaze direction of other emotional faces and of neutral faces. Alternatively, one might have expected that expressive gazing faces would be more powerful cues than neutral gazing faces.

An important feature of the first four experiments was that only short SOAs intervened between the appearance of the cue and the appearance of the target; however, the latency interval was not sufficient for examining the effect of processing time on gaze and expression interaction. As mentioned previously, ERP (Fichtenholtz et al., 2007; Klucharev & Sams, 2004) and TMS (Pourtois et al., 2004) findings suggest that gaze and expression processing are initially separate and take time to become integrated. Behavioural evidence also corroborates this notion (Graham & LaBar, 2007). Therefore, it was important to examine the effect of lengthening the SOA between the cue and the target. If it is indeed the case that more time is necessary in order for gaze and expression interactions to occur, then interactions should not be seen at short SOAs, but should be evident at longer SOAs.

EXPERIMENT 5

Experiments 1–4 used 225, 250, and 275 ms SOAs and found separate effects of facial expression and gaze direction. If these two facial dimensions are initially processed separately and are integrated at a later stage of processing, then these results should be expected—gaze and facial expression should not interact at a short SOA. According to this account, if more time is given to process the face cue, there will be more time for integration to occur and an interaction between gaze and expression may emerge. The exact nature of this interaction is currently speculative. We predicted that as signals of impending threat, fearful gazing faces should be more effective at cueing target location than happy or neutral faces. If the ability to orient quickly to the location of a potential danger provides a significant survival advantage to the perceiver, then fearful faces should elicit faster orienting to the gazed-at location (and faster processing of the target). However, this advantage may occur only if there is enough time to fully process integrate all of the information in the cue.

An additional motive for this study was to confirm that the marginally smaller cueing effect for happy faces observed in Experiment 1 was indeed spurious and was not due to a lack of statistical power. To this end, we included both the short SOAs used in Experiment 1 and a longer set of SOAs, and we increased the sample size from that in Experiment 1.

Method

Participants. Participants were 57 undergraduate students (46 females and 11 males) ranging from 19 to 35 years of age (mean 22.3 years) at Texas State University.

Apparatus and stimuli. Stimulus details and apparatus were identical to Experiment 1.

Design and procedure. Each experimental session was approximately 50 minutes in duration. Participants performed a target detection task in which they were asked to press the spacebar on the computer keyboard as soon as the target appeared. Each trial began with the fixation stimulus. This was replaced after 600 ms by a face with a neutral expression and direct gaze that remained on the monitor for 600 ms. Then, on all trials, the gaze direction cue, a neutral face with averted gaze (left or right), was presented. On neutral expression trials, this image remained on the monitor for another 225 ms (+/− 50 ms) or 525 ms (+/− 50 ms). On fearful and happy expression trials, the neutral gaze cue remained on the monitor for 100 ms and was replaced with an intermediate facial expression with averted gaze for 50 ms, and then a full intensity facial expression with averted gaze for either 75 ms or 375 ms (+/− 50 ms). The trial sequence ended with the appearance of a target to the left or right of the face. Trials were separated with intertrial intervals of either 500 or 1000 ms; both intervals occurred randomly and with equal frequency. Participant instructions were identical to those in the Experiment 1.

All participants completed 640 trials that were presented in four blocks of 160 trials. Of these, 576 trials were used as data trials. The other 64 trials were catch trials, in which no target was presented. Of the 576 data trials, facial expression (fearful, happy, neutral), gaze direction (left, right), target side (left, right), and cue to target SOA (short: 175, 225, 275 ms; and long: 475, 525, 575 ms) were presented in random order and equally within the four blocks. Data reduction and analysis were identical to the other experiments except that SOA (short vs. long) became an additional within-subjects factor in the analyses. Where applicable (i.e., where the assumption of homogeneity was violated), degrees of freedom were adjusted with Greenhouse-Geisser corrections.

Results and discussion

On average, participants made false alarms on 2.3% of the catch trials (i.e., pressed the spacebar when no target appeared). Errors occurred on 0.46% of trials, with anticipations accounting for 0.28% of all responses and timed out trials accounting for 0.18%. Due to the low rate of errors (less than 1% in each trial category), they were not analysed further. The results of Experiment 5 are shown in Table 5. Repeated measures analysis of variance with emotional expression (fearful, happy, neutral), SOA (short, long), and validity (validly cued, invalidly cued) as within-subject factors revealed a main effect of validity, $F(1, 56) = 102.3$, $p < .001$, which was due to the fact that reaction times for validly cued targets were faster than those for invalidly cued targets. The ANOVA revealed a main effect of SOA, $F(1, 56) = 178.7$, $p < .001$; participants were faster to detect targets at the long SOA than at the short SOA. There was also a main effect of expression, $F(2, 99) = 144.4$, $p < .001$. Bonferroni-corrected post hoc pairwise comparisons revealed that participants detected the targets faster when the face was emotional (344 ms for fearful and 342 ms for happy faces) than when the face was neutral (367 ms): Fearful vs. neutral, $t(56) = -14.0$, $p < .01$; happy vs. neutral, $t(56) = -13.3$, $p < .01$. Unlike the four previous experiments, the expression by validity interaction was significant, $F(2, 100) = 4.2$, $p < .05$, but this finding was mitigated by a three-way interaction between expression, validity, and SOA, $F(1.9, 106.8) = 7.6$, $p < .01$.

In order to interpret this interaction, we ran separate ANOVAs for each SOA. At the short SOA, the ANOVA revealed separate effects for expression, $F(2, 87) = 80.0$, $p < .001$, and validity, $F(1, 56) = 35.6$, $p < .001$.

TABLE 5
Means of the individual median reaction times (ms) for the valid and invalid gaze cueing conditions and cueing effect for fearful, happy, and neutral faces at short and long SOAs in Experiment 5

	Valid		*Invalid*		*Cueing effect*	
Facial expression	*M*	*SD*	*M*	*SD*	*M*	*SD*
Short SOA						
Fearful	353	46	361	47	9	16
Happy	354	49	359	47	5	15
Neutral	374	54	384	48	10	23
Long SOA						
Fearful	322	46	338	44	16	15
Happy	322	43	334	52	12	17
Neutral	354	49	354	47	0	19

$N = 57$ (Experiment 5); SD = standard deviation (ms).

Bonferroni-corrected post hoc comparisons confirmed that the main effect of expression was due the fact that participants detected targets cued by fearful and happy faces more quickly than targets cued by neutral faces (357 and 357 ms vs. 379 ms, respectively): Fearful vs. neutral, $t(56) = -9.9$, $p < .01$; happy vs. neutral, $t(56) = -9.6$, $p < .01$. Importantly, the expression by validity interaction was not significant ($F = 1.0$, partial $\eta^2 = .02$). The lack of a smaller cueing effect for happy faces at short SOA suggests that the marginally significant attenuation of the cueing effect of happy faces observed in Experiment 1 was sample specific and not due to a lack of statistical power.

At the long SOA, the ANOVA also revealed separate effects for expression, $F(2, 100) = 99.4$, $p < .001$, and validity, $F(1, 56) = 70.6$, $p < .001$. Bonferroni-corrected post hoc comparisons confirmed that the main effect of expression was due the fact that participants detected targets cued by fearful and happy faces more quickly than targets cued by neutral faces (330 and 328 ms vs. 354 ms, respectively): Fearful vs. neutral, $t(56) = -12.0$, $p < .01$; happy vs. neutral, $t(56) = -11.1$, $p < .01$. However, these effects were mitigated by a significant Expression $\times$ Validity interaction, $F(2, 108) = 11.1$, $p < .001$. Bonferroni-corrected post hoc t-tests comparing the magnitude of the cueing effect (invalid minus valid trials) across the three expressions at this SOA revealed that the cueing effect was larger when the faces were emotional than when the faces were neutral;(ueing effect: Fearful (16 ms) = happy (12 ms) > neutral (0 ms): Fearful vs. happy, $t(56) = 1.4$, $p > .05$; fearful vs. neutral, $t(56) = 4.3$, $p < .01$; happy vs. neutral, $t(56) = 3.2$, $p < .01$. Furthermore, the magnitude of the cueing effect for fearful increased from the short to the longer SOA; effect of SOA on cueing effect for fearful faces, $t(56) = -2.5$, $p = .014$. The effect of SOA on cueing effects for happy and neutral faces was not significant after Bonferroni correction (corrected critical p-value = .0167): effect of SOA on cueing effect for happy faces, $t(56) = -2.4$, $p = .019$; effect of SOA on cueing effect for neutral faces, $t(56) = 2.3$, $p = .027$.

The results of Experiment 5 both replicated our earlier results with short SOAs (Experiments 1–4) and confirmed our prediction that gaze and expression interactions would occur if more time intervened between the gazing face cue and the appearance of the target. When a short SOA intervened between the face cue and the target there were separate effects for facial expression and gaze cueing, and no interaction between the two. In contrast, a gaze and expression interaction was observed at the longer SOA. Providing more time to process the face cue allowed for the integration of gaze and expression information, giving rise to the interaction. At the long SOA, emotional gazing faces, especially fearful faces, became more effective cues and neutral faces became less effective cues. These results provide corroborating evidence that gaze and facial expression information are initially processed in separate, parallel streams (Klucharev & Sams, 2004; Pourtois et al., 2004) and are integrated at later stages of processing (Adams & Kleck, 2003, 2005; Ganel et al., 2005; Graham & LaBar, 2007; Jones et al., 2006) in common brain areas (Hasselmo et al., 1989; Hooker et al., 2003; Wicker et al., 2003).

The emotional modulation of the cueing effect at the long SOA was a greater cueing effect (difference between valid trial RT and invalid trial RT) for emotional faces (both fearful and happy) relative to neutral faces. The cueing effect seemed to be larger at the long SOA compared to the short SOA for both fearful and happy faces; however, after Bonferroni-correction, only the cueing effect for fearful faces changed significantly from the short to the long SOA. In keeping with this finding, we had expected that fearful gazing faces would serve as more effective cues than happy or neutral gazing faces, since they should act as signals of the location of potential danger. Our results suggest that emotional gazing faces, regardless of their valence, become more effective at cueing the location of a target at longer SOAs. We speculate that this enhanced cueing effect for expressive faces occurs because emotional gazing faces indicate that the gazed-at target has some emotional significance. This perceived significance alone may be sufficient to elicit faster attentional shifts to the gazed-at location, regardless of the actual emotion expressed. However, given the marginal increase in the size of the cueing effect from the short SOA to the long SOA for happy faces after correcting for Type I error, it is possible that there is a greater amplification of gaze-triggered orienting for fearful gazing faces over the course of time.

In contrast, the opposite effect was observed for neutral faces: The cueing effect for neutral faces was actually smaller at the longer SOAs than at the short SOAs, although this result was not significant after Bonferroni correction. This finding was unexpected and requires further examination and replication, especially since the gaze cueing effect has been reliably observed in faces with neutral expressions at longer SOAs (e.g., Friesen & Kingstone, 1998; Friesen, Moore, & Kingstone, 2005; Hietanen & Leppänen, 2003; Tipples, 2006). There are different possible interpretations of this finding, the most conservative being that this finding is sample specific. For example, the relatively greater proportion of females in this experiment may have affected the results, since gaze cueing effects may be sensitive to gender (e.g., Bayliss, di Pellegrino, & Tipper, 2005) and gender differences in facial expression processing ability have also been reported (e.g., Montagne, Kessels, Frigerio, de Haan, & Perrett, 2005).

Another interpretation of these results could be that stimulus motion is exerting top-down influences on attentional orienting at the long SOA. For example, the relative enhancement of cueing with expressive faces and the attenuation of cueing with neutral faces at the longer SOA could have been due to the fact that there is motion present in the emotional faces that is not present in the neutral faces. At the long SOA, this difference in motion may have potentiated cueing for faces that moved immediately (i.e., changed expression) after the shift in gaze direction, while attenuating cueing for faces that remained static (i.e., retained the same neutral expression) after the shift in gaze direction. The fact that the cueing effect was enhanced for expressive faces and reduced for neutral faces at the long SOA (compared to the short SOA) could mean that incorporating facial emotion/motion into the gaze cueing task creates a context where the observer begins to form expectations about targets and their significance. Neutral gazing faces only provide information about target location, while emotional faces (either through movement or actual emotional significance) may also signal that the target is important or emotionally significant to the gazer. Expectations of target significance could then trigger top-down processes that mediate the deployment and allocation of attention. In this context, neutral faces may not be as effective at cueing target location.

In sum, the results of Experiment 5 indicate that interaction between the processing of gaze direction and facial expression depends upon complete integration of information from the face cue, a process that requires time. However, it was important to determine whether the results of Experiment 5 were due the combined effects of expression, gaze, and motion for expressive faces.

EXPERIMENT 6

Experiment 5 was motivated by the possibility that gaze and expression interactions would occur if individuals were allowed more time to process the face cue before the appearance of the target. At the short SOA, separate effects for facial expression and gaze cueing were observed, whereas a gaze and expression interaction was observed at the longer SOA, such that there was a greater gaze cueing effect with emotional faces (both fearful and happy) relative to neutral faces. Given that this is the first demonstration of an interaction between gaze-triggered orienting and expression that is modulated by SOA, it was important to replicate Experiment 5. In order to rule out the possibility that gender may have played a role in the effects observed in the Experiment 5, genders were sampled more equally and included as a between-subjects factor in the analyses.

As mentioned earlier, in addition to replicating the pattern of results found in Experiment 5, another motive for Experiment 6 was to address the emotion/motion confound present across the previous experiments: The fact that expressive faces had more feature movement than neutral faces. Our findings in Experiment 4 with inverted faces suggested that stimulus motion was not solely responsible for the emotion differences observed in the earlier short SOA experiments; however, it is possible that the interaction between gaze and expression observed at the long SOA in Experiment 5 were due to feature motion in expressive faces and not facial emotion itself. In order to remedy this potential confound, feature motion was introduced to the neutral cue, such that after the gaze shift, the face cue began to react emotionally (either beginning to smile or becoming fearful) but then returned to a baseline neutral expression prior to the appearance of the target.

Method

Participants. Participants were 41 undergraduate students (21 females and 20 males) ranging from 19 to 32 years of age (mean 22.4 years) at Texas State University.

Apparatus and stimuli. Stimulus details and apparatus were identical to Experiment 5.

Design and procedure. Participants performed a target detection task in which they were asked to press the spacebar on the computer keyboard as soon as the target appeared. Each trial began with the fixation stimulus. This was replaced after 600 ms by a face with a neutral expression and direct gaze that remained on the monitor for 600 ms. Then, on all trials, the gaze direction cue, a neutral face with averted gaze (left or right), was presented. On neutral expression trials, this image remained on the monitor for 100 ms and then changed to an intermediate facial expression (55.5% fearful on half of the neutral trials and 55.5% happy on the other half) with averted gaze for 50 ms and then back to a neutral expression with averted gaze for another 75 ms (+/−50 ms) or 375 ms (+/−50 ms). On fearful and happy expression trials, the neutral gaze cue remained on the monitor for 100 ms and was replaced with an intermediate (55%) facial expression with averted gaze for 50 ms, and then a full (100%) intensity facial expression with averted gaze for either 75 ms or 375 ms (+/−50 ms). The trial sequence ended with the appearance of a target to the left or right of the face. Trials were separated with intertrial intervals of either 500 or 1000 ms; both intervals occurred randomly and with equal frequency. Example trials are shown in Figure 3. Participant instructions were identical to those in Experiment 5.

Each experimental session was approximately 50 minutes in duration. All participants completed 640 trials that were presented in six blocks of 160 trials. Of these, 576 trials were used as data trials. The other 64 trials were catch trials, in which no target was presented. Of the 576 data trials, facial expression (fearful, happy, neutral), gaze direction (left, right), target side (left, right), and cue to target SOA (short: 175, 225, 275 ms and long: 475, 525, 575 ms) were presented in random order and equally often within the

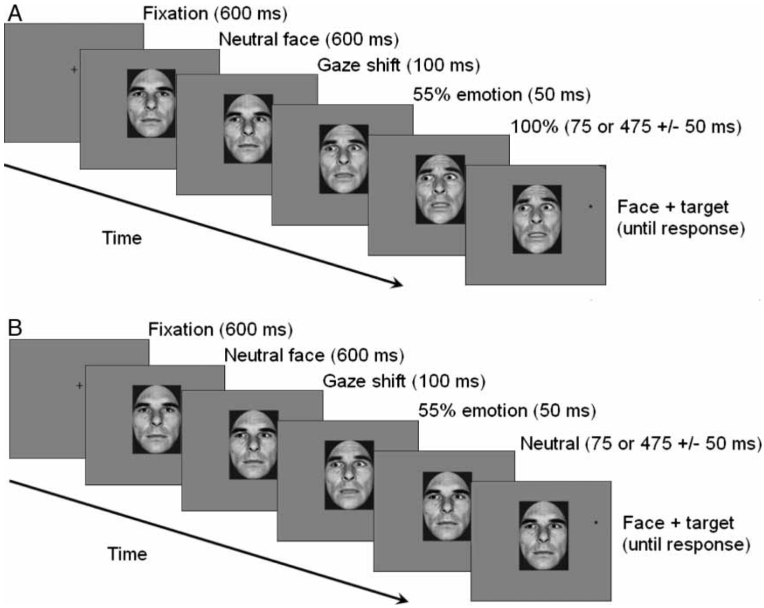

Figure 3. Schematic depiction of the sequence of events in Experiment 6 in (A) an invalidly cued expressive trial with fearful facial expressions and (B) an invalidly cued neutral trial when the face began to get fearful and then went back to neutral. (Note: Both partial fearful and happy faces were used for neutral trials.) (A) On expressive trials, the stimulus sequence was identical to emotional trials in Experiments 1–4, except that the 100% intensity facial expressions with averted gaze were presented for either 75 ms or 375 ms (+/ −50 ms) before target onset. (B) On neutral trials, each trial began with a fixation stimulus (600 ms), and then a face with a neutral expression and direct gaze for 600 ms followed by the gaze direction cue (neutral face with averted gaze). On these trials, the neutral gazing face remained on the monitor for 100 ms and was replaced with 55% intensity facial expressions with averted gaze for 50 ms, and then a neutral expression with averted gaze for 75 ms or 375 ms (+/ −50 ms) prior to target onset.

six blocks. Data reduction and analysis were identical to Experiment 5, with the exception that gender was now included as a between-subjects factor. Where applicable (i.e., where the assumption of homogeneity was violated), degrees of freedom were adjusted with Greenhouse-Geisser corrections.

Results and discussion

On average, participants made false alarms on 3.2% of the catch trials (i.e., pressed the spacebar when no target appeared). Errors occurred on 0.81% of trials, with anticipations accounting for .55% of all responses and timed out trials accounting for 0.26%. Due to the low rate of errors (less than 1% in each trial category), they were not analysed further. The results of Experiment 6 are shown in Table 6. Repeated measures analysis of variance with emotional expression (fearful, happy, neutral), SOA (short, long), and validity (validly cued, invalidly cued) as within-subject factors and gender (male, female) as a between-subjects factor revealed a main effect of validity, $F(1, 39) = 143.9$, $p < .001$, which was due to the fact that reaction times for validly cued trials (314 ms) were faster than those for invalidly cued trials (325 ms). The ANOVA revealed a main effect of SOA, $F(1, 39) = 67.6$, $p < .001$; participants were faster to detect targets at the long SOA (308 ms) than at the short SOA (331 ms). There was also a main effect of expression, $F(2, 58) = 35.9$, $p < .001$. Bonferroni-corrected post hoc pairwise comparisons revealed that participants detected the targets faster when the face was emotional (315 ms for fearful and 316 ms for happy faces) than when the face was neutral (327 ms): Fearful vs. neutral, $t(40) = -7.1$, $p < .01$; happy vs. neutral, $t(56) = -6.0$, $p < .01$. Only two effects involving gender approached significance. First, there was a marginal main effect of gender, $F(1, 39) = 3.3$, $p = .08$, reflecting the tendency for men (310 ms) to have faster overall responses relative to women (329 ms). There was also a trend for a gender by validity interaction, $F(1, 39) = 3.4$, $p = .07$, reflecting the tendency for the cueing effect (faster responses on valid trials than on invalid trials) to be slightly larger in women (14 ms) than men (10 ms), $t(38) = -1.8$, $p = .07$.

Similar to Experiment 5, the expression by validity interaction was significant, $F(2, 100) = 4.2$, $p < .05$. In addition, analysis of reaction times for Experiment 6 revealed a significant Expression × SOA interaction, $F(2, 69) = 13.2$, $p < .001$. Similar to Experiment 5, these two-way interactions were mitigated by a three-way interaction between expression, validity, and SOA, $F(2, 76) = 10.2$, $p < .01$. In order to interpret this interaction, we ran

TABLE 6
Means of the individual median reaction times (ms) for the valid and invalid gaze cueing conditions and cueing effect for fearful, happy, and neutral faces at short and long SOAs in Experiment 6

	Valid		*Invalid*		*Cueing effect*	
Facial expression	*M*	*SD*	*M*	*SD*	*M*	*SD*
Short SOA						
Fearful	323	36	336	38	13	16
Happy	325	37	335	37	10	12
Neutral	330	34	341	34	11	9
Long SOA						
Fearful	291	35	312	35	20	14
Happy	299	36	307	33	7	13
Neutral	314	37	324	40	9	13

$N = 40$ (Experiment 6); SD = standard deviation (ms).

separate ANOVAs for each SOA. The ANOVA for short SOA trials revealed separate effects for expression, $F(2, 65) = 6.8$, $p < .01$, and validity, $F(1, 39) = 82.7$, $p < .001$. Bonferroni-corrected post hoc comparisons confirmed that the main effect of expression was due to the fact that participants detected targets cued by fearful and happy faces more quickly than targets cued by neutral faces (329 and 330 ms vs. 335 ms, respectively): Fearful vs. neutral, $t(40) = -3.2$, $p < .01$; happy vs. neutral, $t(40) = -2.7$, $p < .01$. Importantly, the Expression × Validity interaction was not significant ($F < 1.0$).

The ANOVA for long SOA trials also revealed separate effects for expression, $F(2, 60) = 45.2$, $p < .001$, and validity, $F(1, 39) = 74.2$, $p < .001$. Bonferroni-corrected post hoc comparisons confirmed that the main effect of expression was due the fact that, overall, participants detected targets cued by fearful and happy faces more quickly than targets cued by neutral faces (301 and 303 ms vs. 319 ms, respectively): Fearful vs. neutral, $t(40) = -7.9$, $p < .01$; happy vs. neutral, $t(40) = -6.8$, $p < .01$. However, these effects were mitigated by a significant Expression × Validity interaction, $F(2, 77) = 15.5$, $p < .001$. Post hoc t-tests (Bonferroni-corrected) comparing the magnitude of the cueing effect (invalid minus valid trials) across the three emotions at this SOA revealed that the cueing effect was larger when the faces were fearful than when the faces were happy or neutral; fearful > happy = neutral; fearful vs. happy, $t(40) = 5.5$, $p < .01$; fearful vs. neutral, $t(40) = 4.2$, $p < .01$; happy vs. neutral, $t(40) = -0.8$, $p > .05$. The magnitude of the cueing effect for fearful faces increased from the short to the long SOA (effect of SOA on cueing effect for fearful faces, $t(40) = -2.3$, $p = .026$), although this effect was not significant after Bonferroni correction (corrected critical p-value = .05/3 = .0167). In contrast, the effect of SOA on cueing effects for happy and neutral faces did not approach significance (effect of SOA on cueing effect for happy faces, $t(40) = 1.1$, $p > .05$; for neutral faces, $t(40) = 0.6$, $p > .05$).

The results of Experiment 6 replicate those of the previous experiment and reconfirmed our prediction that gaze and expression interactions would occur if more time intervened between the face cue and the appearance of the target. However, as discussed further below, the nature of those interactions differed somewhat from those of Experiment 5. At the short SOA, the results mirrored those of all previous experiments: When a short SOA intervened between the face cue and the target, there were separate effects for facial expression and gaze cueing. The fact that emotion effects remained after introducing motion to the neutral cue strengthens our conclusion that expression and gaze do not interact at short SOAs and that the effect of expression is not solely due to the presence of feature motion.

Similar to results at the long SOA in Experiment 5 (and in contrast with results at the short SOA in Experiments 1–5), a gaze and expression interaction was observed at the longer SOA. At the long SOA, cueing to fearful gazing faces was potentiated relative to that of happy and neutral faces. This interaction was unaffected by gender, although there was an overall tendency for men to respond more quickly and for the cueing effect to be slightly larger in women, regardless of emotion.

Because stimulus motion was equivalent for all expressions in the present experiment, it is reasonable to conclude that providing more time to process the cue allowed for the integration of gaze and expression information was responsible for this interaction. Thus, the results of Experiment 6 converge with those of Experiment 5 to suggest that gaze and facial expression information are initially processed in separate, parallel streams and are integrated at later stages of processing.

The modulation of the cueing effect by expression at the long SOA was observed as an enhanced cueing effect for fearful faces relative to happy and neutral faces. This result is in keeping with our original prediction that fearful faces would serve as more effective cues than happy or neutral faces, since they could indicate the location of potential danger. These findings are inconsistent with those of Experiment 5, which suggested that expressive faces, in general, were more effective at cueing the location of a target than neutral faces at longer SOAs. This difference could be attributable to the nature of the neutral cues used in the two experiments. The absence of motion in the neutral cues in Experiment 5 may have attenuated the cueing effect for neutral faces, while potentiating it for expressive faces. It is interesting to note that this effect was only observed at the long SOA, suggesting that motion effects also take time to be integrated with gaze information to influence spatial orienting. The introduction of motion to the neutral cue in Experiment 6 would have eliminated this advantage, giving rise to effects that were sensitive to the actual integration of expression and gaze, namely, a cueing advantage for fearful faces at longer SOAs that was not present for either happy or neutral cues. At any rate, these results converge with those of Experiment 5 to suggest that the integration of these two dimensions requires time.

GENERAL DISCUSSION

Changeable aspects of faces provide a wealth of information about the motivations and intentions of other people, and the ability to extract and accurately decode this information is a critical component of social cognition. Facial expressions and the direction of gaze are two such changeable aspects that provide us with powerful cues about the internal states of others. Given ample evidence of behavioural and neuroanatomical interactions between facial expression and gaze processing, it is surprising that studies examining whether emotional expression modulates reflexive orienting to gaze direction have yielded such qualified results. We conducted a series of experiments to examine the effect of dynamic displays of gaze and emotion on this phenomenon. Specifically, the experiments examined attentional orienting to gaze in expressive faces after controlling for gaze discriminability across different emotions and investigated the role of time in the modulation of the cueing effect to expressive faces. If gaze and expression require time to be integrated, then interactions between these dimensions should be seen only at longer SOAs.

Across all experiments, we demonstrated two separate effects at short SOAs using different facial expressions and task demands. First, there was a main effect of cue validity: When gaze validly cued the location of the target, participants were faster to detect and/or identify the target. As mentioned previously, these results replicate the cueing effect that has been reported in many studies of reflexive orienting (e.g., Driver et al., 1999; Friesen & Kingstone, 1998; Hietanen & Leppänen, 2003). Second, there was a main effect of expression such that when the face was emotional, participants detected and/or identified the target more quickly regardless of where gaze was directed. The particular emotion portrayed by the face did not modulate the magnitude of the cueing effect, nor did the particular task demands; if the facial cue was emotional, participants were faster to detect and/or identify the target regardless of where it appeared or how it was cued. Although this main effect of expression has not been seen in other gaze cueing studies, it is consistent with research indicating that facial expressions are processed rapidly and automatically (e.g., Batty & Taylor, 2003) and, under some circumstances, increase arousal (e.g., Critchley et al., 2004). Through this mechanism, expressive faces may act in a directionally nonspecific manner, facilitating target detection and identification regardless of target location. No interactions between cue validity and facial expression were observed. Together, these results suggest that at short SOAs, the processing of emotional expression and gaze direction in the facial cue are not interacting to affect detection or identification of the targets.

Experiment 4 was designed to rule out the possibility that biological motion alone was responsible for the expression effects observed in the first three experiments, since emotional faces moved and neutral faces did not. As in the first three experiments, we observed separate main effects of gaze cueing and facial emotion/motion with no interaction between the two factors. However, relative to Experiment 1, which used an identical design with the same stimuli (except that faces were presented upright), the emotion effect in Experiment 4 was attenuated. These results are significant for two reasons. First, the biological motion inherent in dynamic facial emotional displays is a powerful factor in the facilitating the detection of targets and may be one of the reasons why a change in facial emotion in real life social situations is such a powerful cue. Second, these results suggest that although biological motion is an important facilitator in emotional processing, it is not wholly responsible for the emotion effects observed in the first three experiments. In other words, the fact that the expressive faces were moving was not the only reason why target detection was facilitated; the emotion portrayed in the face was also important.

Experiment 5 and 6, which included both short and long SOAs, were motivated by the possibility that gaze and expression interactions would occur if individuals were allowed more time to process the face cue before the appearance of the target. In Experiments 5, we replicated the finding of separate effects for facial expression and gaze cueing at the short SOA, whereas a gaze and expression interaction was observed at the longer SOA. The modulation of the cueing effect by emotion was an enhancement of the reaction time advantage for detecting targets validly cued by emotional faces (both fearful and happy) relative to neutral faces, but only at longer SOAs. The cueing effect for emotional faces was enhanced at long SOAs relative to the short SOAs, whereas it was attenuated for neutral faces. In Experiment 6, which equated neutral and expressive cues for motion, separate effects for gaze and expression at the short SOA were replicated, lending further credence to the notion that stimulus motion per se was not responsible for the expression effects observed in Experiments 1–3. However, at long SOAs, only cueing to fearful faces was potentiated; cueing to neutral and happy faces did not change as a function of cue-processing time.

As mentioned previously, the differential cueing effects across Experiments 5 and 6 are most likely due to differences between the neutral cues. In Experiment 5, the presentation of static (neutral) gazing faces in the context of moving (expressive) gazing faces may have signalled that the upcoming target was not potentially significant. Perceived target significance on trials with emotionally expressive faces may have elicited faster attentional deployment to the gazed-at location, regardless of the emotion expressed in the face and slowed attentional deployment to the location cued by the neutral gazing faces. It is noteworthy that this confound of motion with emotion appeared to affect results only at the long SOA, suggesting that general facial motion also requires time to become integrated with facial expression and that cueing effects at longer SOAs might be particularly susceptible to top-down influences on attentional processing, such as context. This idea can be further tested in future studies by explicitly varying the significance of the targets. An alternative explanation for this finding could have been individual differences across the two samples. For example, trait anxiety (e.g. Fox et al., 2007) and fearfulness (e.g., Tipples, 2006) have been shown to modulate the cueing effect to emotional faces. Furthermore, recent evidence suggests that the cueing effect may also be sensitive to other individual differences such as self esteem (Wilkowski, Robinson, & Friesen, in press). It is possible that there were systematic differences in individual personality traits like anxiety or self-esteem in the samples used in Experiments 5 and 6. Although the role of individual differences in the cueing effects elicited to different emotional expressions is beyond the scope of the current study, future research investigating this issue might help to further understand the inconsistencies observed in the gaze cueing literature.

The results across the experiments in this study were quite consistent. One possible explanation for why our results were more consistent than those previously reported in the literature is the use of dynamic stimuli in the present experiment where the gaze shift preceded the onset of facial expression. Many experiments have either used static stimulus displays (e.g., Hietanen & Leppänen, 2003, Exps. 1–4; Holmes et al., 2006; Hori et al., 2005), or stimulus sequences with abrupt changes in facial expressions that did not give the appearance of natural motion (Tipples, 2006). One problem with stimulus displays such as these is that it is impossible to rule out the possibility that low-level stimulus parameters like eye aperture are responsible for any emotional modulation of cueing effects, especially those reported for fearful faces (Holmes et al., 2006; Tipples, 2006). Namely, that it is easier to resolve gaze in expressions that have widened eyes and harder to resolve gaze in expressions with narrowed eyes (see Tipples, 2005, for a discussion of this issue). By using a stimulus display where the gaze shift always occurred in a neutral face before a change in facial expression, we were able to rule out the possibility that preexisting differences in eye aperture in emotional faces (and the discriminability of gaze direction) might be responsible for any observed gaze and expression interactions.

Other studies presented static emotional faces and varied gaze such that gaze appeared to be dynamic while emotion remained constant (Hietanen & Leppänen, 2003, Exps. 5 and 6; Mathews et al., 2003). This stimulus sequence is problematic for two reasons. First, a processing advantage for gaze over emotion may have been created, since the gaze cue was dynamic but expression was not. Second, this stimulus sequence lacks ecological validity. If an individual already expresses an emotion prior to the gaze shift, then the relationship between the facial expression and the gazed-at object is less clear. Putman et al. (2006) addressed the first concern by presenting both emotion and gaze cues dynamically, but since both dimensions changed together, their design cannot rule out the possibility that lower level stimulus-based factors were responsible for their findings (i.e., differences in the ability to resolve gaze direction in happy vs. fearful faces). To our knowledge, the present study is the first to examine reflexive orienting to emotionally expressive gazing faces while controlling for gaze discriminability in expressive faces, and the consistent results may be indicative of the importance of ruling out stimulus-driven explanations for modulations of social phenomena such as reflexive orienting to gaze direction.

We had speculated that as signals of potential threat, fearful faces might engender faster orienting to gaze direction since the ability to rapidly shift attention to the location of a potential threat should confer a considerable survival advantage. Consistent with this notion and the findings of other research (e.g., Putman et al., 2006; Tipples, 2006), the results of Experiments 5 and 6 support enhanced orienting in response to fearful faces but unlike the other research, only when there is sufficient time to integrate gaze and expression in the face cue. However, it is important to note that results were not entirely consistent across Experiments 5 and 6. Specifically, where cueing to emotional faces appeared to increase at the longer SOA for both fearful and happy faces and decrease for neutral faces in Experiment 5, cueing to fearful faces increased from the short to the long SOA, whereas cueing to happy and neutral faces remained equal in Experiment 6. An important consideration that may have some bearing on this issue of consistency is that while our design used fairly ecologically valid cues, it did not use ecologically valid targets. In other words, the targets used in this study (asterisks and letters) were symbols devoid of emotional meaning. However, when individuals gaze at and react emotionally to events in their environment, there is usually congruence between the emotion expressed and the target of that emotion. Future studies should reexamine this issue using the expressive facial cues employed here with congruent target stimuli (as in Fichtentholtz et al., 2007).

Previous studies have used a variety of SOAs to examine the effect of facial expression on reflexive orienting to gaze direction. For example, some studies have used both short and long SOAs (Hietanen & Leppänen, 2003; Tipples, 2006), whereas other studies have used only short SOAs of 200 ms or less (e.g., Hori et al., 2005; Putman et al., 2006) or long SOAs of 500 ms or longer (e.g., Bayliss et al., 2007; Mathews et al., 2003), and still others have used intermediate SOAs between 250 and 400 ms (e.g., Holmes et al., 2006; Mathews et al., 2003). This variability in SOA, coupled with differences in stimulus displays, make the results from the various studies difficult to integrate. Our results suggest that choice of SOA is a critical consideration in experiments of reflexive orienting using gazing emotional faces. The finding of separate behavioural effects for facial expression and gaze direction at short SOAs and gaze and expression interactions at longer SOAs converges with neuroscientific evidence that gaze and facial expression processing initially occur in separate, parallel streams (Pourtois et al., 2004) and do not begin to interact until approximately 300 ms (Fichtenholtz et al., 2007; Klucharev & Sams, 2004).

In summary, using dynamic facial displays that controlled for local changes in eye aperture during the gaze shift, our study demonstrates the first consistent evidence that facial expression and gaze information have separate effects on target detection and identification in Posner-style cueing tasks when a short interval intervenes between the gaze shift and the appearance of the target. When a face is emotional, participants detect and identify targets more quickly than when the face is neutral, regardless of where the eyes are looking. This effect is independent of reflexive orienting to gaze direction, where participants are faster to detect and identify targets that are validly cued by eye gaze. If individuals have time to process the cue more fully, however, the two kinds of information interact to influence visual orienting. The present findings advance an understanding of how humans process multiple, overlapping dynamic features in faces by showing that gaze and expression information are initially processed independently and become integrated during later stages of processing. These results have implications for psychological and neurobiological models of face processing, which have traditionally considered emotion and gaze together as part of a dynamic featural processing stream, and suggest that a complete account of these processes must include the time-dependent nature of their interactive effects on social cognitive functions such as joint attention.

REFERENCES

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

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

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.

Adolphs, R., Tranel, D., Koenigs, M., & Damasio, A. R. (2005). Preferring one taste over another without recognizing either. *Nature Neuroscience*, *8*(7), 860–861.

Allison, T., Puce, A., & McCarthy, G. (2000). Social perception from visual cues: Role of the STS region. *Trends in Cognitive Science*, *4*(7), 267–278.

Ambadar, Z., Schooler, J. W., & Cohn, J. F. (2005). Deciphering the enigmatic face: The importance of facial dynamics in interpreting subtle facial expressions. *Psychological Science*, *16*(5), 403–410.

Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind*. Cambridge, MA: MIT Press.

Bartlett, J. C., & Searcy, J. (1993). Inversion and configuration of faces. *Cognitive Psychology*, *25*(3), 281–316.

Batty, M., & Taylor, M. J. (2003). Early processing of the six basic facial emotional expressions. *Cognitive Brain Research*, *17*(3), 613–620.

Bayliss, A. P., di Pellegrino, G., & Tipper, S. P. (2005). Sex differences in eye-gaze and symbolic cueing of attention. *Quarterly Journal of Experimental Psychology*, *58A*(4), 631–650.

Bayliss, A. P., Frischen, A., Fenske, M. J., & Tipper, S. P. (2007). Affective evaluations of objects are influenced by observed gaze direction and emotional expression. *Cognition*, *104*(3), 644–653.

Campbell, R., Lawrence, K., Mandy, W., Mitra, C., Jeyakuma, L., & Skuse, D. (2006). Meanings in motion and faces: Developmental associations between the processing of intention from geometrical animations and gaze detection accuracy. *Development and Psychopathology*, *18*(1), 99–118.

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

Critchley, H. D., Rotshteina, P., Nagaid, Y., O'Doherty, J., Mathias, C. J., & Dolan, R. J. (2004). Activity in the human brain predicting differential heart rate responses to emotional facial expressions. *NeuroImage*, *24*(3), 751–762.

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition*, *6*(5), 509–540.

Ekman, P., & Friesen, W. (1976). *Pictures of facial affect*. 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.

Engell, A. D., & Haxby, J. V. (2007). Facial expression and gaze-direction in human superior temporal sulcus. *Neuropsychologia*, *45*, 3234–3241.

Fichtenholtz, H. M., Hopfinger, J. B., Graham, R., Detwiler, J. M., & LaBar, K. S. (2007). Happy and fearful emotion in cues and targets modulate event-related potential indices of gaze-directed attentional orienting. *Social, Cognitive, and Affective Neuroscience*, *2*(4), 323–333.

Fox, E., Mathews, A., Calder, A., & Yiend, J. (2007). Anxiety and sensitivity to gaze direction in emotionally expressive faces. *Emotion*, *7*(3), 478–486.

Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology*, *130*(4), 681–700.

Fox, E., Russo, R., & Dutton, K. (2002). Attentional bias for threat: Evidence for delayed disengagement from emotional faces. *Cognition and Emotion*, *16*, 355–379.

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin and Review*, *5*(3), 490–495.

Friesen, C. K., Moore, C., & Kingstone, A. (2005). Does gaze direction really trigger a reflexive shift of spatial attention? *Brain and Cognition*, *57*(1), 66–69.

Frischen, A., Bayliss, A. P., & Tipper, S. P. (2007). Gaze cueing of attention: Visual attention, social cognition, and individual differences. *Psychological Bulletin*, *133*(4), 694–724.

Frith, U., & Frith, C. D. (2003). Development and neurophysiology of mentalizing. *Philosophical Transactions of the Royal Society of London, Series B: Biological Sciences*, *358*(1431), 459–473.

Ganel, T., Goshen-Gottstein, Y., & Goodale, M. (2005). Interactions between the processing of gaze direction and facial expression. *Vision Research*, *49*(9), 1911–1200.

Graham, R., & LaBar, K. (2007). Garner interference reveals dependencies between emotional expression and gaze in face perception. *Emotion*, *7*(2), 296–313.

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*(3), 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*(6), 223–233.

Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2002). Human neural systems for face recognition and social communication. *Biological Psychiatry*, *51*(1), 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*(6), 1228–1243.

Hoffman, E. A., & Haxby, J. V. (2000). Distinct representations of eye gaze and identity in the distributed human neural system for face perception. *Nature Neuroscience*, *3*(1), 80–84.

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., & Nishijo, H. (2005). Effects of facial expression on shared attention mechanisms. *Physiology and Behavior*, *84*(3), 397–405.

Jenkins, J., & Langton, S. R. H. (2003). Configural processing in the perception of eye-gaze direction. *Perception*, *32*, 1181–1188.

Jones, B. C., DeBruine, L. M., Little, A. C., Conway, C. A., & Feinberg, D. R. (2006). Integrating gaze direction and expression in preferences for attractive faces. *Psychological Science*, *17*(7), 588–591.

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.

Kirita, T., & Endo, M. (1995). Happy face advantage in recognizing facial expressions. *Acta Psychologica*, *89*(2), 149–163.

Kirouac, G., & Dore, F. Y. (1983). Accuracy and latency of judgment of facial expressions of emotions. *Perceptual and Motor Skills*, *57*(3), 683–686.

Klucharev, V., & Sams, M. (2004). Interaction of gaze direction and facial expressions processing: ERP study. *Neuroreport*, *15*(4), 621–626.

Koster, E. H. W., Crombez, G., van Damme, S., Verschuere, B., & de Houwer, J. (2004). Does imminent threat capture and hold attention? *Emotion*, *4*(3), 312–317.

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

Langton, S. R. H., & Bruce, V. (1999). Reflexive visual orienting in response to the social attention of others. *Visual Cognition*, *6*(5), 541–567.

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

McKelvie, S. J. (1995). Emotional expression in upside-down faces: Evidence for configurational and componential processing. *British Journal of Social Psychology*, *34*(3), 325–334.

Montagne, B., Kessels, R. P. C., Frigerio, E., de Haan, E. H. F., & Perrett, D. I. (2005). Sex differences in the perception of affective facial expressions: Do men really lack emotional sensitivity? *Cognitive Processing*, *6*(2), 136–141.

Pelphrey, K. A., 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., Viola, R. J., & McCarthy, G. (2004). When strangers pass: Processing of mutual and averted social gaze in the superior temporal sulcus. *American Psychological Society*, *15*(9), 598–603.

Pourtois, G., Sander, D., Andres, M., Grandjean, D., Reveret, L., Oliver, 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.

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.

Sander, D., Grandjean, D., Kaiser, S., Wehrle, T., & Scherer, K. R. (2006). Interaction effects of perceived gaze direction and dynamic facial expression: Evidence for appraisal theories of emotion. *European Journal of Cognitive Psychology*, *19*(3), 470–480.

Tipples, J. (2005). Orienting to eye gaze and face processing. *Journal of Experimental Psychology: Human Perception and Performance*, *31*(5), 843–856.

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

Valentine, T. (1988). Upside-down faces: A review of the effect of inversion upon face recognition. *British Journal of Psychology*, *79*(4), 471–491.

Van Honk, J., Peper, J. S., & Schutter, D. J. L. G. (2005). Testosterone reduces unconscious fear but not consciously experienced anxiety: Implications for the disorders of fear and anxiety. *Biological Psychiatry*, *58*(3), 218–225.

Vuilleumier, P. (2005). Staring fear in the face. *Nature*, *433*, 22–23.

Vuilleumier, P., & Pourtois, G. (2007). Distributed and interactive brain mechanisms during emotion face perception: Evidence from functional neuroimaging. *Neuropychologia*, *45*(1), 174–194.

Wicker, B., Perrett, D. I., Baron-Cohen, S., & Decety, J. (2003). Being the target of another's emotion: A PET study. *Neuropsychologia*, *41*(2), 139–146.

Wilkowski, B.M., Robinson, M. D., & Friesen, C. K. (in press). Gaze-triggered orienting as a tool of the belongingness self-regulation system. *Psychological Science*.

Yoshikawa, S., & Sato, W. (2008). Dynamic facial expressions of emotion induce representational momentum. *Cognitive, Affective, and Behavioral Neuroscience*, *8*, 25–31.

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