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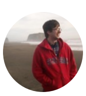

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# Masked Fearful Faces Modulate the Orienting of Covert Spatial Attention

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Dot probe studies indicate that masked fearful faces modulate spatial attention. However, without a baseline to compare congruent and incongruent reaction times, it is unclear which aspect(s) of attention (orienting or disengagement) is affected. Additionally, backward masking studies commonly use a neutral face as the mask stimulus. This method results in greater perceptual inconsistencies for fearful as opposed to neutral faces. Therefore, it is currently unclear whether the effects of backward masked fearful faces are due to the fearful nature of the face or perceptual inconsistencies. Equally unclear, is whether this spatial attention effect is due to orienting or disengagement. Two modified dot probe experiments with neutral (closed mouth in Experiment 1) and smiling (open mouth in Experiment 2) masks were used to determine the role of perceptual inconsistencies in mediating the spatial attention effects elicited by masked fearful faces. The results indicate that masked fearful faces modulate the orienting of spatial attention, and it appears that this effect is due to the fearful nature of the face rather than perceptual inconsistencies between the initial faces and masks.

*Keywords:* spatial attention, backward masking, faces, fear, and emotion

Spatial attention is the direction of cognitive resources and/or the amplification of cognitive processing at specific retinotopic areas of visual space. This can be achieved by overt movements of the head or eyes to bring the stimulus of interest into the fovea or by covert, internal, mechanisms that increase processing in one retinotopic location and inhibit activity in another (i.e., manipulating the signal to noise ratio; Posner, 1980). Covert spatial attention can be driven by either endogenous or exogenous factors (Posner, 1980). Emotional, particularly threatening, stimuli appear to be salient exogenous cues, which elicit an observer's attention. Indeed, it has been suggested that attending to threatening environmental stimuli is evolutionarily adaptive and increases an organism's likelihood of survival (LeDoux, 1996).

LeDoux claims that fear-eliciting stimuli reach the fear processing region of the brain known as the amygdala through two routes. There is a subcortical route for rapid relatively nondiscriminative responses to fear-eliciting stimuli, which contrasts with a cortical based route for slow discriminative responses. The subcortical route is vital for immediate behavioral and physiological fear responses, while the cortical route helps determine with greater accuracy if the initial response should be sustained or terminated. Consistent with a subcortical mechanism for fear processing, research has indicated that nonconsciously processed backward masked threatening faces modulate spatial attention (Fox, 2002; Mogg & Bradley, 1999). However, the existence of a subcortical route to the amygdala is not universally accepted and neuroimaging research has produced both supporting (Jiang & He, 2006; Liddell et al., 2005; Morris, DeGelder, Weiskrantz, & Dolan, 2001; Pasley, Mayes, & Schultz, 2004) and conflicting (Pessoa, Japee, Sturman, & Ungerleider, 2006) evidence. The current study is intended to further explore the properties of spatial attention that are influenced by backward masked fear-eliciting stimuli.

The dot probe task is one method in which exogenously elicited covert spatial attention to threatening stimuli can be measured (MacLeod & Mathews, 1988). A typical threat-related dot probe task begins with a fixation cue presented on the center of the computer screen. The fixation cue is followed by two visual images simultaneously presented to each visual field where one image is threat-related and the other is neutral. These images are then followed by a target dot appearing in one visual field or the other. Congruent trials (threatening image is spatially congruent with the target) produce faster reaction times than incongruent trials, reflecting participants' allocation of spatial attention to the threat location. Faster responses for congruent trials have been found for fearful faces (Fox, 2002), angry faces (Mogg & Bradley, 1999, 2002), emotional words (Hunt, Keogh, & French, 2006; MacLeod & Mathews, 1988), and other threatening pictorial stimuli such as weapons or mutilations (Koster, Crombez, Verschuere, & De Houwer, 2004) in individuals with high levels of anxiety. Additionally, congruency effects have been reported for fearful faces (Pourtois, Grandjean, Sander, & Vuilleumier, 2004; Pourtois, Schwartz, Seghier, Lazeyras, & Vuilleumier, 2006), conditioned faces (Armony & Dolan, 2002), and conditioned snakes and spiders (Beaver, Mogg, & Bradley, 2005) in studies not selecting for high levels of anxiety.

Directing attention to a new stimulus is thought to be comprised of three components: (a) The initial orienting or shifting of atten-

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tion, (b) engaging or focusing attention onto a stimulus, and (c) disengaging or the release of attention from a stimulus (Posner, 1980). Reaction time differences between fear-eliciting congruent and fear-eliciting incongruent trial types can result from speeded orienting to and engagement of threat stimuli, delayed disengagement from threat stimuli, or a combination of these factors (Koster et al., 2004). Based on LeDoux's theory, it would be expected that *unmasked* fear stimuli (with relatively long stimulus durations) receive elaborate cortical processing by the time attention is sampled and therefore are more likely to be involved in sustaining attention to fear stimuli (i.e., delayed disengagement). Neutral-Neutral and no-cue baseline conditions have, respectively, been used in dot probe and visual cueing studies to determine which aspect(s) of attention is influenced by unmasked threat. Disengagement, but not orienting, effects have been found with the relatively long stimulus duration of 500 ms (Koster et al., 2004; Salemink, van den Hout, & Kindt, 2007; Yiend & Mathews, 2001). Studies sampling attention between 100 and 300 ms post stimulus onset have produced mixed results on orienting and disengagement where in one study with highly anxious participants both effects were reported (Koster, Crombez, Verschuere, Van Damme, Wiersema, 2006), but in other studies, with anxious (Fox, Russo, Bowles, & Dutton, 2001) and general (Cooper & Langton, 2006; Fox et al., 2001, Experiment 1) participants, only disengagement effects have been found.

Dot probe studies using backward masking methods provide the opportunity to limit the amount of processing that fear-eliciting stimuli receive. Indeed, several studies provide evidence that briefly presented backward masked faces are processed nonconsciously (Liddell et al., 2005; Morris, Ohman, & Dolan, 1999; Whalen et al., 1998, but see Szczepanowski & Pessoa, 2007, for alternative evidence). Studies using backward masked threat-related (fearful or angry) face stimuli in the dot probe task have found that these stimuli facilitate spatial attention in individuals with high levels of social (Mogg & Bradley, 2002) or trait anxiety (Fox, 2002; Mogg & Bradley, 1999). However, it is unclear what aspect(s) of attention is affected by *masked* fearful face stimuli as the aforementioned studies (Fox, 2002; Mogg & Bradley, 1999, 2002) have only compared congruent and incongruent trial types.

We attempt to address this issue by including Neutral-Neutral baseline conditions to assess whether any observed attention effects are due to speeded orienting or delayed disengagement. If congruent trials are faster than the Neutral-Neutral trials, this indicates the orienting of attention is influenced by masked fearful faces. If incongruent trials are slower than Neutral-Neutral trials, this suggests that delayed disengagement is affected. As in previous studies (Liddell et al., 2005; Morris et al., 1999; Whalen et al., 1998), we used a neutral face to mask the initial neutral and fearful faces in Experiment 1. However, this leads to a larger change in the mouth area for fearful faces (open to closed mouth) than neutral faces (closed to closed). Therefore, it is unclear whether an attention effect would be due to fearful facial expressions or perceptual inconsistencies. Experiment 2 is intended to address this issue by using a smiling (open mouth) mask. In Experiment 2, there are greater changes in the mouth area for neutral to smiling (closed to open) than fear to smiling trials (open to open). If there is an attention effect due to the fearful nature of the masked faces, then the results from Experiments 1 and 2 should be identical. On the other hand, if the attention effect is due to perceptual inconsistencies then the results for Experiments 1 and 2 should be the opposite of each other. That is, in Experiment 1 responses to fearful faces will have greater perceptual inconsistencies with the neutral masks and elicit faster responses than neutral faces, whereas in Experiment 2 responses to neutral faces will have greater perceptual inconsistencies with the smiling masks and elicit faster responses than fearful faces.

## Experiment 1

In Experiment 1 we conducted a masked fearful face dot probe detection task including not only congruent and incongruent trial types, but also Neutral-Neutral and Fearful-Fearful trial types to test the hypotheses that masked fearful faces will modulate spatial attention. Therefore, reaction times to congruent trials should be faster than incongruent trials. The other aim of Experiment 1 was to assess which aspect(s) of spatial attention (orienting and/or disengagement) is modulated by masked fearful faces.

### *Method*

*Participants.* Thirty (18 female, 12 male) introductory psychology students from Southern Illinois University Carbondale participated in Experiment 1 for partial course credit. Participants reported their handedness. Three were left-handed, one was ambidextrous, and 26 were right-handed. Participants were screened for normal or corrected to normal vision. Participants were provided with informed consent and treated according to the guidelines of the Institutional Review Board.

*Stimuli.* Four (two male and two female) gray scale facial identities of fearful and neutral 3-D faces from a standardized facial collection (Gur et al., 2002) were used for the initial faces. A fifth neutral female face from this database was used as the mask. Additionally, phase-scrambled Fourier faces were used in this study as control stimuli. The Fourier faces were constructed in MatLab using a method similar to that outlined in Sadr and Sinha (2004). For the Fourier transform the phase dimension is extracted from the face stimuli. This phase information is then scrambled and recombined with the unscrambled magnitude or amplitude information. The resulting phase-scrambled Fourier face maintains the overall phase distribution and power spectrum of the original face stimulus without the concurrent representation of a face.

A backward masking procedure was used to present neutral, fearful, and Fourier face stimuli. This procedure consisted of the initial stimulus (described below) being presented for 33 ms and immediately replaced by a neutral stimulus for 100 ms. Masks were offset by 1° of visual angle on the vertical Y-axis to reduce apparent motion of the facial features (Liddell et al., 2005). Horizontal shifts in the X-axis were not used in order to prevent biasing participants' attention toward one side of the screen or the other.

*Procedure.* Stimuli were presented on a 60 Hz 16" Dell computer monitor. Each trial started with a white fixation cue (+) centered on a black background for 1000 ms. For face trials, two face stimuli were simultaneously presented (33 ms) to the left and right of fixation. Facial stimuli subtended approximately $5 \times 7°$ of visual angle and were separated by 14° of visual angle. The initial neutral and fearful faces were instantly masked with a neutral face (100 ms). Fourier scrambled faces had Fourier masks. Immediately afterward, a target dot was presented in the location of either the left or the right face. For Fourier/control trials, the same procedure was followed with the Fourier stimuli in place of the faces. The participants' task was to identify the location of the target dot as quickly as possible by using an Electrical Geodesics Inc response pad. All subjects used their right index finger to indicate the target occurred on the left side of the screen and right middle finger to indicate the target occurred on the right side of the screen. The target dot remained on the screen until the participant responded. In addition, the fixation cue remained in the center of the screen throughout the entirety of each trial and participants were instructed to always fixate on this cue (see Figure 1a for a visual schematic). The study consisted of five blocks, each of which consisted of 100 trials resulting in a total of 500 trials. Participants' were provided with feedback of their average reaction time after each block in order to elicit fast responses and provide task motivation.

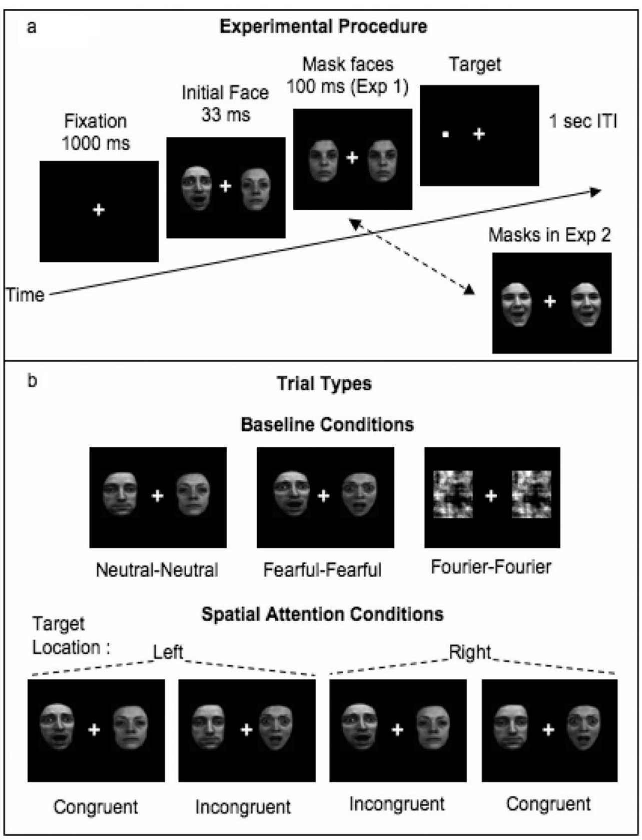


*Figure 1.* (a) During the dot probe task a fixation cue appears in the center of the screen for 1000 ms and is immediately followed by two faces presented for 33 ms. The faces are then masked with neutral faces in Experiment 1 or open mouth smiling faces in Experiment 2 for 100 ms. The target dot then appears on the right or left side of the screen. Depicted is an example of a congruent trial type. (b) There are five different masked face trial types. These trials consist of Neutral-Neutral, Fearful-Fearful, Fourier-Fourier face baseline conditions devoid of attentional bias in addition to congruent and incongruent spatial attention conditions. Trials are congruent when the fearful face is on the same side of the screen as the target dot and are incongruent when the fearful face is on the opposite side of the target dot. Stimulus faces reprinted with permission of Ruben C. Gur, copyright by the Trustees of the University of Pennsylvania.

There are five different trial types (congruent, incongruent, Neutral-Neutral, Fearful-Fearful, and Fourier-Fourier) in the experiment, which occurred randomly throughout each block (see Figure 1b). Trials were weighted so that there were approximately 142 congruent and 142 incongruent trials counterbalanced for visual field in addition to 71 trials of the Neutral-Neutral, Fearful-Fearful, and Fourier-Fourier trial types. Trials in which the initial faces are both fearful (Fearful-Fearful) or both neutral (Neutral-Neutral) are considered baseline conditions for reaction time independent of an attentional bias to one face over the other. These baseline conditions are conceptually identical to the "divided attention" conditions from Armony and Dolan (2002). These trial types differ in overall fear processing. Therefore, both Neutral-Neutral and Fearful-Fearful trial types were used. The Fourier-Fourier condition is also considered to be a baseline condition independent of attentional bias. Directed spatial attention trials consist of one fearful and one neutral face. Directed spatial attention trials were half congruent (target dot is presented on the same side of the screen as the fearful face) and half incongruent (target dot is presented on the same side as the neutral face with the fearful face on the opposite side).

## *Results*

A $2 \times 2$ repeated measures analysis of variance (ANOVA) was conducted to assess the effects of visual field (left vs. right) and congruency (congruent vs. incongruent) on participants' number of incorrect responses during directed attention trials. A main effect of congruency ($F(1, 29) = 8.40$, $p < .01$, $\eta_p^2 = .23$) was found where congruent trials had fewer incorrect responses ($M = 3.83$) than incongruent trials ($M = 5.43$). There was not a main effect of visual field, $F(1, 29) < 1$, $\eta_p^2 < .01$. Nor was there a significant interaction between visual field and congruency, $F(1, 29) < 1$, $\eta_p^2 < .01$. These results indicate that, during directed attention trials, targets following fearful faces are correctly identified more often than targets following neutral faces.

Only data from correct responses were included in the analysis of reaction time data. This resulted in 2.9% of the data being discarded for incorrect responses. Trials with reaction times less than 100 ms or more than 750 ms were discarded to respectively eliminate premature and delayed responses not associated with the participant's initial allocation of attention. This accounted for an additional .6% of the data lost. Therefore, data analysis was performed on 96.5% of the data.

A one-way repeated measures ANOVA assessing trial-type (congruent vs. incongruent vs. Fearful-Fearful vs. Neutral-Neutral vs. Fourier-Fourier) was conducted on participants' reaction time data. There was a significant effect of trial-type, $F(4, 116) = 8.38$, $p < .001$, $\eta_p^2 = .22$). All displayed $p$ values for follow up $t$ tests were adjusted using the Bonferroni method (i.e., the original $p$ value was multiplied by the number of comparisons [10] and this adjusted $p$ value must be below $\alpha$ at .05 to be considered significant). Post hoc analyses revealed that reaction times for congruent trials ($M = 323.80$ ms) were faster than all other trial types: incongruent ($M = 332.75$ ms, $t(29) = -4.6$, $p = .001$, $\eta_p^2 = .42$), Neutral-Neutral ($M = 329.30$ ms, $t(29) = -3.08$, $p < .05$, $\eta_p^2 = .25$), Fearful-Fearful ($M = 330.02$ ms, $t(29) = -3.44$, $p < .05$,

$\eta_p^2 = .29$), and Fourier-Fourier ($M = 337.54$ ms, $t(29) = -4.67$, $p = .001$, $\eta_p^2 = .43$). The aforementioned difference between congruent and Neutral-Neutral trial types suggests that masked fearful faces modulate the orienting of attention. Disengagement effects were assessed by comparing the means for incongruent and Neutral-Neutral trial types, which were not significantly different from each other, $t(29) = 2.01$, $p = .536$, $\eta_p^2 = .12$, possibly due to a lack of power. However, even if there is an effect of disengagement that we were unable to detect, the disengagement effect size is smaller than that of orienting. All comparisons between Fearful-Fearful, Neutral-Neutral, Fourier-Fourier, and Incongruent trial types were not significant. Attention-related differences between trial types are presented in Table 1.

Previous research has found a left visual field bias for congruency effects to masked threatening faces (Fox, 2002; Mogg & Bradley, 1999, 2002). Therefore, a 2 visual field (left vs. right) × 2 congruency (congruent vs. incongruent) repeated measures ANOVA was conducted to assess the effects of visual field and congruency on participants' reaction times. A main effect for congruency was found where reaction times to congruent trials ($M = 323.91$ ms) were faster than incongruent ($M = 333.96$ ms) trials, $F(1, 29) = 30.78$, $p < .001$, $\eta_p^2 = .52$. The main effect of visual field was not significant, $F(1, 29) = 2.14$, $p < .05$, $\eta_p^2 = .07$. Additionally, no interaction effects between visual field and congruency were observed, $F(1, 29) = 1.69$, $p > .05$, $\eta_p^2 = .06$.

### *Discussion of the Results from Experiment 1*

Consistent with previous research (Fox, 2002; Mogg & Bradley, 1999, 2002), we found that congruent trial types resulted in faster reaction times than incongruent trial types suggesting that masked fearful faces facilitate spatial attention. This enhancement of spatial attention did not seem to be influenced by visual field. By comparing congruent and incongruent trials to the Neutral-Neutral baseline condition, we were able to assess which aspects of attention were modulated by masked fearful faces. Congruent trials had faster response times compared to Neutral-Neutral trial types indicating masked fearful faces enhance the orienting of attention to the location of threat. We did not find reaction time differences between incongruent and Neutral-Neutral conditions suggesting that participants did not have difficulties disengaging from the location of incongruent fearful faces. Finally, the results of Experiment 1 suggest that this spatial attention effect cannot be attributed to an overall arousal response to fear stimuli. If an arousal response was mediating this effect, we would expect to find comparable reaction times for congruent and Fearful-Fearful trial types. In contrast to an overall arousal response, the data from Experiment 1 appear to be location specific and consistent with the fear-induced orienting of spatial attention explanation.

Congruent trial types resulted in more accurate target detection than incongruent trial types. This improvement in congruent target detection may represent enhanced processing at the location of threat. This is consistent with the recent finding that visual discrimination at a location immediately following a fearful face is improved (Phelps, Ling, & Carrasco, 2006). This facilitation of visual perception may be attributed to the selective amplification of cognitive processing associated with the modulation of spatial attention.

## Experiment 2

In Experiment 1 we attempted to reduce apparent motion by offsetting the neutral mask by 1° of visual angle. However, there was still the issue of perceptual inconsistencies in the mouth area. In Experiment 1 and other backward masking studies (Liddell et al., 2005; Morris et al., 1999; Whalen et al., 1998), the initial faces were masked with neutral faces. However, this leads to a larger change in the mouth area for fearful faces (open to closed mouth) than neutral faces (closed to closed). Therefore, it is unclear whether the attention effect in Experiment 1 is due to fearful facial expressions or perceptual inconsistencies. We addressed this issue in Experiment 2 by using a smiling (open mouth) mask. We predicted the results of Experiment 1 were due to the fear-eliciting nature of the masked faces. Thus, the results of Experiment 2 should be consistent with Experiment 1.

### *Method*

*Participants.* A separate sample of 30 (17 female, 13 male) introductory psychology students from Southern Illinois University Carbondale participated in Experiment 2 for partial course credit. All 30 participants reported that they were right-handed. Participants were provided with informed consent and treated according to the guidelines of the Institutional Review Board. As in Experiment 1 participants were screened for normal or corrected to normal vision.

*Procedure and Stimuli.* All aspects of Experiment 2 were identical to those of Experiment 1 with the exception of the

Table 1
*Mean Reaction Times and Standard Errors From Experiment 1*

| Trial type | Reaction time (ms) | Standard error | Attention related reaction time differences | Reaction time (ms) | Standard error |
|---|---|---|---|---|---|
| Congruent[a] | 323.80 | 4.92 | Overall attention effect | 8.96** | 1.95 |
| Incongruent | 332.75 | 4.81 | (incongruent - congruent) | | |
| | | | Orienting effect | | |
| Neutral - neutral | 329.30 | 4.54 | (congruent - baseline[b]) | −5.50* | 1.78 |
| Fearful - fearful | 330.02 | 4.58 | Disengagement effect | 3.45 | 1.72 |
| Fourier - fourier | 337.54 | 5.85 | (incongruent - baseline) | | |

[a] Congruent trials were significantly faster than all other trials types. [b] The neutral - neutral condition is considered baseline.
* $p < .05$. ** $p = .001$.

stimulus used as the mask. A female open mouthed happy facial expression from the same facial database (Gur et al., 2002) was used as the mask (see Figure 1a). Masked facial stimuli consisted of the same four (2 male and 2 female) gray scale facial identities of fearful and neutral expressions used in Experiment 1. As in Experiment 1, faces were offset 1° of visual angle on the vertical axis. Participants' were again provided feedback on their average reaction times at the end of each block. In addition, to reduce the amount of errors participants' were provided with their total percentage of correctly identified targets at the end of each block in Experiment 2.

### Results

We again performed 2 × 2 repeated measures ANOVA assessing the effects of visual field (left vs. right) and congruency (congruent vs. incongruent) on the number of incorrect responses during directed attention trials. A main effect of congruency, $F(1, 29) = 4.51$, $p < .05$, $\eta_p^2 = .14$, was found where congruent trials had fewer incorrect responses ($M = 3.60$) than incongruent trials ($M = 4.93$). There was again no effect of visual field, $F(1, 29) < 1$, $\eta_p^2 = .01$. An interaction between visual field and congruency failed to reach significance, $F(1, 29) = 1.28$, $p > .05$, $\eta_p^2 = .04$. Consistent with Experiment 1, these results indicate that targets following fearful faces in directed attention trials are correctly identified more often than targets following neutral faces. This increased target accuracy may be a product of enhanced attention to the location of the fearful face.

As in Experiment 1, only data from correct responses were used in analyses of reaction time data. As a result, 2.8% of the data was discarded for incorrect responses. To eliminate premature and delayed responses, trials with reaction times less than 100 ms or more than 750 ms were discarded, which resulted in the removal of an additional .3% of the data. Thus, a total of 3.1% of the data were discarded leaving 96.9% of the data available for analysis.

A one-way repeated measures ANOVA assessing trial-type (congruent vs. incongruent vs. Fearful-Fearful vs. Neutral-Neutral vs. Fourier-Fourier) was conducted on participants' reaction time data. There was a significant effect of trial-type, $F(4, 116) = 12.11$ $p < .001$, $\eta_p^2 = .30$, on participant's reaction time data. As in Experiment 1, the $p$ values reported for follow up tests were Bonferroni adjusted. Reaction times for congruent trials ($M = 312.46$) were significantly faster than all other trial types: incongruent, $M = 323.82$, $t(29) = -6.30$, $p < .001$, $\eta_p^2 = .58$; Neutral-Neutral, $M = 320.65$, $t(29) = -3.73$, $p < .01$, $\eta_p^2 = .33$; Fearful-Fearful, $M = 321.20$, $t(29) = -5.60$, $p < .001$, $\eta_p^2 = .52$; and Fourier-Fourier, $M = 326.21$, $t(29) = -6.40$, $p < .001$, $\eta_p^2 = .56$. The difference between congruent and Neutral-Neutral trial types reported above indicates that masked fearful faces facilitate orienting. The means for incongruent and Neutral-Neutral trial types did not significantly differ from each, $t(29) = 1.55$, $p > .05$, $\eta_p^2 = .08$ indicating no effect on disengagement. There were no significant differences between Fearful-Fearful, Neutral-Neutral, Fourier-Fourier, and incongruent trials types. The attention-related reaction time data from Experiment 2 are presented in Table 2.

A 2 × 2 repeated measures ANOVA was conducted to assess the effects of visual field (left vs. right) and congruency (congruent vs. incongruent) on participants' reaction times. A main effect for congruency was found where reaction times to congruent trials ($M = 312.58$) were faster than incongruent (324.17) trials, $F(1, 29) = 33.343$, $p < .001$, $\eta_p^2 = .54$. The main effect of visual field did not reach significance, $F(1, 29) = 1.05$, $p > .05$, $\eta_p^2 = .04$. No interaction effects between visual field and congruency were observed, $F(1, 29) < 1$, $\eta_p^2 < .01$.

### Discussion of the Results from Experiment 2

The results of Experiment 2 were very similar to those of Experiment 1. Congruent trial types resulted in the faster response times than incongruent trial types, indicating that it is not the perceptual inconsistencies that grabbed attention in Experiment 1, but is instead the fearful expression. Similarly, targets were detected more accurately during congruent compared to incongruent trials. Again, this modulatory effect of masked fearful faces on spatial attention was not influenced by visual field. As in Experiment 1, we found that congruent trial types were faster than the Neutral-Neutral trial types suggesting that masked fearful faces facilitate the orienting aspect of spatial attention.

## General Discussion

Consistent with previous research, the results from Experiments 1 and 2 suggest that masked fearful faces modulate spatial attention (Fox, 2002; Mogg & Bradley, 1999, 2002). Both experiments indicate that this effect is primarily due to speeded orienting of spatial attention. That is, there is an automatic directing or shifting of attention to the location of the masked fearful face. Our results suggest that this effect cannot be attributed to a general increase in

Table 2
*Mean Reaction Times and Standard Errors From Experiment 2*

| Trial type | Reaction time (ms) | Standard error | Attention related reaction time differences | Reaction time (ms) | Standard error |
|---|---|---|---|---|---|
| Congruent[a] | 312.46 | 5.88 | Overall attention effect | 11.36** | 1.80 |
| Incongruent | 323.82 | 5.82 | (incongruent - congruent) | | |
| | | | Orienting effect | | |
| Neutral - neutral | 320.65 | 5.80 | (congruent - baseline[b]) | −8.20* | 2.20 |
| Fearful - fearful | 321.20 | 5.42 | Disengagement effect | 3.17 | 2.05 |
| Fourier - fourier | 326.21 | 5.97 | (incongruent - baseline) | | |

[a] Congruent trials were significantly faster than all other trials types. [b] The neutral-neutral condition is considered baseline.
* $p < .01$. ** $p < .001$.

arousal or vigilance, but rather suggests that the "spotlight of attention" is narrowed to the location of possible threat. While the results of Experiment 1 were somewhat ambiguous as to whether fearful faces or perceptual inconsistencies modulated spatial attention, the results from Experiment 2 indicate that this effect cannot be attributed to perceptual inconsistencies in the mouth area between the initial faces and masks. That is, open-mouthed masks were used in Experiment 2 where there were greater perceptual inconsistencies for incongruent trial types; however, congruent trial types still resulted in faster reaction times than incongruent trial types. Additionally, targets were detected more accurately for congruent compared to incongruent trial types, suggesting the modulation of spatial attention enhances target detection.

### *Overall Attention Effect*

The results from these experiments are consistent with previous research that suggests fearful faces and other threatening stimuli modulate spatial attention (Armony & Dolan, 2002; Beaver et al., 2005; Blanchette, 2006; Fox, 2002; Fox & Damjanovic, 2006; Mogg & Bradley, 1999, 2002; Ohman, Flykt, & Esteves, 2001; Pourtois et al., 2004, 2006). Furthermore, fearful faces have been found to modulate the temporal allocation of attention, as seen in the attentional blink paradigm (Fox, Russo, & Georgiou, 2005), and both of these aspects of attention are mediated by trait anxiety (Fox, 2002; Fox et al., 2005). Threat modulated attention is thought to represent an automatic fear response dependent upon limited processing of the threat stimulus (LeDoux, 1996). Previous research suggests the automatic fear response modulates spatial attention to masked fearful faces even in the absence of conscious awareness (Fox, 2002). Given the short duration of our fearful faces and their immediate masking by nonthreatening faces, we were able to restrict the amount of sensory processing these fearful faces received. Therefore, our results are consistent with the notion that fearful faces automatically enhance attention even under conditions of restricted stimulus processing. There is an ongoing debate as to whether visual attention and visual awareness are dissociable (e.g., Koch & Tsuchiya, 2006). Our results taken together with previous research (e.g., Fox, 2002; Mogg & Bradley, 1999, 2002) suggest that certain aspects of visual attention such as threat-elicited spatial attention, operate with limited stimulus processing. However, future threat-elicited spatial attention studies assessing participant awareness (see Szczepanowski & Pessoa, 2007, for methods of assessing awareness) are needed to determine the extent to which this aspect of visual attention operates independently of visual awareness.

Our results indicate that the overall spatial attention effect was not influenced by visual field. This contrasts with previous research, which suggests that masked threatening faces presented in the left visual field have a greater effect on modulating attention (Fox, 2002; Mogg & Bradley, 1999, 2002). In studies using masked angry faces there are only attention effects in the left visual field (Mogg & Bradley, 1999, 2002). On the other hand, masked fearful faces enhance attention in both visual fields, but the left visual field produces a greater attention effect (Fox, 2002). It is somewhat unclear as to why there are inconsistencies between our results and these studies. One potential explanation is participant population. Our study did not prescreen for anxiety level whereas Mogg and Bradley (1999, 2002) and Fox (2002) selected for only low and high anxious individuals. Another potential difference is the variant of the dot probe task used. We used a simple detection task whereas Mogg and Bradley (1999, 2002) and Fox (2002) used a more complex discrimination task (but see Mogg & Bradley, 1999, Experiment 1). Future research is needed to determine what factor(s) is mediating this difference in visual field effects. Nonetheless, our results suggest that the attention related congruency effect for masked fearful faces is not influenced by visual field in our sample.

### *Baseline Conditions*

We used three different baseline conditions for reaction times each of which added a new element to the dot probe paradigm. Phase scrambled Fourier faces contain several low level features of faces without a form based representation of a face. If faces in general influence reaction times, Neutral-Neutral trials should differ from the Fourier-Fourier trials. Similarly, if there is a general influence of fear that is not location specific (e.g., an overall increase in arousal), there should be differences between the Neutral-Neutral and Fearful-Fearful trials. Fearful-Fearful trials might be expected to result in faster reaction times than Neutral-Neutral trials due to increases in fear-elicited arousal and nonretinotopic specific fear processing as research has revealed bilateral subcortical amygdala afferents (Usunoff, Itzev, Rolfs, Schmitt, & Wree, 2006). There are two possible explanations for our lack of an overall fear effect: (a) it could be the case that attention is always focused at the location of one fearful face or the other, which would result in congruent-like reaction times on half of the trials and incongruent-like reaction times on the other trials resulting in the intermediate response times observed in the present study or (b) it could also be the case that the "spotlight" of attention is equally distributed across both visual fields in these trial types by endogenous attentional mechanisms that are operating at maximum efficiency and fear-eliciting stimuli can only enhance spatial attention when the focus of attention is restricted to a single spatial location. We did not find any differences between Neutral-Neutral, Fearful-Fearful, and Fourier-Fourier trial types, suggesting that all of these trial types equally represented baseline reaction time.

### *Orienting and Disengagement*

Our results suggest that masked fearful faces primarily enhance spatial attention by modulating orienting, but not disengagement effects. These results are contrary to the impaired disengagement typically observed in studies of unmasked threat stimuli (Fox et al., 2001; Koster et al., 2004, 2006; Salemink et al., 2007; Yiend & Mathews, 2001). However, unmasked threat stimuli have relatively long stimulus durations, which result in a delayed sampling of attention that may be insensitive to the initial allocation of spatial attention or orienting. Therefore, it is possible that facilitated orienting to unmasked threat occurs at a time point earlier than that typically sampled (i.e., $<$ 150 ms). Alternatively, Jolij and Lamme (2005) propose a framework in which unconscious and conscious processing are involved in an inhibitory interaction. Therefore, masked fearful faces may initiate an orienting response, mediated by unconscious mechanisms, that is inhibited by conscious mechanisms in studies of unmasked threat.

The observed pattern of orienting and disengagement in our study is consistent with LeDoux's dual pathway theory. That is, masked threatening stimuli receive limited processing and may reach the amygdala through the quick subcortical route. However, the existence of such a subcortical route in humans is debated and imaging research on this issue has yielded mixed results (see Jiang & He, 2006; Liddell et al., 2005; Morris et al., 2001; Pasley et al., 2004, for supporting evidence and Pessoa et al., 2006, for conflicting evidence). Nonetheless, activation of the amygdala through the proposed subcortical route is believed to initiate the directing of attentional resources to the location of threat. However, this initial subcortical information is then integrated with more detailed cortical information projecting to the amygdala. By masking our fearful faces with nonthreatening faces, this may signal that there is no longer a threat in this location. This contrasts with unmasked fear stimuli where attention may be sustained due to the cortical confirmation of threat.

To the best of our knowledge, this is the first study that has directly assessed which aspect of attention (orienting or disengagement) is influenced by masked threatening stimuli. While our study indicates that the orienting of attention is modulated by masked fearful faces in individuals not selected based on anxiety, it is unclear as to what extent this effect generalizes to other populations or stimulus types. For example, it is uncertain what aspect(s) of attention is mediating spatial attention effects to masked threatening faces in individuals with high levels of anxiety. Anxious individuals could preattentively orient to threat, have difficulties disengaging from threatening stimuli, or a combination of these effects. Indeed, highly anxious individuals generally tend to have difficulties in disengaging from unmasked threat stimuli (see Fox et al., 2001; Yiend & Mathews, 2001, for detailed discussion), but combined disengagement and orienting effects have also been reported (Koster et al., 2006). Finally, the backward masking parameters used in the current study appear to be on the edge of participant awareness. While several studies have found this method to result in unawareness (Fox, 2002; Glascher & Adolphs, 2003; Liddell et al., 2005; Mogg & Bradley, 1999, 2002; Morris et al., 1999; Whalen et al., 1998) others have found that the degree of awareness varies across participants (see Szczepanowski & Pessoa, 2007). Future research exploring the aspects of attention modulated by masked fearful stimuli should include a measure of awareness to assess the extent to which orienting and disengagement effects are mediated by participant awareness.

## Conclusions

In conclusion, the results from Experiments 1 and 2 indicate that masked fearful facial expressions modulate the orienting of spatial attention. Experiment 2 reveals that this preferential orienting of attention cannot be explained by perceptual inconsistencies between the initial faces and masks, but rather to the emotional significance of the masked face. While the results indicate masked fearful faces enhance the orienting of attention, there is no evidence of a disengagement effect in the current set of experiments. This is consistent with LeDoux's dual pathway theory of fear processing where fearful stimuli are initially processed through a subcortical route, which would enable a quick orienting response to the location of masked fearful faces. More elaborate or detailed information is processed through a cortical route, which would enable the allocation of attention to be terminated upon the processing of the nonthreatening face mask. Finally, our results indicate that a baseline for reaction time is important for distinguishing between orienting and disengagement effects in masked threat dot probe tasks.

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