4-2014

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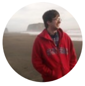
Article *in* Journal of Nonverbal Behavior · April 2014

DOI: 10.1007/s10919-014-0185-1



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J Nonverbal Behav
DOI 10.1007/s10919-014-0185-1

ORIGINAL PAPER

Facilitated Attentional Orienting and Delayed Disengagement to Conscious and Nonconscious Fearful Faces

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Abstract Fearful facial expressions are salient nonverbal social cues that signal the existence of potential threat within the environment. These threat signals capture spatial attention both when processed consciously (unmasked) and nonconsciously (masked). Studies using masked fearful faces have most reliably found speeded orienting towards their location, but delayed disengagement from this location has also been observed. Surprisingly however, the extent to which orienting and disengagement processes underlie modulations in spatial attention to conscious/unmasked fearful faces has yet to be explored. Here, participants performed an unmasked and masked fearful face dot-probe task, which included a baseline condition to assess attentional orienting and disengagement effects. We found that both unmasked and masked fearful faces capture spatial attention through facilitated orienting and delayed disengagement. These results provide new evidence that consciously and nonconsciously processed social expressions of fear facilitate attention through similar mechanisms.

Keywords Awareness · Facial expressions · Fear · Threat · Attention bias

Introduction

Emotional facial expressions are highly salient social signals, which enable rapid non-verbal communication of affective information from one individual to other individuals. In the case of fearful facial expressions, these nonverbal cues communicate the existence of a perceived threat—although the location of this perceived threat is unknown to the observer.

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Published online: 19 April 2014

Evolutionarily, fearful facial expressions act to alert and prepare other members of the species to an imposing danger (Darwin 1872) by capturing observers' attention and by initiating the threat response. Indeed, fearful faces have been found to facilitate spatial attention both when awareness is unrestricted (Pourtois et al. 2004) and when awareness has been restricted through the use of backward masking (Carlson and Reinke 2008; Fox 2002). This is especially true in highly anxious individuals (Fox 2002). Thus, fearful faces are important nonverbal signals of threat that facilitate attention.

Human lesion studies indicate that the recognition of fearful facial expressions, compared to other emotional expressions, is uniquely dependent upon an intact amygdala (Adolphs et al. 1999). In healthy individuals, the amygdala activates both to consciously (Morris et al. 1996) and nonconsciously (Liddell et al. 2005; Whalen et al. 1998) processed fearful faces. The extent to which the amygdala is activated in response to fearful faces in any given individual correlates with a number of dispositions including anxiety (Etkin et al. 2004) and aggression (Carlson et al. 2010). In addition to the recognition of fearful expressions, the amygdala is also necessary for the experience of fear (Feinstein et al. 2011) and the facilitation of perceptual processing by fearful facial expressions (Vuilleumier et al. 2004). In healthy individuals, the capture of spatial attention by fearful faces is mediated through the amygdala (Carlson et al. 2009) and this effect is exaggerated in anxious individuals (Monk et al. 2008). Collectively, the literature implicates the amygdala as a critical mechanism for the recognition of others' fearful facial expressions and the attentional response to these faces.

The capture of spatial attention serves to prioritize visual information at specific retinotopic locations in visual space through three stages: (1) orienting or shifting attention to a stimulus of interest, (2) engaging or focusing attention onto a stimulus, and (3) disengaging or releasing attention from a stimulus (Posner 1980; Posner et al. 1987). However, as will be demonstrated in greater detail, the role that attentional orienting and disengagement play in the facilitation of attention by conscious and nonconscious fearful faces is not fully understood.

The "dot-probe" task is a widely used method of assessing attentional bias to facial expressions and other types of salient environmental stimuli (Macleod et al. 1986). Traditionally, trials contain two differentially valenced stimuli simultaneously presented to the left and right of (or above and below) fixation followed by a single dot-probe appearing at either the left or right location. The rationale is that threatening (or more salient) stimuli automatically capture spatial attention and therefore reaction times should be faster for spatially congruent compared to incongruent probes. However, without establishing a clear baseline for reaction times, the difference in congruent versus incongruent reaction times could theoretically result from speeded orienting/engagement, delayed disengagement/reorienting, or a combination of these factors (Koster et al. 2004). Recently, neutral–neutral (baseline) conditions have been used in dot-probe studies to assess the relative contribution of orienting and disengagement to the overall capture of spatial attention by backward masked fearful faces. These studies have consistently found facilitated orienting toward masked fearful faces (Carlson et al. 2012; Carlson and Reinke 2008, 2010; Carlson et al. 2011). Of these studies, two reported only orienting effects (Carlson et al. 2012; Carlson and Reinke 2008), while two reported combined orienting and disengagement effects (Carlson and Reinke 2010; Carlson et al. 2011). Given that fearful facial expressions are salient signals of threat with both adaptive and maladaptive influences on behavior, it is important to understand how these cues influence attention both at the conscious and nonconscious level. Yet astoundingly, to the best of our knowledge, no study has explored the relative contribution of orienting and disengagement effects in the facilitation of spatial attention by unmasked, consciously processed, fearful faces.

Accordingly, the aim of the current investigation was to assess the extent to which orienting and disengagement attentional sub-components contribute to the capture of spatial attention by unmasked and masked fearful faces. This study uniquely assesses the influence of unmasked and masked fearful faces on orienting and disengagement effects within a single sample. Participants completed unmasked and masked versions of the dot-probe task with neutral–neutral baseline conditions. Given that unmasked and masked fearful faces elicit similar patterns of amygdala reactivity and the amygdala mediates the attentional response to fearful faces, we hypothesized that unmasked and masked fearful faces would modulate attention through similar behavioral mechanisms. Namely, through facilitated orienting and delayed disengagement.

Method

Participants

Sixty-two consenting young adults (28 male) between the ages of 18 and 33 ($M = 20.94$, $SD = 2.61$) participated in the study. Fifty-seven individuals reported being right handed, while five reported being left handed. The Institutional Review Board approved this study and participants were compensated for their time ($20.00). Participants' trait anxiety (Spielberger et al. 1970) scores were between 24 and 56 ($M = 39.10$, $SD = 8.67$).

Procedure

The task was programmed in E-Prime and was presented on a 60 Hz 16″ LCD computer monitor. Four fearful and four neutral grayscale expressions (half female) were used as the facial cues. A fifth (female) open mouthed happy facial expression from the same facial database (Gur et al. 2002) was used as the mask. An open mouth mask was used to restrict perceptual inconsistencies in the mouth area for fearful face cues and masks to help rule out non-expression based explanations for potential effects. Each trial started with a white fixation cue (+) centered on a black background for 1,000 ms. Two face stimuli were then simultaneously presented 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. For the masked condition, initial faces were displayed for 33 ms and were then instantly masked for 100 ms. For the unmasked condition, faces were presented for 133 ms. In both instances, a target dot was immediately presented in the location of either the left or the right face and remained until the participant responded. Using an E-prime response box, participants were instructed to identify the location of the dot as quickly as possible by pressing the first button with their right index finger for left sided targets and pressing the second button with their right middle finger for right sided targets. Participants were instructed to always fixate on the fixation cue, which remained in the center of the screen throughout each trial. A response terminated the current trial and initiated the following trial.

The task contained a total of 240 trials presented in a unique random sequence for each participant. The primary trials of interest contained one fearful and one neutral face. Half of these trials were fearful face *congruent* (target dot presented on the same side as the fearful face) and half *incongruent* (target dot presented on the same side as the neutral face). A capture of spatial attention by fearful faces is measured by faster reaction times (RTs) on congruent compared to incongruent trials. Thus, these trials were considered directed spatial attention trials. An undirected (neutral–neutral) condition was included as a baseline. On baseline trials, attention should not be preferentially directed to either side of the screen. Congruent versus baseline RTs and incongruent versus baseline RTs were compared to assess orienting and disengagement effects, respectively (e.g., see Carlson and Reinke 2008; Koster et al. 2004). The task consisted of two blocks: the first masked and the second unmasked. Masked faces were always presented in the first block to limit participants' expectations or suspicions that masked trials might contain fearful/emotional faces. There were 120 trials in each block: 40 congruent and 40 incongruent trials each counterbalanced for visual field as well as 40 neutral–neutral trials.

Participants then completed a task to assess awareness of the masked faces. This task was identical to the dot-probe task in all aspects through the backward masking procedure. That is, the facial identities, visual angles, and stimulus presentation times were identical to those in the dot-probe task. After the masking procedure participants were asked to indicate with the response box whether they saw: *a fearful face on the left*, *a fearful face on the right*, or *two neutral faces*. Participants were instructed that each trial would contain two sets of faces presented in rapid succession and their task was to identify the facial expressions of the first set of faces. There were 60 randomly presented trials: 20 of each type. Note that the three possible choices regarding the expressions of the initial faces were the same as those used in the dot-probe task. Therefore, this task tests awareness for the presence or absence of a fearful face at two possible locations, which is the level of awareness that would be needed for a conscious facilitation of performance on the dot-probe task.

Results

Awareness Check

Using single sample t-tests it was determined that 7 out of 62 participants performed significantly better than chance (i.e., 33.33 %, $p < .05$) on the awareness check task (Group $M = 48.57$ %, $SE = 0.84$ %). These individuals were excluded from analyses of dot-probe data. For each of the remaining 55 individuals, accuracy on the awareness check task was at chance (p's $> .05$; Group $M = 35.49$ % correct, $SE = 0.70$ %).

Dot-Probe Task

Analyses were performed on correct responses occurring between 150 and 750 ms after target presentation (Carlson and Reinke 2008). As a result, 1.71 and 0.85 % of the data were discarded for inaccurate and premature or delayed responses, respectively. The remaining 97.44 % of the original data was used for analysis. A 2 × 2 × 2 repeated measures analysis of variance was conducted to assess the effects of visual field (fearful face left vs. fearful face right), congruency (congruent vs. incongruent), and presentation type (masked vs. unmasked) on participants' RTs during directed attention conditions in the dot-probe task. There was a significant effect of congruency, $F(1, 54) = 66.59$, $p = .00000000005$, $\eta_p^2 = 0.55$. Reaction times were faster on congruent ($M = 354.34$ ms, $SE = 6.19$) compared to incongruent ($M = 364.75$ ms, $SE = 6.03$ ms) trials. There was a significant effect of presentation type, $F(1, 54) = 6.44$, $p = .01$, $\eta_p^2 = 0.11$, where RTs were faster for unmasked face trials ($M = 354.41$ ms, $SE = 6.37$) compared to masked face trials ($M = 364.68$ ms, $SE = 6.43$).[1] However, presentation type did not interact with congruency, $F(1, 54) = 2.26$, $p = .14$, $\eta_p^2 = 0.04$: congruent trials ($M = 360.43$ ms, $SE = 6.61$; $M = 348.25$ ms, $SE = 6.50$) were faster than incongruent trials ($M = 368.93$ ms, $SE = 6.40$; $M = 360.57$ ms, $SE = 6.38$) for both masked ($p = .00004$) and unmasked conditions ($p = .000000001$), respectively. No other effects were significant.

We then ran a 2 × 2 linear mixed model to assess the effects of facilitated orienting (congruent–baseline RTs) and delayed disengagement (incongruent–baseline RTs) to masked and unmasked fearful faces. We also assessed the effect of the continuous measure trait anxiety. As can be seen in Fig. 1, the analysis revealed a significant effect of attention type, $F(1, 212) = 33.42$, $p = .00000003$, $\eta_p^2 = 0.13$, where facilitated orienting was observed for both masked ($M = -4.17$ ms, $SE = 1.94$, $p = .04$, $d = 0.29$) and unmasked ($M = -6.02$ ms, $SE = 1.62$, $p = .0005$, $d = 0.51$) faces and delayed disengagement was observed for masked ($M = 4.34$ ms, $SE = 1.89$, $p = .03$, $d = 0.31$) and unmasked ($M = 6.31$ ms, $SE = 1.74$, $p = .001$, $d = 0.49$) faces. There was no interaction between attention type and presentation type, $F(1, 212) = 1.12$, $p = .29$, $\eta_p^2 = 0.005$. However, an interaction between attention type, presentation type, and trait anxiety approached significance, $F(1, 212) = 2.16$, $p = .097$, $\eta_p^2 = 0.03$. As displayed in Fig. 2, there is a greater delay in disengagement for unmasked fearful faces in high trait anxious individuals, $r = .37$, $p = .006$. This relationship appears to be partially driven by two deviant scores. When removing the individual with the highest disengagement score the relationship remains significant ($r = .28$, $p = .04$), but when the individual with the lowest disengagement score is also removed the effect only approaches significance, $r = .20$, $p = .08$ (see Fig. 2). Unmasked orienting ($r = .07$, $p = .63$) as well as masked orienting ($r = -.03$, $p = .86$) and disengagement ($r = -.07$, $p = .60$) did not correlate with trait anxiety.[2] No other effects were significant.

Discussion

Consistent with prior work (Carlson and Reinke 2008; Fox 2002; Pourtois et al. 2004), the findings show that fearful facial expressions capture spatial attention both when unmasked and masked. A neutral–neutral baseline condition was included to assess the relative contribution of attentional orienting and disengagement to the overall capture of spatial attention by fearful faces. The results suggest that both unmasked and masked fearful faces facilitate orienting and delay disengagement. Post-task assessment of awareness for the masked faces ensured that participants' performance was at chance. Thus, the current results indicate that both conscious and nonconscious biases to facial expressions of fear modulate spatial attention by faster orienting and delayed disengagement.

Fearful facial expressions communicate the existence of potential threat within the environment to other members of the species; yet, information about the location of this potential threat is not communicated by a fearful expression alone. One's direction of gaze in juxtaposition with a fearful expression does relay this information and accordingly, leads

[1] It should be noted that this effect is very likely driven by the order of the blocks. That is, overall reaction times decreased as participants became more familiar with the task.

[2] We ran additional correlations to ensure that participants' level of awareness did not influence orienting or disengagement scores, all p's > .10 (Wiens, 2006).

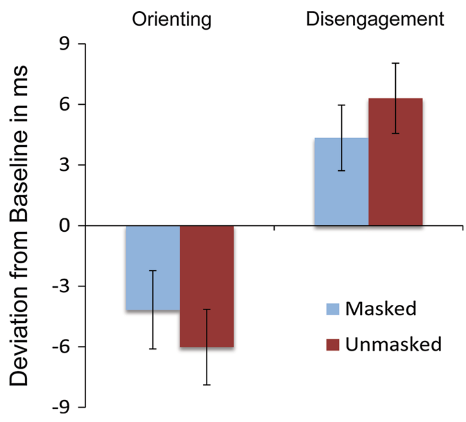

Fig. 1 For both masked and unmasked faces, congruent trials were faster than baseline (i.e., orienting), while incongruent trials were slower than baseline (i.e., disengagement). *Error bars* reflect the standard error of the mean

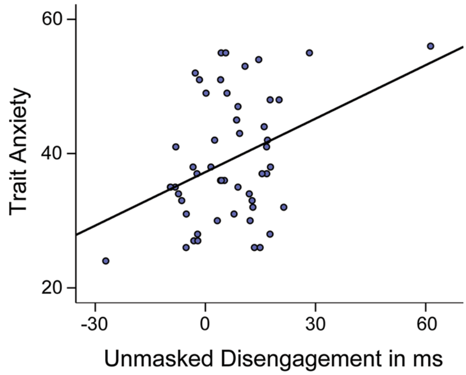

Fig. 2 Disengagement scores for unmasked faces correlated with trait anxiety: higher levels of anxiety were associated with delayed disengagement from fearful faces ($r = .37$, $p < .05$). This relationship remains significant when removing the individual with a disengagement score >60 ($r = .28$, $p < .05$), but only approaches significance when the individual with a disengagement score near −30 is also removed, $r = .20$, $p = .08$

to shifts of attention towards the direction of gaze (Fox et al. 2007; Mathews et al. 2003). Thus, to maximally utilize the information communicated by fearful faces, it would be advantageous for an individual to rapidly orient towards expressions of fear and to delay their disengagement of attention from this location until further information is obtained. Once information about gaze direction is obtained or the fearful expression subsides (i.e., indicating the expresser no longer perceives threat), then it would be appropriate to disengage one's attention from this location. Note that it would also be advantageous to disengage attention after a prolonged period of time even if additional information is not communicated. This logic would explain the observed pattern of orienting and disengagement effects observed in the current study. Additionally, this logic may explain the inconsistency in disengagement effects observed in prior masking studies (Carlson et al. 2011, 2012; Carlson and Reinke 2008, 2010). That is, the change from a fearful face cue to a non-threat expressing mask may render this location less salient and thus initiate an attentional disengagement from this location, which would make detecting disengagement effects more difficult or less reliable.

In a similar vein, it makes intuitive sense that attentional orienting processes should occur early, while disengagement processes should occur later. With this in mind, an interesting avenue for future research would be an assessment of the time-course for orienting and disengagement to unmasked and masked fearful faces. That is, similar to prior work assessing the time course for the overall capture of attention to threat (i.e., the congruent vs. incongruent comparison with no baseline trials; e.g., Mogg et al. 1997), orienting and disengagement effects could be measured at time points between 0 and 500 ms post face onset. In addition to typical dot-probe trials where attention is sampled post-cue (up to 500 ms), dot-probes could be embedded into the face/stimulus cues so that attention is immediately sampled (i.e., 0 ms). If this research were to be carried out, one might expect that early attention effects (<100 ms) are driven by orienting, later effects by disengagement (>250 ms), and as observed here, both types of attentional effects should be present in the transitory middle timeframe (100–200 ms).

Although prior research has not assessed the degree to which unmasked fearful faces facilitate orienting or delay disengagement, a number of studies have assessed these attentional effects to other types of threats including angry faces, threatening words, and negatively valenced IAPS images. Of these studies, those that used longer (i.e., 250–500 ms) presentation times found disengagement, but not orienting, effects in both anxious and general samples (Fox et al. 2001; Koster et al. 2004; Fox et al. 2007; Yiend and Mathews 2001). At shorter (100 ms) stimulus durations orienting and disengagement effects were found in a sample of anxious participants (Koster et al. 2006), while only disengagement effects were observed in a general sample (Cooper and Langton 2006). Thus, disengagement effects have consistently been observed in studies of unmasked threat, while orienting effects have been observed to a lesser degree. Our results suggest that, similar to other types of consciously processed threat, fearful faces delay attentional disengagement from their location. Furthermore, our results suggest that unmasked fearful faces initiate a rapid orienting of attention to their location. Additional research is needed to understand why such orienting effects have not been consistently observed for other types of consciously processed threat.

By understanding the roles of attentional orienting and disengagement in the processing of fearful faces and other types of threat cues the field can gain insight into the behavioral components underlying individual differences in personality and genetics. Heightened anxiety has previously been associated with a heightened attentional bias to fearful faces (Fox 2002) in addition to other types of threat cues (MacLeod and Mathews 1988; Macleod et al. 1986; Mogg and Bradley 1999, 2002) and the delayed disengagement from these cues (Arndt and Fujiwara 2012; Fox et al. 2001; Koster et al. 2006; Salemink et al. 2007; Yiend and Mathews 2001). Our results support the relationship between anxiety and disengagement to consciously processed threats. Additional recent research has found that short allele carriers (relative to homozygous L_AL_A individuals) of the serotonin transporter polymorphism (i.e., *5-HTTLPR*) rapidly orient attention to backward masked fearful faces, but do not show delayed disengagement from such faces (Carlson et al. 2012). On the other hand, additional research has found that high trait cognitive reappraising individuals show delayed disengagement, but not facilitated orienting, to unmasked angry faces relative to high trait suppressors (Arndt and Fujiwara 2012). The authors attributed this sustained attention to threat in high reappraisers to represent a more detailed analysis of the threat stimulus. Thus, a number of individual differences appear to have specific effects on orienting and disengagement processes. Understanding these differences in orienting and disengagement may have important implications for understanding aspects of individual variability. Other than the current work, very little research has assessed how individual differences are related to orienting and disengagement effects to both unmasked and masked threat within a single sample. The relationship between disengagement and anxiety observed in the current study appears to especially true for individuals at the extreme ends of the spectrum. Thus, future research should make an effort to sample from these extreme ends of the spectrum when studying the relationship between individual differences and attentional orienting and disengagement.

The amygdala is necessary for processing fearful faces (Adolphs et al. 1999) and is reactive to both consciously (Morris et al. 1996) and nonconsciously (Liddell et al. 2005; Whalen et al. 1998) processed fearful faces. The amygdala is also necessary for (unmasked) fearful face facilitated visual perceptual processing (Vuilleumier et al. 2004) and is typically activated during the allocation of spatial attention to masked fearful faces (Carlson et al. 2009). Therefore, the amygdala appears to be a shared substrate for the processing of conscious and nonconscious fearful faces and the attentional response to such faces. Here, we provide complementary results indicating that fearful face threat cues, whether consciously or nonconsciously processed, elicit a similar facilitation in orienting and a delayed disengagement of attention. Thus, similar underlying behavioral mechanisms contribute to the capture of attention by conscious and nonconscious threats alike.

Acknowledgments Research supported by Army Research Office Grant W911NF1110246 (LRMP & JMC).

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