Angry faces hold the eyes

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VISUAL COGNITION
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Abstract

Efficient processing of complex social and biological stimuli associated with threat is crucial for survival. Previous studies have suggested that threatening stimuli such as angry faces not only capture visual attention, but also delay the disengagement of attention from their location. However, in the previous studies disengagement of attention was measured indirectly and was inferred on the basis of delayed manual responses. The present study employed a novel paradigm that allows to directly examine the delayed disengagement hypothesis by measuring the time it takes to disengage the eyes from threatening stimuli. The results showed that participants were indeed slower to make an eye movement away from an angry face presented at fixation than from either a neutral or a happy face. This finding provides converging support that the delay in disengagement of attention is an important component of processing threatening information.

Keywords: emotion, saccades, disengagement, threat, facial expressions

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Research on visual attention has shown that certain simple stimuli, such as abrupt onsets, sudden motion or salient color singletons can capture attention automatically, irrespectively of the goals of the observer (Theeuwes, Olivers, & Belopolsky, in press; Yantis & Jonides, 1984). Orienting to these objects may be important because often they signal unexpected and potentially dangerous events in the environment. However, equally important is fast orienting to more complex biological and social stimuli that potentially can signal danger. For example, directing attention to an angry face, a spider or a snake can be of a great advantage and can help to quickly prepare an appropriate response.

Several researchers have proposed that complex biological stimuli associated with threat trigger an automatic orienting response (Ohman & Mineka, 2001; Vuilleumier, 2005). Presumably, such response has developed in the course of evolution in order to reduce potential harm inflicted by the threatening stimuli. In accordance with this view, recent studies have demonstrated that potentially dangerous objects, such as spiders, snakes or angry faces receive priority in visual selection. For example, in visual search tasks participants are faster to find an angry face among distractors than to find a happy or a sad face. As the time to find an angry face is less affected by the number of stimuli present in the visual field than search for other facial expressions this type of search is often classified as efficient (Fox et al., 2000; Ohman, Lundqvist, & Esteves, 2001). Similarly, participants are faster and more efficient to find snakes and spiders than non-threatening objects, like flowers or mushrooms (Ohman, Flykt, & Esteves, 2001). These search advantage is further enhanced if participants have a specific phobia for snakes or spiders and this enhancement is phobia-specific, indicating that it is due to the fear experienced by the participants (e.g. Lipp, 2006).

Further evidence for prioritized attentional selection of threatening stimuli comes from a so-called dot-probe paradigm, which is a modification of a classic spatial cueing task developed by Posner and colleagues (Posner, 1980). In this task participants are required to detect a target (i.e. a dot-probe), which can occur either at the location previously occupied by a threat-related stimulus (i.e. an angry face) or at the location of the non-threatening stimulus (a neutral or a happy face). Both stimuli are presented side by side and the location of the threatening stimulus is irrelevant to the task, since it does not predict the location of the target. It has been demonstrated that participants are faster to detect a dot-probe appearing at the location of a threat-related stimulus, suggesting that attention was directed to its location (Bradley, Mogg, Falla, & Hamilton, 1998; Fox et al., 2000; Mathews, Mackintosh, & Fulcher, 1997).

The findings from visual search and cueing paradigms have commonly been interpreted as evidence that fear-related stimuli capture attention in an automatic bottom-up way (e.g., Mathews et al., 1997; Ohman, Flykt et al., 2001; Ohman, Lundqvist et al., 2001). However, in visual search tasks the threat-related stimulus is often the target, which makes it difficult to isolate the bottom-up component associated with the threatening stimulus (Devue, Belopolsky, & Theeuwes, submitted). Furthermore, recently Fox and colleagues (Fox, Russo, Bowles, & Dutton, 2001; Fox, Russo, & Dutton, 2002; Georgiou et al., 2005) have challenged the interpretation of results from dot-probe tasks. They pointed out that these studies cannot distinguish between a more efficient orienting to threat-related stimuli and a slower disengagement of attention from these stimuli once attention has been oriented to them (for a similar argument see also Theeuwes & Van der Stigchel, 2006). Fox and colleagues (Fox et al., 2001) presented faces (angry, happy or neutral) or words (threatening, positive or neutral) as exogenous cues. As expected, participants were faster in detecting targets occurring at the location of the cue (Mathews et al., 1997). However, there were no additional benefits associated with threatening cues, since response times on validly cued trials were similarly fast for all types of cues. Interestingly, invalid threat-related cues were associated with increased costs in reaction time, suggesting that participants had trouble disengaging attention from these cues (for a similar result see also Yiend & Mathews, 2001).

In a follow-up study (Fox et al., 2002) the delayed disengagement hypothesis was further investigated using the phenomenon of inhibition of return (IOR). IOR is thought to reflect a bias away from the recently attended locations and is manifested by slower RTs to targets at validly cued locations when the time between the cue and the target is extended. It has been suggested in the literature that IOR occurs after attention is disengaged from the cued location (Klein, 2000) and that IOR is postponed if attention lingers at the cued location. In a study by Fox and colleagues (2002) no inhibition of return (IOR) was observed at the location of the threat-related stimulus while typical IOR was elicited at the location of non-threatening stimuli. The absence of IOR at the threat-related stimulus indicates that attention was maintained at its location and suggests that the disengagement of attention was delayed.

The ability of threatening stimuli to delay disengagement of attention was tested more directly in a recent study by Georgiou et al (Georgiou et al., 2005). The authors presented either a fearful, neutral or happy face at fixation while participants had to discriminate onset targets in the periphery. The results showed that participants were slower in discriminating the target after a fearful face was presented. Based on this study and on the results of Fox and colleagues (Fox et al., 2001; Fox et al., 2002; Georgiou et al., 2005) it was proposed that threat-related objects may not necessarily facilitate the orienting of attention, but instead may delay the disengagement of attention from these threatening stimuli. Such delay in disengagement of attention could reflect the inborn desire to process the object of potential threat in more depth. It makes ecological sense to monitor and evaluate potentially threatening stimuli and to be reluctant in leaving them unattended (Fox et al., 2001). Examining the object of potential threat in more detail gives the person more time to assess the danger and to come up with the most appropriate reacting strategy.

The goal of the present study was to critically test the delayed disengagement hypothesis by directly measuring the disengagement of attention from the threat-related face by means of eye movements. Many studies have shown that covert attention and saccades are tightly coupled (Belopolsky & Theeuwes, 2009; Deubel & Schneider, 1996). Importantly, it has been demonstrated that it is impossible to make a saccade without first shifting covert attention precisely to the saccade target location (Deubel & Schneider, 1996). The fact that covert attention precedes the eye movements in an obligatory fashion makes the oculomotor disengagement the most direct and sensitive measure of the time to shift attention away from the attended object (Brockmole & Boot, 2009).

In covert attention tasks (as in the study by Georgiou et al., 2005) the time-course of disengagement had to be approximated by presenting the face for 500 ms before the appearance of a peripheral target. The disengagement itself had to be inferred from the responses to the target and it is not clear how accurately attention had to be focused on the target in order to make a response. Furthermore, peripheral onset targets are known to capture attention in a bottom-up fashion (Yantis & Jonides, 1984), which can also cloud the measure of disengagement. In our task a schematic face was presented in the center of the screen and could have either an angry, happy or neutral expression. Observers had to determine whether the face was slightly tilted to the left or to the right and to make a saccade to a box located in the direction of the tilt. Importantly, the facial expression itself was irrelevant to the task. Therefore, in our task participants had to engage their attention on the face to determine the direction of the tilt and then to disengage it in order to make an eye movement.

According to the delayed disengagement hypothesis the emotional expression of the face should have an effect on the speed of disengagement. Specifically, we predicted that disengagement would be the slowest when an angry face was presented relative to when a happy or a neutral face was presented. In order to control for the low-level differences among different facial expressions we have included a condition in which all faces were inverted.

Methods

Participants

Eighteen volunteers (10 females) from the Vrije Universiteit Amsterdam were paid to participate in a 20 minute session. Their age varied between 19 and 28, with a mean age of 22. They all had normal or corrected to normal visual acuity and normal color vision.

Apparatus

Eye movements were recorded with EyeLink II tracker (500 Hz temporal and 0.2° spatial resolution). Eye movement was considered a saccade when its velocity exceeded 35°/s and its acceleration exceeded 9500°/s^2.

Stimuli, Design & Procedure.

The stimuli were presented against a white background (90 cd/m^2) and consisted of a schematic face (2.8°x 3.2°), presented at the fixation and two boxes (2.4°x 2.8°, 5 pixel wide) presented 8° to the left and to the right of the fixation. The faces used were identical to those used by Lundqvist & Öhman (Lundqvist & Ohman, 2005). They could have either neutral, happy or angry expression and could be tilted 10° either to the left or to the right of the vertical plane. The face was drawn in black and the rest of the stimuli were dark gray (27 cd/m^2). One group of participants was presented with an upright face, while another group of participants were presented with the same faces, but inverted. The between-subject manipulation was chosen in order to avoid potential carry-over effects that upright faces could have on the processing of inverted faces (Lipp, Price, & Tellegen, 2009).

Participants were seated approximately 75 cm from the screen. The trial started with a fixation point (0.5°), which stayed on the screen for random time between 1150 and 1650 ms. It was followed by a presentation of a schematic face at the fixation for 2000 ms. Participants were instructed to determine in which direction the face was tilted and to make an eye movement to the box positioned in that direction. Hence, if the face was tilted to the left, participants had to make a saccade to the box on the left, and when the face was tilted to the right, participants had to make a saccade to the box on the right (see Figure 1). Participants were informed that the expression of the face was irrelevant to the task.

Insert Figure 1

The face was equally likely to be tilted either to the left or to the right and there was an equal number of different facial expressions in a block of trials. All types of trials were randomly mixed within a block. For each condition (upright face or inverted face) there were 120 trials in total divided in blocks of 30 trials each. Before the start of the experiment participants received a block of 30 practice trials. If during a trial participants moved their eyes in a wrong direction they heard a tone. Participants also received feedback about their accuracy and reaction time after each block. They were encouraged to respond quickly and accurately.

Results

One participant in the upright face condition was replaced because of a high error-rate (>10%). Trials in which participants responded faster than 80 ms or slower than 500 ms were excluded from the analysis. This led to a loss of approximately 4% of the trials.

The saccade latencies for the upright and inverted face conditions are presented in Figure 2. A mixed-effects ANOVA with condition (upright or inverted) as between-subject factor and emotional expression (angry, happy or neutral) as within-subject factor showed only significant interaction between the condition and expression ($F(2, 32) = 4.97$, $p<.05$). There was no main effect of condition ($F(1, 16) = 0.20$, $p=.67$) and a marginal effect of emotional expression ($F(2, 32) = 3.02$, $p=0.06$). Planned comparisons showed that in the upright face condition the emotional expression of the face had an effect on saccade latency ($F(2, 16) = 10.61$, $p<.005$). Participants were 12 ms slower when an angry face was presented at the fixation compared to a happy face ($t(8) = 3.90$, $p < 0.005$). Eye movements following an angry face were also slower (8 ms) than for the neutral face ($t(8) = 3.11$, $p < 0.05$). There was no significant difference between the happy face and the neutral face (3 ms; $t(8) = 1.67$, $p = 0.13$). However in the inverted face condition, there was no effect of the emotional expression whatsoever ($F(2, 16) = 0.40$, $p=.68$).

Insert Figure 2

Overall, participants were quite accurate in both upright and inverted face conditions (97% correct). ANOVA on accuracy did not reveal any significant effects or interactions.

Discussion

The present results clearly show that angry facial expressions tend to hold the eyes and delay disengagement of attention. When participants had to determine the orientation of an angry face the disengagement of the eyes from it was delayed relative to when either happy or neutral facial expressions were presented. Interestingly, there was no difference in disengagement between happy and neutral faces, suggesting that delay in disengagement was specific to angry faces. Furthermore, there was no difference in disengagement among different expressions when the faces were inverted, indicating that the low-level features were not responsible for this effect.

It is important to realize that in our task the facial expression was completely irrelevant: participants only had to determine the orientation of the face and make a saccade in the appropriate direction. We believe that the task of orientation discrimination engaged attention, which was subsequently disengaged when saccade had to be made. One could argue that the face tilt was very salient and its discrimination did not require attention. This is highly unlikely given that attention is needed even for detection of very simple features, such a color pop-out (Theeuwes, Van Der Burg, & Belopolsky, 2008). Therefore, a much more demanding discrimination task certainly requires the engagement of attention.

Despite being irrelevant, threatening information conveyed by angry emotional expression delayed disengagement, suggesting that processing of such information is largely automatic. This is consistent with previous studies that showed that the amygdala - a subcortical structure that is specialized in detection of fear-related stimuli - is activated very rapidly, requires minimal attentional resources (e.g., Vuilleumier, Armony, Driver, & Dolan, 2001) and can operate without conscious awareness (Pasley, Mayes, & Schultz, 2004).

Our results confirm and expand the results from previous studies that measured disengagement of covert attention (Fox et al., 2001; Fox et al., 2002; Georgiou et al., 2005). In the present study we recorded eye movements and were able to directly assess the time-course of disengagement of attention from threat-related faces. Eye movements allow us to select and track the most important information in the environment by directing the high-resolution fovea to the locations of interest. This is particularly important when confronted with dangerous objects in the environment, which we do not want to leave out of sight. Since eye movements provide a good indication of where the cognitive resources are allocated to and for how long (Just & Carpenter, 1980), the delayed disengagement of the eyes from the angry faces suggests that extended monitoring of this potentially threatening information was initiated automatically. According to one hypothesis this delayed disengagement of attention can be related to behavioral freezing, frequently observed when an animal is faced by a predator (Fox et al., 2001; Le Doux, 1996). This freezing might be an evolutionary mechanism developed in order to help the animal to stay undetected and perhaps to develop an escape option before leaving the predator unattended. Indeed, shortly before they eyes leave fixation, the processing resources shift to the location of the future fixation (Deubel & Schneider, 1996), leaving the individual vulnerable to attack. Therefore, disengagement of the eyes from the source of threat only makes sense when the safety plan is developed and is ready to be executed. This view of delayed disengagement as a separate monitoring component of reaction to threat can explain the paradox that threatening stimuli are generally detected and processed faster, but at the same time require more attention and trigger elaborate processing.

In other view, delayed disengagement from threat has been suggested to represent maladaptive form of behavior since it has been primarily observed in high-anxious individuals (Fox et al., 2001; Fox et al., 2002; Georgiou et al., 2005). Specifically, it has been proposed that the bias to maintain attention at the source of threat could be related to the increased levels of anxiety (Compton, 2000). Note that threat monitoring function that is common to all individuals could be exaggerated in high-anxious individuals. Manual reaction time tasks could be sensitive enough to detect the delayed disengagement of attention in high-anxious people, but might be not sensitive enough to detect it in low-anxious people. This could be the reason why we were able to observe delayed disengagement of the eyes in a random sample of college students. In the future studies it would be interesting to examine whether angry faces hold the eyes even more in high-anxious individuals.

To summarize, our results show that threatening faces can hold the eyes. Even though a threatening face may be unpleasant people have trouble moving their eyes away even when they are instructed to do so. These findings provide direct support for the delayed disengagement hypothesis (Fox et al., 2001; Fox et al., 2002; Georgiou et al., 2005). In addition to frequently reported fast orienting of attention to threatening information (e.g., Mineka & Ohman, 2002), the delayed disengagement of attention constitutes another important behavioral component, which might have evolved because of the need to monitor the threatening information and to have time to develop an escape plan before leaving the source of threat unattended.

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Figure Caption

Figure 1. Examples of the stimulus displays used in the experiment. Participants had to make an eye movement to the box in the direction of which the face was tilted. The facial expression was irrelevant to the task.

Figure 2. Mean correct reaction times as a function of facial expression. The error bars represent normalized standard errors of the mean for within-subject design within each condition (Loftus & Masson, 1994).

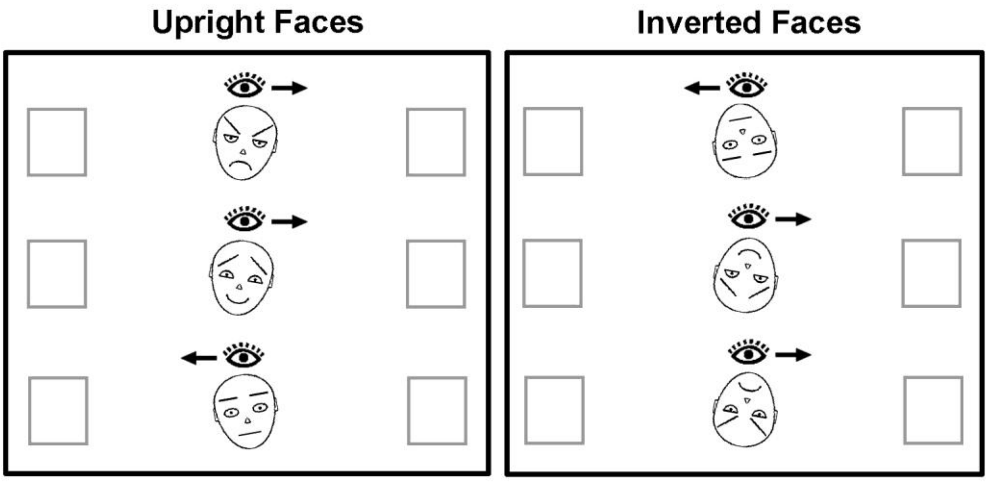

Figure 1

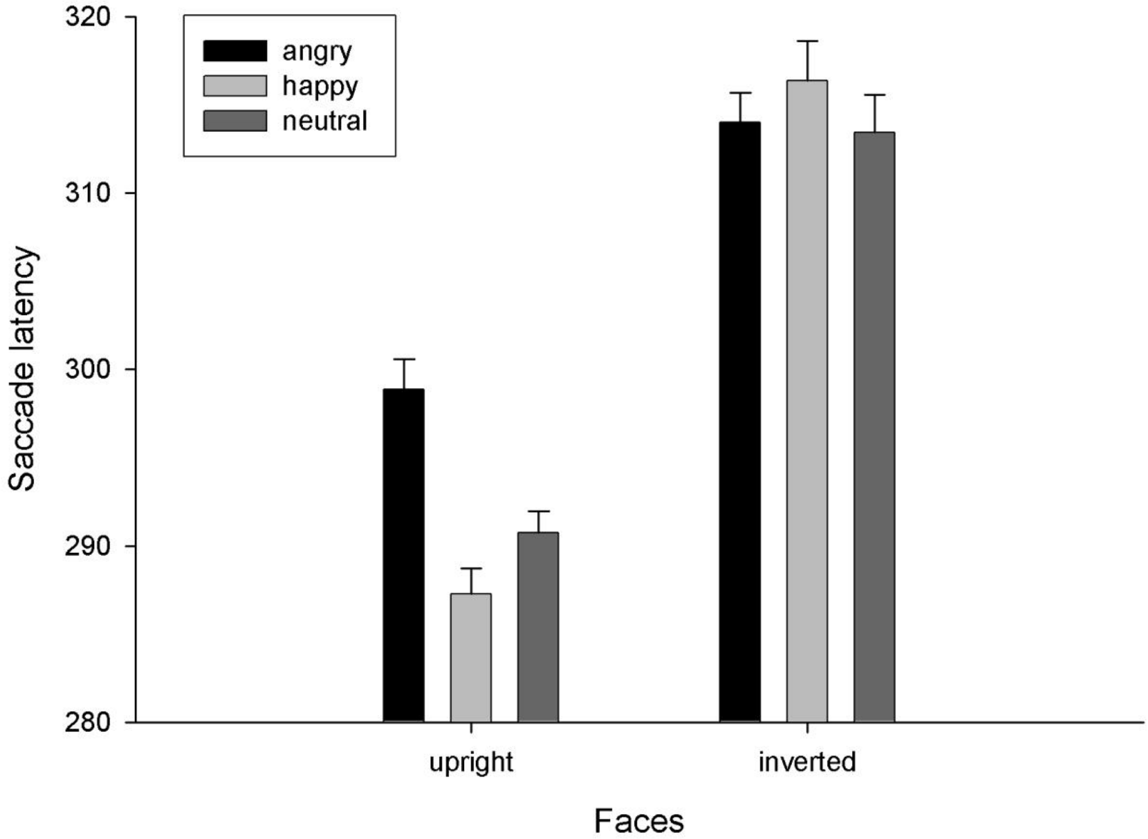
angry
happy
neutral
Saccade latency
320
310
300
290
280
upright
inverted
Faces

Figure 2