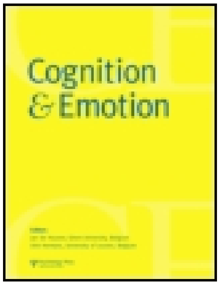

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Gaze direction and facial expressions exert combined but different effects on attentional resources

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BRIEF REPORT

Gaze direction and facial expressions exert combined but different effects on attentional resources

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Gaze direction and facial expressions are critical components of face processing and have been shown to influence attention deployment. We investigated whether gaze direction (direct vs. averted) combined with a neutral or angry expression modulates the deployment of attentional resources over time. In a Rapid Serial Visual Presentation (RSVP) paradigm participants had to decide the gender of a neutral or an angry target face with direct or averted gaze (T1) and then to judge the orientation of a target picture of a landscape (T2), following the face at different time intervals. Results showed no attentional blink effect (i.e., no deterioration in T2 accuracy) when T1 was an angry face with direct gaze, whereas it was present for angry faces with averted gaze or neutral faces with either averted or direct gaze. These findings are consistent with appraisal theories and are discussed against the background of automatic processing of threat stimuli.

Keywords: Angry facial expressions; Gaze direction; Attentional resources; RSVP paradigm; Attentional blink.

Faces are important social stimuli. The information contained in faces, especially the eye region, is multifaceted and of high biological relevance as it allows inferences to be made about the internal state and intentions of others. Evidence suggests that both gaze direction and facial expression are

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critical components of face processing and exert a strong influence on attention (e.g., Palermo & Rhodes, 2007; Vuillemier, 2005). Both gaze direction and facial expressions are changeable aspects of faces, thus it is useful for our cognitive system to rely on more than just one source of information. In particular, the emotional expression, coupled with the direction of gaze, indicates not only where another person is attending to but also whether the person is benevolent or hostile toward the attended object. Hence, from an evolutionary point of view it is plausible that gaze direction and facial emotion interact and are processed in an integrated manner (e.g., Ganel, Goshen-Gottstein, & Goodale, 2005; Lombmaier, Tiddeman, & Perrett, 2008). Recent studies have suggested a degree of interaction between gaze direction and facial expression (e.g., Adams & Kleck, 2003; Bindemann, Burton, & Langton, 2008; Lombmaier et al., 2008). For example, Adams and Kleck (2003) showed that gaze direction influenced the perception of particular emotional expressions. Namely, direct gaze enhanced the perception of approach-oriented emotions, such as anger and joy, while averted gaze enhanced the perception of avoidance-oriented emotions, such as sadness and fear. In particular, they found shorter response latencies when participants had to judge angry and joyful emotions on faces with direct gaze than when their gaze was averted. The opposite was true when they had to judge fearful and sad faces. In agreement with these behavioural data, several recent studies have suggested the existence of some overlap in the brain areas that underlie facial emotion processing and gaze perception (e.g., Engell & Haxby, 2007).

In addition, it has been proposed that the interaction between facial expressions and gaze direction is the basis of the appraisal of the emotional meaning of a stimulus because it signals the intention and the target of visual attention of the other person expressing the emotion. Within the framework of the appraisal theory of emotions (Sander, Grandjean, Kaiser, Wehrle, & Scherer, 2007), an angry face, for example, represents a greater threat when combined with a direct gaze rather than an averted gaze. This is because an angry face with a direct gaze not only communicates to the observer that a threat is approaching but also that the target of the threat is the observer.

There is an open debate on whether emotional faces and threatening stimuli demand attention to be processed (see Palermo & Rhodes, 2007, for a review). Recently, it has been argued that threatening stimuli have a prioritised access to limited cognitive resources (e.g., Öhman, Lundqvist, & Esteves, 2001). This suggests that few attentional resources are required for processing stimuli associated with threat or danger. A paradigm commonly used to assess the deployment and temporal dynamics of attentional resources is the Rapid Serial Visual Presentation (RSVP) paradigm. In this paradigm, two target elements (referred to as T1 and T2) are embedded within a stream of successive distracters, and participants are required to identify both of them. When T2 is presented in close proximity to T1 (100–500 ms) participants often fail to identify T2. This phenomenon is known as attentional blink (AB) and is thought to reflect competition between the two stimuli (T1 and T2) for attentional resources. In other words, attending to T1 and consolidating it into working memory leaves little or no attentional resources for the processing of T2 (see Olivers & Nieuwenhuis, 2006, for a review; see also Martens & Wyble, 2010, for alternative interpretations).

The effects of emotional face expression and threatening stimuli on AB have already been demonstrated using the RSVP paradigm (e.g., de Jong, Koster, van Wees, & Martens, 2010; Maratos, Mogg, & Bradley, 2008; Milders, Hietanen, Leppänen, & Braun, 2011; Milders, Sahraie, Logan, & Donnellon, 2006; Most, Chun, Widders, & Zald, 2005; Most & Jungè, 2008). However, gaze direction has not been taken into account as a factor influencing the emotional and social meaning of face expressions. In the context of social interactions, angry faces represent a particular class of emotional and socially threatening stimuli as they express a strong disapproval towards the observer. Therefore, their processing may be facilitated and require few attentional resources. Few studies have presented an angry face in T1 and the studies that did so have required an explicit judgement of the emotion (e.g., de Jong & Martens, 2007; de Jong et al., 2010). For instance, de Jong et al. (2010) administered a RSVP task to high and low socially anxious women with emotional faces (neutral, happy and angry) presented as T1, and neutral letter stimuli presented as T2. Participants were instructed to indicate whether they had seen an upright face and to indicate its emotional expression and, if they subsequently had seen a letter, to identify it. They found that, irrespective of anxiety level, the AB effect (i.e., impaired T2 identification) was larger when angry faces were presented as T1. However, the fact that emotion was always relevant for the T1 task might have biased the extent to which attention gates emotion processing, resulting in less spontaneous processing of emotional expressions regardless of the threatening meaning of facial expression. Moreover, to date it has not been specifically tested whether the AB effect, evident with emotional facial expression in T1, is modulated by gaze direction.

As outlined above, an angry face represents a greater threat when combined with a direct gaze rather than an averted gaze because it signals to the observer that the target of the threat is the observer her- or himself. Therefore, it is plausible that its prioritised processing is affected by gaze direction. In other words, the priority in the selection process of an angry face with a direct gaze (compared to one with an averted gaze) could occur without the need of a top-down deployment of attention (e.g., Fox, Russo, & Georgiou, 2005), leaving more attentional resources available for processing subsequent stimuli. This would reduce the AB for any stimulus following an angry face with direct gaze.

To test this hypothesis, we manipulated gaze direction and employed the RSVP paradigm in which we presented a neutral or angry facial expression either with a direct or an averted gaze as T1 and a landscape as T2. Importantly, to make sure that we were testing the spontaneous requirement of attention for the processing of the threatening angry face, we made the emotional face expression task-irrelevant. Participants, in fact, were instructed to discriminate the gender of the T1 face and the orientation of the T2 landscape. We expected that, if an angry face with a direct gaze demands little or no attentional resources to be processed, resources should be available for the processing of T2 and hence we should not find a decrease in accuracy on T2 (reduced or no AB). The AB should instead be evident when the direction of gaze was averted.

METHOD

Participants

Twenty-one right-handed students (mean age: 22.1 years; *SD* 5.8; 14 females) from the University of Bologna participated in the experiment. All had normal or correct-to-normal vision.

Apparatus and stimuli

Participants entered a sound-attenuated, dimly lit room and were seated with their chin placed on a rest. Stimuli were presented on a 17″ CRT screen driven by a 700 MHz processor computer, located 60 cm from the observer. Stimulus presentation and response registration were controlled by the E-Prime v1.1 software.

Stimuli were greyscale photographs of four different Caucasian faces and 14 landscapes. All stimuli were cropped to remove extraneous background and measured $4.1° \times 5.9°$. The landscape photographs were selected from open-access internet images. Face stimuli were selected from the Karolinska Directed Emotional Faces set (KDEF; Lundqvist, Flykt, & Öhman, 1998) and depicted two women and two men (all unknown to the participants) showing both a neutral and an angry facial expression with direct gaze. We focused only on angry expressions because, on the basis of the appraisal theory, we hypothesised that the threatening value of an angry expression is stronger for the observer than that of any other emotional expressions (see also introduction) including fearful expressions. Although a fearful face with an averted gaze (more than with a direct gaze) can also be associated with a threat, it nevertheless indicates only the presence of an unknown threat in the environment, but it is unclear whether the threat is direct to the observer or not. Moreover, in the literature the influence of averted gaze on the perception of fearful faces has not always been confirmed and has been shown to be less robust than that of direct gaze on angry faces (e.g., Bindemann et al., 2008).

Two new versions of each face stimulus were created using Adobe Photoshop software: one version gazing left and the other gazing right, resulting in twenty-four pictures (4 different individuals $\times$ 2 facial expressions $\times$ 3 gaze directions). An example of the stimuli used in the experiment is displayed in Figure 1a.

A rating analysis was performed on the selected faces to assess whether the neutral and angry emotions were actually conveyed.[1] Landscapes were drawn from a pool of 50 landscape photographs that had been rotated 90° either clockwise or counter clockwise (while maintaining the same proportions as the non-rotated images), resulting in forty-two pictures (14 different landscapes $\times$ 3 orientations).

Procedure

Trials consisted of an RSVP of 16 images, each presented centrally for 135 ms. Except for two images, all were upright landscape photos. These two images consisted of angry or neutral versions of the faces (T1) with direct or averted (50% direct gaze, 25% gaze averted right and 25% gaze averted left, respectively) gaze direction and the rotated (90 degrees to the right or to the left) landscape target (T2) stimulus. Thus, trial types across gaze, facial emotion and lag were equiprobable. A different random order of trials was automatically assigned to each participant by the E-Prime software. Depending on the trial, at the beginning of the sequence a number of empty images (i.e., square patches with the same colour as the background) were presented in place of the upright landscape images, so that the number of visible items preceding T1 randomly varied from 4 to 7. T2 was presented one, three or six items after T1 (Lag 2, 4, 7, respectively; see Figure 1b). Accordingly, stimulus onset asynchronies (SOAs) between T1 and T2 were 270 ms (Lag 2), 540 ms (Lag 4), and 945 ms (Lag 7).

Participants initiated each trial by pressing the space bar. At the end of the trial, a first question appeared on the screen prompting participants to discriminate the gender of the T1 face by pressing the F-key, labelled with a tag "F" (female) and the K-key, labelled with a tag "M" (male). A second question was then presented requiring participants to distinguish the orientation of the T2 landscape by pressing the M-key, labelled with a tag "O" (clockwise) and the V-key, labelled with a tag "A" (anti-clockwise). Subsequently, a feedback on accuracy for both responses was given.

Instructions emphasised that the response speed was not recorded, and stressed response

[1]Ten raters, tested individually, were instructed to evaluate on a 5-point Likert scale (1 = *for nothing*, 5 = *extremely*) how intensely five different emotions (i.e., angry, disgusted, happy, neutral and sad) were conveyed by the face targets (2 women and 2 men) who showed angry or neutral facial expressions with both averted and direct gaze direction. The mean rating scores were submitted to a repeated-measures ANOVA with Type of Question (angry vs. disgusted vs. happy vs. neutral vs. sad), Type of Expression (angry vs. neutral) and Gaze Direction (averted vs. direct) as factors. The main results were the significant Type of Question $\times$ Type of Expression, $F(4, 36) = 107.99$, $p < .001$, and Type of Question $\times$ Type of Expression $\times$ Gaze Direction, $F(4, 36) = 8.49$, $p < .001$, interactions. Post hoc analyses of the first-order interaction indicated that for the angry facial expression, the mean rating scores were higher in the angry type of question condition (4.4) than in the others (1.2, on average), $ts(9) > 7.87$, $ps < .001$. For the neutral facial expression, the mean rating scores were higher in the neutral type of question condition (3.8) than in the others (1.4, on average), $ts(9) > 4.33$, $ps < .001$. Post hoc analyses of the second-order interaction clarified that scores for averted and direct gaze did not differ in any combination with type of expression and type of question except for the neutral expression–neutral question condition (4.2 and 3.4, respectively). To investigate the role of each face identity, a further ANOVA was performed with Congruent Question and Face Expression (angry–angry vs. neutral–neutral), Gaze Direction (averted vs. direct) and Individuals (1 vs. 2 vs. 3 vs. 4) as within-subjects factors. No significant interaction of these three factors was found, $F < 1$, indicating that the previous results applied to each of the four identities.

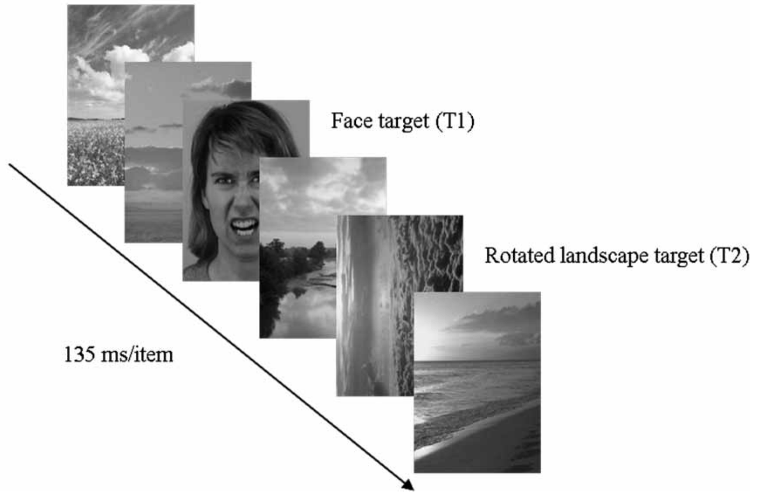


Figure 1. *(a) Example of face stimuli showing angry and neutral facial expressions with a direct or an averted (left or right) gaze. (b) Example of part of a rapid serial visual presentation (RSVP) trial. Here, the face target (T1) is an angry face with direct gaze and the rotated landscape target (T2) appears one item after it (Lag 2).*

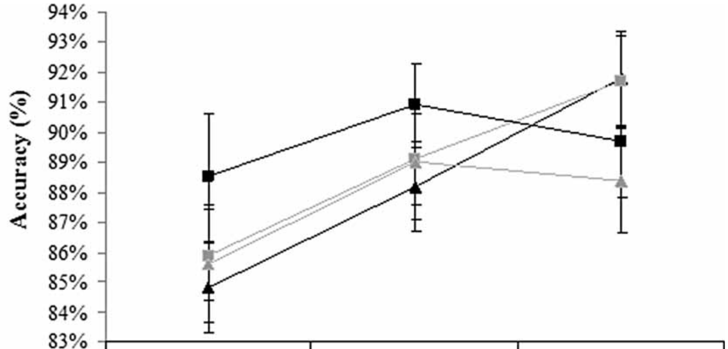
accuracy. The experiment comprised 384 trials split into two blocks of 192 trials. Participants were allowed to take a short break between the blocks.

RESULTS

T2 accuracy rates were computed for T1-correct trials only (99% of total trials, $SD = 0.86\%$) and submitted to a 2 (Facial Expression: angry vs. neutral) $\times$ 2 (Gaze Direction: averted vs. direct) $\times$ 3 (Lag: Lag 2 vs. Lag 4 vs. Lag 7) within-subject analysis of variance (ANOVA). The respective data are shown in Figure 2.

The analysis revealed main effects of Gaze Direction, $F(1, 20) = 4.51$, $p < .05$, $\eta^2_p = .18$ and Lag, $F(2, 40) = 11.65$, $p < .001$, $\eta^2_p = .37$. Accuracy was lower when gaze was averted ($M = 88\%$, $SD = 6.04\%$) compared to when it was direct ($M = 89\%$, $SD = 5.98\%$). Mean accuracy rates were 86% ($SD = 6.87\%$), 89% ($SD = 5.79\%$), and 90% ($SD = 6.21\%$) for Lag 2, 4 and 7, respectively. Paired-samples t-tests showed significant differences between Lags 2 and 4, $t(20) = 3.05$, $p < .01$, and between Lags 2 and 7, $t(20) = 5.0$, $p < .001$. The difference between Lags 4 and 7 did not reach significance, $t(20) = 1.29$, $p = .21$.

First-order interactions did not reach significance, Fs < 1, $\eta^2_p < .02$. However, the second-order Facial Expression $\times$ Gaze Direction $\times$ Lag interaction was significant, $F(2, 40) = 3.38$, $p < .05$, $\eta^2_p = .14$. Separate analyses by levels of Facial Expression showed that the Gaze Direction $\times$ Lag interaction was significant for angry Facial Expression, $F(2, 40) = 3.69$, $p < .05$, $\eta^2_p = .16$ but not for neutral Facial Expressions, $F < 1$, $\eta^2_p = .04$.



	Lag2	Lag4	Lag7
angry face_direct gaze	89%	91%	90%
angry face_averted gaze	85%	88%	92%
neutral face_direct gaze	86%	89%	92%
neutral face_averted gaze	86%	89%	88%

Figure 2. *Mean accuracy for angry and neutral facial expressions with averted and direct gaze directions at Lag 2, 4 and 7. Error bars in the graph show standard error of the mean.*

For angry facial expressions, accuracy did not differ as a function of Lag for the direct gaze condition ($M = 89\%$, $SD = 9.85\%$; $M = 91\%$, $SD = 6.40\%$; and $M = 90\%$, $SD = 8.57\%$, for Lags 2, 4 and 7, respectively), $ts(20) < 1.2$, $ps > .24$. In contrast, in the averted gaze condition, accuracy increased as a function of Lag ($M = 85\%$, $SD = 7.01\%$; $M = 88\%$, $SD = 6.91\%$; and $M = 92\%$, $SD = 7.22\%$, respectively). T-tests showed significant differences between Lags 2 and 4, $t(20) = 2.29$, $p < .05$, between Lags 4 and 7, $t(20) = 2.38$, $p < .05$, and crucially between Lags 2 and 7, $t(20) = 4.79$, $p < .001$. The difference between averted and direct gaze conditions was significant at Lag 2, $t(20) = 2.11$, $p < .05$, tended to significance at Lag 4, $t(20) = 1.87$, $p = .08$, and was not significant at Lag 7, $t(20) = 1.18$, $p = .25$.

For neutral facial expressions, only the main effect of Lag was significant, $F(2, 40) = 8.08$, $p < .01$, $\eta_p^2 = .29$. Mean accuracy rates were 86% ($SD = 7.09\%$), 89% ($SD = 6.57\%$), and 90% ($SD = 6.18\%$) for Lags 2, 4 and 7, respectively. T-tests showed significant differences between Lags 2 and 4, $t(20) = 2.67$, $p < .05$, and between Lags 2 and 7, $t(20) = 3.85$, $p < .01$. The difference between Lags 4 and 7 did not reach significance, $t(20) = 0.98$, $p = .34$ (see Figure 2).

DISCUSSION

We sought to investigate using the RSVP paradigm whether the processing of gaze direction (direct vs. averted), combined with a neutral or angry facial expression, demands different amounts of attentional resources. Although gaze direction and facial expression were task-irrelevant we found a modulation of the AB effect depending on their specific combination. Specifically, we found that an angry face with direct gaze (T1) does not disrupt the processing of a subsequent non-face target (T2), as indicated by the absence of the AB effect. However, the AB effect was present for angry faces with averted gaze and for neutral faces with either averted or direct gaze. It is implausible that the drop in accuracy at Lag 2 (270 ms; i.e., the AB) in the averted gaze conditions is due to attention being spatially and temporarily oriented away from T2 by gaze direction, given that spatial attention needs some time to be oriented by gaze cues. Driver and coworkers (1999) in their pioneering study on gaze cueing of visuospatial attention found that with complex visual stimuli such as photos of faces (similar to those used here), the cueing effect, due to the orienting of spatial attention, emerged only after considerable time was given to process the face and when the target appeared after at least 300 ms from the gaze-cue onset. Therefore, on the contrary, our results are in line with AB literature, which shows that typically AB occurs during a brief time window (about 250 ms). Moreover, we ran an additional ANOVA on averted gaze T2 accuracy with Facial Expression and Lag as factors to test whether AB was similar for angry and neutral faces. This was the case since the analysis showed only a significant main effect of Lag, $F(2, 40) = 6.5$, $p < .01$, due to a significant difference between Lags 2 and 4 ($p < .05$) and Lags 2 and 7 ($p < .001$). No other main effects or interaction reached significance. Comparisons (t-tests) of averted angry and neutral faces at each lag showed only a significant difference at Lag 7 ($p < .05$, 92% vs. 88%, respectively). To directly compare AB in angry and neutral faces with direct gaze we ran a further ANOVA. This analysis showed only a significant main effect of Lag, $F(2, 40) = 5.2$, $p < .05$, due to a significant difference between Lags 2 and 4 ($p < .05$) and Lags 2 and 7 ($p < .01$). The interaction between Facial Expression and Lag failed to reach significance ($p = .13$). Nevertheless, t-tests showed AB only for direct gaze neutral faces since T2 accuracy improved between Lag 2 and Lag 7 only in this condition ($p < .01$, 86% vs. 92%, respectively) but not in the direct gaze angry condition ($p = .46$, 89% vs. 90%, respectively). AB was absent in direct gaze angry faces for which accuracy did not vary as a function of Lag (ps $> .24$). These last comparisons make it unlikely that our main result might be due to direct-gaze faces in general (i.e., independent of facial expression) being processed more efficiently (thus interfering less with the identification of T2), although future research is needed to further corroborate it. Our results are new and extend those of other studies that used RSVP procedures to study the amount of attentional resources required to process threatening stimuli (e.g., de Jong et al., 2010; Fox et al., 2005) by showing that the presence of AB for face stimuli depends on specific combinations of gaze direction and emotional facial expressions.

The functional implications of this interaction are likely to rest on the biological and social meaning of different combinations of gaze direction and facial expression. In fact, consistent with the appraisal theory (Sander et al., 2007), direct gaze with an angry face signals impending aggression towards the observer. This is a condition of clear threat in which we need a very fast and possibly automatic encoding of the threatening face because a swift response to it would provide an evolutionary and adaptive advantage (e.g., LeDoux, 2000). Such rapid processing may be mediated by subcortical brain structures such as the amygdala, which, as well as being involved in emotion and direct gaze processing, can also modulate cortical and attentional processing (e.g., Palermo & Rhodes, 2007; Vuilleumier, 2005). Therefore, this priority in the selection process of the threatening stimulus can then leave more attentional resources available for processing subsequent stimuli, therefore reducing the AB for any stimulus following the threat stimulus. This would explain why we found an absence of AB effect only for angry faces with direct gaze.

In contrast, a direct gaze within a neutral face is less threatening so it may not be processed rapidly and automatically. Similarly, an averted gaze within an angry or a neutral face is less threatening because it signals that the focus of attention of the person is directed elsewhere or, in the case of an angry face, that the threat is addressed elsewhere. Therefore, the processing of these combinations of gaze direction and facial expression may not be prioritised and thus require some attentional resources because they are less threatening. This would explain the presence of AB effect for neutral faces with direct and averted gaze and for angry faces with averted gaze. Although one might expect that, due to their threatening value, faces with an angry direct gaze should produce more interference this might depend on task demand. Direct gaze fast-track processing in fact could compete, thus interfering, with top-down allocation of attention based on instruction and/or task demand (Senju & Johnson, 2009; see also below).

Our results are also consistent with the existence of an early warning system, which, as well as providing a rapid and preattentive evaluation of the emotional threatening stimulus, concurrently enhances the sensory processing of *subsequent* non-threatening stimuli (e.g., Becker, 2009) by devoting more attentional resources to them. Indeed, it may be that the prioritised processing of the threatening stimuli calls and directs attention to the threatening stimulus itself and holds attention in that place, boosting the processing of subsequent stimuli that appear in the same position. This enhanced processing would also explain the lack of AB effect for targets appearing after angry faces with direct gaze.

Both these explanations (i.e., prioritised processing of threatening stimuli, which leaves spare attentional resources for processing a subsequent target, and enhanced processing of a target following a threatening stimulus) are plausible and do not exclude each other because the spared resources can then be devoted to enhancing the processing of a non-threat stimulus that follows the threatening one.

However, the present findings seem to be in conflict with the findings by Most et al. (2005), which showed that irrelevant emotionally negative pictures induced temporary visual processing impairments for targets appearing soon after them. Specifically, within an RSVP of pictures, people often failed to discriminate rotated targets (i.e., landscapes or architectural buildings) following the presentation of images of violence, distress and medical trauma. Such emotion-induced blindness was interpreted as reflecting a delayed disengagement of attention from negative valence stimuli. However, in Most et al.'s study threatening emotional faces with different gaze direction were not used and the apparent conflicting results might be due to a difference in the appraisal of emotional stimuli of direct relevance to the observer (e.g., Murphy, Hill, Ramponi, Calder, & Barnard, 2010; Sander et al., 2007). Angry faces with direct gaze are more likely to trigger a faster and automatic (or bottom-up) appraisal process, sparing more attentional resources than a picture reproducing a scene of violence.

Similarly, the discrepancy with the findings of de Jong et al. (2010) might be due to some methodological differences with the present study. In particular, these authors explicitly asked participants to identify the emotional expression of the face presented in T1, whereas in our task the emotional expression was task-irrelevant since participants were asked to discriminate the gender of the face presented in T1. This might have unbalanced the top-down allocation of attentional resources towards T1, resulting in an exaggerated or disproportional allocation of attention to threatening faces. Instead, as also acknowledged by de Jong and colleagues (2010) themselves, making the emotional expression task-irrelevant, as we did, allows a better bottom-up examination of the amount of attention required through time by the processing of emotional expressions.

An interesting issue for future research would be to investigate the effect on attention of combining direct and averted gaze with other facial emotions. For example, a fearful face with an averted gaze is also an important stimulus for survival because gaze direction signals where in the surrounding environment a threat may come from. As mentioned earlier, the threatening value of a fearful face with an averted gaze might be weaker than that of an angry face with direct gaze, nevertheless such a stimulus has an important adaptive value therefore its processing may be prioritised. While the present article was being revised, a relevant study by Milders and co-workers (2011) came to our attention. In an AB task, the authors asked participants to judge the gender of a neutral face presented in T1 and indicate whether they had seen a second face (T2). Fearful faces presented in T2 were detected more frequently with an averted gaze than with a direct gaze. To find that fearful faces with averted gaze do not produce AB when presented in T1 would extend our explanation of fast and automatic processing of threat signals to another combination of gaze direction and emotional facial expression.

In conclusion, the present findings provide further evidence that sensory processing and attention can be modulated by the affective significance of stimuli. This suggests that a complete account of the processing of gaze and expression information must include their interactive effects on attention.

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