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BRIEF REPORTS

The Fearful-Face Advantage Is Modulated by Task Demands: Evidence From the Attentional Blink

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Fearful faces receive privileged access to awareness relative to happy and nonemotional faces. We investigated whether this advantage depends on currently available attentional resources. In an attentional blink paradigm, observers detected faces presented during the attentional blink period that could depict either a fearful or a happy expression. Perceptual load of the blink-inducing target was manipulated by increasing flanker interference. For the low-load condition, fearful faces were detected more often than happy faces, replicating previous reports. More important, this advantage for fearful faces disappeared for the high-load condition, during which fearful and happy faces were detected equally often. These results suggest that the privileged access of fearful faces to awareness does not occur mandatorily, but instead depends on attentional resources.

Keywords: attention, awareness, fearful faces, attentional blink, perceptual load

In daily life, the visual system is typically confronted with complex and cluttered visual scenes. To allow for adaptive behavior, relevant subsets of the scene have to be selected for further perceptual analysis. *Selective attention* refers to the process of enhancing representations of behaviorally relevant sensory input at the cost of irrelevant input. Attention can be allocated based on endogenous, top-down, factors as well as exogenous, stimulus-related factors such as sensory salience. Although these sources of attentional control are obviously important in daily life, for the survival of the organism it is fundamental to rapidly process emotional and in particular threat-related stimuli, even when attention is currently engaged. Indeed, a large number of studies have provided evidence that attentional resources are biased toward emotional stimuli, particularly fearful and threatening stimuli, in a relatively reflexive manner (for a review, see Vuilleumier, 2005). This attentional bias subsequently leads to enhanced processing of emotionally salient events. In the present study we tested whether this processing advantage for emotionally salient stimuli can still occur under conditions in which attentional resources are depleted. Specifically, we used a modified version of the attentional blink paradigm (AB; Raymond, Shapiro, & Arnell, 1992) to investigate to what extent the processing advantage for fearful faces, relative to happy faces, depends on available attentional resources.

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In a typical AB experiment two target items are presented in close temporal succession in a rapid serial visual presentation (RSVP) of irrelevant items. Report of the first target (T1) leads to an impoverished detection of the second target (T2) when the two targets are separated by few intervening irrelevant items. The AB has been attributed to attentional demands associated with T1 processing, because identification performance of T2 is not affected when T1 can be ignored (Chun & Potter, 1995; Shapiro, Raymond, & Arnell, 1994). We find it interesting that the AB is attenuated when emotion-laden items are presented at T2, such as arousing words (Anderson, 2005; Anderson & Phelps, 2001; Keil & Ihssen, 2004; Ogawa & Suzuki, 2004), fearful faces (De Martino, Kalisch, Rees, & Dolan, 2009; Fox, Russo, & Georgiou, 2005; Milders, Sahraie, Logan, & Donnellon, 2006), schematic angry faces (Maratos, Mogg, & Bradley, 2008), arousing scene photographs (Trippe, Hewig, Heydel, Hecht, & Miltner, 2007), or aversively conditioned stimuli (Milders et al., 2006). Thus, emotionally arousing stimuli partially overcome attentional limitations imposed by T1 processing and gain preferential access to subjective awareness.

Similarly, nonemotional high-priority stimuli such as the participant's own name can survive the AB (Shapiro, Caldwell, & Sorensen, 1997), indicating that T2 information is processed to late, postperceptual processing stages. This finding is in accordance with models that assume the AB to reflect a failure of a postperceptual selection mechanism (Chun & Potter, 1995; Jolicœur & Dell'Acqua, 1998; Shapiro et al., 1994). By contrast, current theories of spatial attention typically propose that selection can operate at multiple-processing stages and flexibly adapt to current task demands. For example, the prominent "load theory" (Lavie, 2005) posits that task-irrelevant distractors are processed to late stages when processing of task-relevant stimuli does not require all perceptual resources. However, when the task at hand involves high perceptual load, distractors are hardly processed beyond the perceptual level. Consistent with the assertion of flexible attentional selection according to perceptual load, Giesbrecht, Sy, and Lewis (2009) recently demonstrated that the participant's own name does not survive the AB better than other names presented at T2 when T1 perceptual load is high. Thus, the advantage of highly familiar and personally salient information such as the observer's own name depends on currently available resources.

In the present study we investigated if this dependence on T1 task demands is also observed for the advantage of emotionally arousing T2 stimuli. Specifically, we asked how increased demands in reporting T1 affected the detection of fearful and happy faces presented at T2. To that end, we manipulated the perceptual load of T1 by using a variant of the flanker paradigm (Eriksen & Eriksen, 1974). Higher perceptual load associated with T1 processing should lead participants to devote more resources to T1, thereby leaving less capacity for T2 detection (Lavie, 2005). This manipulation allowed us to test whether the processing advantage for fearful relative to happy faces depends on available attentional resources.

Participants were required to identify the gender of an emotionally neutral face (T1) and subsequently report if they detected a second intact face (T2) embedded in an RSVP sequence of scrambled faces. T1 could be either flanked by the same face ("low-T1-load" condition), or by randomly assigned different faces ("high-T1-load" condition). When T2 was present, it followed T1 by a lag of either two or seven items and could depict either a happy or a fearful face. An effective T1-load manipulation would be indicated by worse T1 performance in the high-T1-load condition compared to the low-T1-load condition. We expected T2 to be detected less accurately when it closely succeeded T1, that is, to observe an AB. In line with a previous report (Milders et al., 2006), faces displaying a fearful expression were expected to partly overcome the AB relative to faces displaying a happy expression. Further, we hypothesized that high-T1-load would induce generally lower T2 performance.

The critical comparison was whether the advantage for fearful faces over happy faces presented at Lag 2 depended on T1 load. Following results obtained with nonemotional high priority information (Giesbrecht et al., 2009) one prediction is an attenuated AB for fearful faces under low-T1-load only, and a similarly strong AB for fearful and happy faces under high-T1-load. Alternatively, the advantage of survival-relevant stimuli such as fearful facial expressions might be immune to the T1-load manipulation and may thus be observed both under high- and low-T1 load.

Method

Participants

Participants were 26 (15 women, $M = 25.5$ years) volunteers who had normal or corrected to normal vision. All participants gave informed consent.

Apparatus and Stimuli

Observers viewed a 19" CRT monitor in a dimly lit room at a free viewing distance of approximately 55 cm. Stimuli constituting the RSVP series were grayscale photographs (subtending 3.9° × 5.5° of visual angle) derived from the Karolinska Database of Emotional Faces (Lundqvist, Flykt, & Öhman, 1998) that were presented on a black background. T1 stimuli were 12 emotionally neutral face photographs (six female, six male). Concurrently with T1, two flanking stimuli were centered 4.5° to the left and to the right of T1. In the low-T1-load condition, T1 was flanked on each side by the same photograph. In the high-T1-load condition, two different images were randomly sampled from the T1 pool. Thus, in the high-T1-load condition, the flanking stimuli were noninformative regarding T1's gender. Both T1 and its flanking stimuli were dyed green to be distinguishable from the other images. Seventy-two RSVP filler items were generated by dividing the inner elements of the 12 neutral faces used as T1 stimuli into 35 squares and randomly recomposing them. Finally, two photographs depicting a fearful or a happy facial expression, respectively, were derived from 12 newly selected actors (six female, six male) yielding a pool of 12 fearful T2 stimuli, and a pool of 12 happy T2 stimuli. Twenty-two independent judges rated each of the face photographs used as T2 stimuli for valence based on a scale ranging from 1 (*negative*) to 7 (*positive*) and arousal based on a scale ranging from 1 (*unstimulating*) to 7 (*very stimulating*). Fearful faces were rated to be more negative than happy faces ($M = 2.12$ and $M = 5.98$, respectively), $t(22) = -21.51$, $p < .001$. Furthermore, fearful faces received higher arousal scores than happy faces ($M = 5.42$ and $M = 3.94$, respectively), $t(22) = 9.19$, $p < .001$.

Design and Procedure

Each trial started with a 1.5-s presentation of a white fixation cross in the center of the screen that disappeared for a period of 300 ms to indicate the beginning of the RSVP series, followed by the sequential presentation of 22 centered stimuli (see Figure 1). In 50% of the trials, T1, T2, and 20 filler items were displayed (T2 present trials), while in the other 50% of the trials, only T1 and 21 filler items were presented (T2 absent trials). In all trials, two

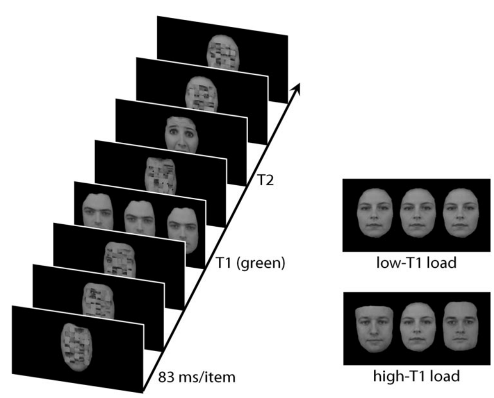

Figure 1. Schematic of an example trial. Participants had to report the gender of the centrally presented face photograph colored in green (T1) and subsequently indicate if they detected a second intact face (T2). T1 was always flanked by two other faces that were dyed green also. In the low-T1-load condition, T1 was flanked by an identical face. In the high-T1-load condition, two different randomly sampled faces were presented at both sides of T1. In 50% of the trials, T2 was present and could either depict a fearful or a happy facial expression. Participants were instructed to make the gender discrimination their first priority.

flanking stimuli appeared concurrently with T1. All items in the sequence were presented for 83 ms and immediately followed by the trailing item. T1 appeared equally often in serial Positions 8 through 12. There were two possible lags between T1 and T2, Lag 2 (one intervening item, stimulus onset asynchrony [SOA] 167 ms), and Lag 7 (six intervening items, SOA 498 ms). At the end of the series, participants were prompted to indicate the gender of the central green face (T1) and subsequently asked if they detected a second intact face (T2). Participants were instructed to make the gender discrimination their first priority (Ward, Duncan, & Shapiro, 1997). No information about the emotional expressions displayed by the face stimuli presented at T2 was provided. Participants were informed that their responses should be made as accurately as possible, without speed pressure. Responses to T1 were made with the left hand by typing "1" for "male face" and "2" for "female face". T2 responses were made with the right hand by pressing "8" for "second face present" and "9" for "second face absent". No feedback was given. The next trial started immediately after the participant made both responses.

Before the testing session started, participants received a practice block containing 20 trials that were excluded from the analysis. Within each testing session, there were six blocks consisting of 80 trials each. The two T1-load conditions were presented in separate blocks and their order was counterbalanced across participants. This blocked design was chosen because randomly intermixing trials with different T1 difficulty levels does not affect the AB (McLaughlin, Shore, & Klein, 2001), probably because participants assume all trials to be of equal difficulty (cf. Giesbrecht et al., 2009). By contrast, when different difficulty levels are segregated to different blocks, T1 difficulty does affect the AB (e.g., Seiffert & Di Lollo, 1997; Shore, McLaughlin, & Klein, 2001). Within a block, during the T2 present trials each combination of the five possible T1 positions × two different T1 lags × two T2 expressions occurred with equal probability. The identities of T1, filler items, and T2 stimuli were selected at random without replacement from their respective stimulus pool for each trial and the trial order was randomized.

The mean false alarm rate on T2 absent trials was 5.3% (SD = 6.2%). T2 absent trials were not included in the analysis.

Results

T1 Identification Accuracy

T1 gender discrimination performance was analyzed in a 2 (T1 load: high, low) × 2 (T2 expression: fearful, happy) × 2 (lag: two, seven) repeated-measures analysis of variance (ANOVA). There were two significant main effects. First, T1 performance was better when T2 was displayed at Lag 7 as compared to Lag 2, $F(1, 25) = 13.35$, $p = .001$, $\eta_p^2 = .35$. Critically, there was an effect of T1 load, $F(1, 25) = 4.60$, $p < .05$, $\eta_p^2 = .16$, showing that T1 performance was better during the low-T1-load condition, thereby confirming the effectiveness of our manipulation (see Figure 2a). There was no main effect of T2 expression, $F(1, 25) < 1$, and neither the two-way interactions between T2 expression and lag, $F(1, 25) = 2.82$, ns, $\eta_p^2 = .10$, and between T1 load and T2 expression, $F(1, 25) = 1.12$, ns, $\eta_p^2 = .03$, nor the three-way interaction between T1 load, T2 expression, and lag, $F(1, 25) < 1$, reached significance.

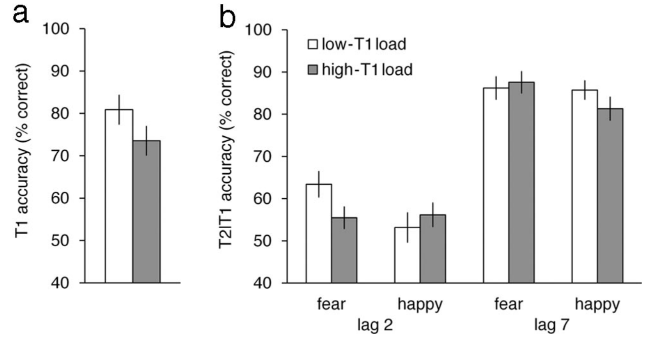

Figure 2. Results. (a) Mean percentage of accurate T1 gender identification for the T2-present trials, presented separately for the low-T1-load condition and the high-T1-load condition. (b) Mean percentage of correct T2 detection at each T1–T2 lag, depicted separately for the load conditions and T2's emotional expressions. Error bars represent standard errors of the means (Loftus & Masson, 1994).

T2 Detection Accuracy

For T2 present trials, analyses of T2 detection rates were based solely on trials in which T1 was correctly reported because in T1 incorrect trials the source of T2 errors is unknown (Chun & Potter, 1995). Figure 2b shows the percentages of correct T2 detection as a function of T1 load, T2 expression, and lag. Comparing T2 detection rates in a 2 (T1 load: high, low) × 2 (T2 expression: fearful, happy) × 2 (lag: two, seven) repeated-measures ANOVA revealed a main effect of expression, $F(1, 25) = 8.69$, $p < .01$, $\eta_p^2 = .26$, demonstrating that fearful faces were more frequently detected than happy faces. There was also a main effect of lag, $F(1, 25) = 38.41$, $p < .0001$, $\eta_p^2 = .61$, with higher detection rates at Lag 7 as compared to Lag 2, indicating that an AB was successfully induced (Chun & Potter, 1995). T1 load did not exert a significant effect on T2 detection, $F(1, 25) = 1.60$, ns, $\eta_p^2 = .06$. More important, the three-way interaction between T1 load, expression, and lag was significant, $F(1, 25) = 11.25$, $p < .005$, $\eta_p^2 = .31$.

We followed up on the significant three-way interaction by performing separate two-way ANOVAs for both lags.

The two-way ANOVA for Lag 2 trials yielded a main effect of expression, $F(1, 25) = 5.08$, $p < .05$, $\eta_p^2 = .17$, with fearful faces being overall more frequently detected than happy faces, replicating previous reports (De Martino et al., 2009; Milders et al., 2006). Critically, we found an interaction between T1 load and expression, $F(1, 25) = 5.91$, $p < .05$, $\eta_p^2 = .19$. In the low-T1-load condition detection rates for fearful faces were higher than for happy faces, $t(25) = 3.21$, $p < .005$, although this advantage for fearful faces was absent in the high-T1-load condition, $t(25) = 0.23$, ns. Furthermore, fearful faces were detected significantly more frequently in the low-T1-load compared to the high-T1-load condition, $t(25) = 2.53$, $p < .05$. For happy faces, no such difference was observed, $t(25) = -0.86$, ns.

The two-way ANOVA for Lag 7 trials revealed only a main effect of expression, $F(1, 25) = 9.13$, $p < .01$, $\eta_p^2 = .27$, showing that fearful faces were better detected than happy faces. No effect of T1 load emerged, $F(1, 25) = 1.37$, $p = .254$, $\eta_p^2 = .05$, and the interaction between T1 load and expression did not reach significance, $F(1, 25) = 3.28$, $p = .082$, $\eta_p^2 = .12$.

Discussion

Applying a modified AB paradigm, we found that preferential access of fearful faces to subjective awareness was dependent on the availability of attentional resources. Although fearful faces attenuated the AB under conditions of low-T1 load, the AB was similarly strong for fearful and happy faces in the high-T1-load condition. Thus, the advantage for fearful faces during the AB is subject to resource limitations. These results suggest that increased task demands diminish processing of threatening stimuli during the AB period.

Although previous studies have repeatedly demonstrated an attenuated AB for emotionally salient stimuli, it is worth mentioning that AB effects still occur for these emotion-laden stimuli. Similarly, in the present study detection performance for fearful faces was greatly reduced at Lag 2, both under low and under high-T1 load. Furthermore, the AB for fearful faces has been shown to vary as a function of the observers' self-reported levels of trait anxiety (Fox et al., 2005). These findings argue against proposals that assume emotion-laden stimuli to be processed automatically and independent of the allocation of attention (Öhman & Mineka, 2001; Vuilleumier, Armony, Driver, & Dolan, 2001), and support the idea that at least some attentional resources are required for processing fearful faces (Pessoa, Kastner, & Ungerleider, 2002; Vuilleumier, 2005). Here we provide further evidence that attention is needed to access emotional meaning. Under conditions of high perceptual load fear processing seems to be restrained and even the consistently reported advantage of fearful faces during the AB period (De Martino et al., 2009; Fox et al., 2005; Milders et al., 2006) vanishes.

Theoretical accounts of the AB attribute the T2 deficit at short lags to the depletion of limited resources by T1 processing (Chun & Potter, 1995; Jolicœur & Dell'Acqua, 1998; Shapiro et al., 1994). For example, Chun and Potter (1995) proposed a two-stage theory that assumes all items to be processed up to a high-level short-term representation. This initial first stage representation is vulnerable to interference, and a second stage is required for a more stable representation enabling a response to a target item. However, the second stage is limited in capacity and when it is occupied with T1 processing, T2 performance suffers. The advantage of emotion-laden T2 items in the AB has been attributed to their preferential access to the second processing stage (Keil & Ihssen, 2004). It seems plausible to assume that a similar mechanism underlies the present observation of an attenuated AB for fearful faces during the low-T1-load condition. Following this argument, we suggest that in the low-T1-load condition sufficient processing capacity was left to access the emotional value of T2 and to unfold the detection advantage for fearful faces during the AB period (Milders et al., 2006). By contrast, the advantage for fearful over happy faces disappeared when perceptual load associated with T1 identification was increased. In the framework of a two-stage model, this finding can be explained by hypothesizing that high-T1 load required increased second stage processing capacities to successfully identify T1, thereby leaving insufficient resources to process the emotional value of faces presented in the AB.

The detection advantage for emotional stimuli during the AB has been closely linked to the amygdala, because patients with focal brain damage affecting bilateral amygdalae no longer show an improved T2 identification for arousing as compared to neutral words (Anderson & Phelps, 2001). This implies that the amygdala responds to threatening sensory information, even when the visual system has to process a vast amount of rapidly appearing stimuli as during a typical RSVP. Indeed, the amygdala is activated by the presentation of fearful facial expressions even when this information is task irrelevant and attention is directed elsewhere (Vuilleumier et al., 2001). However, the neural processing of highly relevant emotional cues like fearful facial expressions might not be completely automatic, but rather depends on a certain amount of attention. For instance, when attentional resources are fully depleted by a highly demanding task, the amygdala ceases to respond to task irrelevant fearful facial expressions (Pessoa, McKenna, Gutierrez, & Ungerleider, 2002). Although it should be noted that the design of these neuroimaging studies (Pessoa, McKenna, et al., 2002; Vuilleumier et al., 2001) differed significantly from the present study, it seems tempting to reconcile these results with the present behavioral data. Future studies should test whether the effect of T1 load on the awareness of fearful faces observed here is indeed mediated by the amygdala.

Somewhat surprising, in the present study T1 load did not exert an effect on face detection per se, but only on the advantage of fearful faces. This raises the possibility that face detection and emotion processing in AB tasks are located at different stages in the processing hierarchy. Possibly, extracting the emotional meaning requires higher order stages that cannot be accessed under conditions of high-T1 load.

Finally, it should be noted that the detection advantage of faces displaying a fearful facial expression under low-T1 load does not imply that observers are also better in identifying threatening than nonthreatening facial expressions. A recent study by de Jong, Koster, van Wees, and Martens (in press) asked participants to identify the emotional expression displayed by a T2 face and found the AB to be similarly attenuated by angry and happy faces.

In summary, the present study provides further evidence for preferential processing of emotionally salient events, by showing an attenuated AB for fearful relative to happy faces during the low-load condition. More important, however, we show here that this advantage is not immune to competing task demands. When attention is engaged in a highly demanding task, such as during our high-load condition, emotionally salient events are no longer preferentially processed.

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