Awareness of Faces Is Modulated by Their Emotional Meaning

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A central question in perception is how stimuli are selected for access to awareness. This study investigated the impact of emotional meaning on detection of faces using the attention blink paradigm. Experiment 1 showed that fearful faces were detected more frequently than neutral faces, and Experiment 2 revealed preferential detection of fearful faces compared with happy faces. To rule out image artifacts as a cause for these results, Experiment 3 manipulated the emotional meaning of neutral faces through fear conditioning and showed a selective increase in detection of conditioned faces. These results extend previous reports of preferential detection of emotional words or schematic objects and suggest that fear conditioning can modulate detection of formerly neutral stimuli.

Keywords: awareness, faces, meaning, threat

Because we are aware of only a fraction of the available visual information at any one time, a central question in perception is how stimuli are selected for access to awareness. There is increasing evidence that selection is based on an interaction between low-level stimulus features (e.g., movement, sudden onset) and high-level factors such as the expectations and goals of the observer (Yantis, 1998). Certain goals are relevant only for the current task or situation (e.g., detect a red target among green distractors), whereas goals related to one’s safety and well-being are relevant in any situation. Therefore, it would be functional from an evolutionary perspective if stimuli that were evaluated as emotionally significant had priority in the selection process, because of the potential impact of such stimuli on the observer’s safety or well-being (Öhman & Mineka, 2001). Consequently, one would expect that under conditions in which multiple stimuli compete for selection and access to awareness, stimuli with an emotional meaning are more likely to be consciously perceived than are neutral stimuli that lack clear emotional significance. Preferential access to awareness of emotional stimuli would have a further adaptive advantage in that awareness of a stimulus allows more flexible and controlled responses to that stimulus compared with the relatively automatic responses elicited by unconscious processing (Baars, 1989; Damasio, 1999).

It is still a matter of debate whether processing of emotional stimuli is completely automatic, that is, without requiring any attention to or awareness of these stimuli (Pessoa, 2005). However, there is ample evidence that emotional stimuli can influence subsequent task performance (e.g., De Houwer, Hendrickx, & Baeyens, 1997; Mogg & Bradley, 1999), elicit physiological responses (e.g., Öhman & Soares, 1998), and produce activation in brain areas involved in emotion processing (e.g., Morris, De Gelder, Weiskrantz, & Dolan, 2001; Morris, Öhman, & Dolan, 1998), even when observers’ subjective reports indicate no awareness of the presence of those stimuli. Although these findings suggest that evaluation of emotional meaning occurs rapidly and without requiring subjective awareness of the stimuli, what the findings do not reveal is whether emotional stimuli can also have preferential access to awareness.

Studies using visual search tasks have provided indirect evidence of an advantage in the detection of emotional stimuli. Reaction times to detect the presence of stimuli with a negative emotional meaning (e.g., schematic angry faces, spiders) among distractors were shorter than to detect neutral or positive emotional stimuli (Fox et al., 2000; Öhman, Flykt, & Esteves, 2001). More direct evidence for the influence of emotional significance on awareness has come from masking studies, inattentional blindness, and the attentional blink. Dijksterhuis and Aarts (2003) showed that participants were more likely to detect the presence of briefly presented masked words if the words had a negative compared with a positive emotional meaning. Mack and Rock (1998), using the inattentional blindness paradigm, demonstrated that although observers failed to detect the presence of simple color or motion targets if attention was directed at another task, detection of one’s own name or a schematic happy face was largely unimpaired. The attentional blink (AB) refers to the phenomenon that detection of a visual target presented in a rapid stream of visual stimuli is impaired when it appears about 400–700 ms after another target, which observers have to identify. The AB is known to produce impaired awareness of lexical information (e.g., Raymond, Shapiro, & Arnell, 1992), faces (Awh et al., 2004), as well as basic visual features like orientation and color (Joseph, Chun, & Nakayama, 1997; Ross & Jolicoeur, 1999). It is interesting that a number of studies have shown that one’s own name (Shapiro, Caldwell, & Sorensen, 1997), emotionally meaningful words or ideographs (Anderson & Phelps, 2001; Keil & IJssel, 2004; Ogawa & Suzuki, 2004), or schematic happy faces (Mack, Pappas, Silverman, & Gay, 2002) were less affected by the AB and more likely to be reported than were emotionally neutral stimuli.

So far, the findings suggesting preferential selection and awareness of emotionally meaningful stimuli are restricted to words or...
schematic objects. However, if preferential access to awareness of emotionally salient stimuli arises from processes that evolved in response to biological pressures, the same effect should also be found for more naturalistic stimuli. This hypothesis was investigated in the three experiments reported here, in which we used photographs of human faces as stimuli in an AB paradigm. Human faces are clearly socially and biologically important stimuli, in which emotional meaning varies with the emotional expression on the face. Previous studies have shown an AB for faces (Awh et al., 2004), but to our knowledge, there have been no studies comparing awareness of faces as a function of their emotional expression. Experiment 1 compared detection of faces displaying either neutral or fearful expressions. Expressions of fear are signals of potential danger or threat, and rapid detection of such signals would have obvious advantages for survival (Öhman & Mineka, 2001). Recent electrophysiological studies have indeed identified differential brain activity in response to fearful faces that developed earlier after stimulus onset than responses to other expressions (Krolak-Salmon, Henaff, Vighetto, Bertrand, & Mauguiere, 2004; Pourtois, Grandjean, Sander, & Vuilleumier, 2004; Schupp et al., 2004; L. Williams et al., 2004). If emotionally meaningful faces have preferential access to awareness, faces with a fearful expression should be detected more frequently in an AB task than the same faces displaying a neutral expression.

Experiment 1

Method

Participants. Ten participants (6 women, 4 men) took part in this experiment in exchange for course credit or were paid £4 (U.S. $7). The participants were undergraduate or postgraduate students in the School of Psychology at the University of Aberdeen and were between 21 and 27 years of age (M = 23.4 years). All had normal or corrected to normal visual acuity and gave informed consent to participate.

Materials and procedure. The stimulus display consisted of a fearful and a neutral face embedded in a rapid serial visual presentation (RSVP) of scrambled faces. All stimuli came from a standard set of facial expression pictures (Ekman & Friesen, 1976). Three male and three female faces were used as target faces. Twenty-four different scrambled faces were made by rearranging the internal features of two neutral faces, one male and one female face. The stimulus display was presented on a 21-in. CRT monitor using a Visual Stimulus Generator graphics card (Cambridge Research Systems, England). The faces subtended 15.6° × 19.7° at a viewing distance of 57 cm. The participants’ head position was stabilized with a head and chin rest.

A trial consisted of 22 images of scrambled faces and target faces. Each image was presented for 80 ms at the center of the monitor and was immediately masked by the next image (see Figure 1). The first target face (T1) was the only image in RSVP stream with a greenish tint, to distinguish it from the other images, which were all black and white. The only other target face (T2) in the stream was present in 50% of the trials and always appeared after T1. T1 appeared between 640 and 960 ms (images 8–12) into the trial, and the stimulus onset asynchrony (SOA) between the T1 and T2 face was either 160, 240, 400, or 560 ms. T1 and T2 never had the same identity or expression; if T1 was a neutral face, T2 was fearful, and vice versa. In half the trials, T1 was female, and in the other half, T1 was male. The gender of T2 could be the same as or different from T1. There were 60 trials at each of the four SOAs, 30 with neutral T1 and fearful T2 and 30 with fearful T1 and neutral T2, resulting in 240 trials with T2 present. In a further 240 trials, T2 was absent, and only T1 was presented. Trials with different SOAs and different facial expressions and trials without T2 were all interleaved and presented in random order. Immediately after each trial, participants reported the sex of the T1 face and whether they had seen a second face by pressing the appropriate keys on a response box. Expression recognition was implicit, as participants did not have to report the expressions shown in the faces. Participants received no feedback about their performance.

Figure 1. Schematic representation of the rapid serial visual presentation stream. Faces and scrambled faces appear at the center of the monitor. Each image is presented for 80 ms and immediately replaced by the next image. A trial contains 22 images, including the first target face (T1; a face with a green tint) and, on 50% of the trials, a second target face (T2). After each trial, participants report the sex of the T1 and whether they had seen a second face. Face images are reproduced from Pictures of Facial Affect, by P. Ekman and W. Friesen, 1976, Palo Alto, CA: Consulting Psychologists Press, with permission. Also, see www.paulekman.com.
Results and Discussion

The mean false alarm rate (i.e., reporting that T2 was present on T2-absent trials) was 7.8% (SD = 8.9) when T1 was a fearful face and 10.5% (SD = 3.9) when T1 was neutral; this difference was not significant (p > .10). On T2-present trials, only trials with correct responses to both T1 and T2 were included in the T2 detection counts. Mean percentage of correct responses to T1 and T2 as a function of facial expression and across the four SOAs are displayed in Figure 2. Comparing correct sex discrimination of fearful and neutral T1s at different SOAs in a 2 (expression: fearful, neutral) × 4 (SOA: 160, 240, 400, 560) within-subjects analysis of variance (ANOVA) revealed no main effect of expression (p > .40), but a significant main effect of SOA, F(3, 27) = 5.20, p < .01, η² = .42, and a significant SOA × Expression interaction, F(3, 27) = 3.89, p < .05, η² = .26. Further analysis of this interaction with pairwise comparisons showed no differences in performance between neutral and fearful T1s at any SOA, except at the longest SOA (560 ms), where sex discrimination was marginally better for fearful than for neutral T1s (p = .057). Comparison of the detection rate of T2 in a 2 (expression) × 4 (SOA) within-subjects ANOVA revealed main effects of expression, F(1, 9) = 9.07, p < .05, η² = .50, and SOA, F(3, 27) = 15.41, p < .001, η² = .63, as well as an Expression × SOA interaction, F(3, 27) = 12.49, p < .001, η² = .58. Pairwise comparisons of fearful and neutral T2s at each SOA showed that the presence of fearful faces was detected significantly more frequently than the presence of neutral faces at the three shortest SOAs (pS < .05, η² = .41), and there was no difference in detection rate at the longest SOA of 560 ms (p > .30).

Detection of the T2 face was impaired at short SOAs between T1 and T2, reflecting an AB for faces, but this impairment was more severe when the T2 had a neutral expression than when T2 had a fearful expression. The high level of correct scores on T1 sex discrimination indicates that participants were following task instructions and attended to T1. It is unlikely that the advantage in fearful T2 detection was caused by a trade-off in performance to T1. First, correct sex discrimination did not differ between fearful and neutral T1s, except at SOA 560, but at this SOA there was no longer a difference between detection of fearful and neutral T2s.

Figure 2. Results of Experiment 1. Mean percentage of correct sex discriminations of first target faces (T1s) and mean number of second target faces (T2s) correctly detected when faces displayed neutral expressions or fearful expressions as a function of stimulus onset asynchrony (SOA; in ms) between T1 and T2. Error bars represent standard errors of the mean.

The fact that there was a significant difference at all between neutral and fearful T1s, despite overall high T1 performance, was due to the small variance in T1 performance. Second, and more important, T2 detection scores required correct responses to both T2 and T1, thereby taking into account performance on T1. False alarm rates were similar on neutral T1 only and fearful T1 only trials. Therefore, it is unlikely that a criterion shift among participants was responsible for the enhanced detection of fearful T2s—that is, T2s presented after neutral T1s—as this would have produced more false alarms on T2-absent trials following neutral than following fearful T1s. The low overall false alarm rate of 9.1% further indicates that participants were not simply guessing on T2 detection. Correct T2 detection at the shortest SOA approached 50%, and although a similar percentage of correct responses would be expected if participants were randomly responding T2 present or absent, such strategy should also have produced a false alarm rate of around 50%.

The results suggest that emotionally salient faces are indeed more likely to enter awareness than are emotionally neutral faces. This confirms and extends previous studies demonstrating preferential detection of emotionally meaningful words or schematic objects. The design of Experiment 1, however, allows an alternative explanation. Because the expressions of both T1 and T2 varied, the enhanced detection of fearful T2s could have been caused by differences in processing fearful or neutral T1s. It is possible that more attentional resources were directed to fearful T1s than to neutral T1s because of their emotional saliency, despite the fact that the emotional expressions were irrelevant to the gender discrimination task. Such effects have been reported for the emotional Stroop task (J. Williams, Mathews, & MacLeod, 1996) or the dot-probe task (Fox et al., 2000). The demands of processing T1 in AB tasks are known to influence the impairment in reporting T2 (Jolicour, 1998; Marois, Chun, & Gore, 2000). Therefore, if more attention were directed at fearful T1s, detection of the next target face (neutral T2) could be more impaired than the target face (fearful T2) following neutral T1s. This would mean that the advantage in detecting fearful over neutral T2s was caused by differences in the emotional meaning of the T1s and not, as hypothesized, by the emotional meaning of the second face.

In Experiment 2, we controlled the influence of the emotional meaning of T1 on T2 detection by keeping the expressions of the T1s constant and varying only the emotional meaning of T2. T1s were always neutral, whereas the T2s were either fearful or happy. Following reports of preferential detection of the presence of negative compared with positive words or symbols under masked presentations (Dijksterhuis & Aarts, 2003) or in AB tasks (Ogawa & Suzuki, 2004), we expected that fearful T2s would be detected more frequently than happy T2s, if access to awareness is modulated by emotional meaning.

Experiment 2

Method

Participants. Ten participants (8 women, 2 men), none of whom had participated in Experiment 1, took part in this experiment. The participants were undergraduate students in the School of Psychology and received course credits for their participation. Age ranged between 18 and 22 years (M = 20 years). All participants had normal or corrected to normal visual acuity and gave informed consent to participate.
Materials and procedure. The experimental setup and stimuli were identical to those used in Experiment 1, except that the selected faces displayed happy expressions in addition to neutral and fearful expressions. Unlike in Experiment 1, T1s were always neutral and T2s were either happy or fearful. As in Experiment 1, there were 240 trials with T2 present: 60 trials at each of the four SOAs between T1 and T2 (160, 240, 400, and 560 ms), 30 with a fearful T2, and 30 with a happy T2. We brought the total number of trials to 336 by reducing the number of T2-absent trials to 96 (40% of trials). The most relevant dependent variable, T2 detection, was obtained from T2-present trials only, and 96 trials without T2 were sufficient to assess false alarm rates. Trials from different conditions were interleaved and presented in random order. Immediately after each trial, participants reported the sex of the T1 and whether they had seen a second face. Participants received no feedback on their performance.

Results and Discussion

The mean false alarm rate on trials without T2 was 4.3% (SD = 2.7%) and was not analyzed further. Mean percentage of correct responses to T1 and T2 for the four SOAs as a function of facial expression are displayed in Figure 3. Only trials with correct responses to both T1 and T2 were included in the correct T2 responses. Responses to T1s preceding a fearful or happy T2 at the different SOAs were compared in a 2 (expression: fearful, happy) x 4 (SOA: 160, 240, 400, 560) withinsubjects ANOVA. This analysis revealed no main effects of expression (p > .05) or SOA (p > .05) but a significant interaction between the two, F(3, 27) = 4.53, p < .05, ηp² = .33. Pairwise comparisons of the T1s preceding fearful and happy faces at each SOA, showed that at SOA 240 ms, but at none of the other SOAs, sex discrimination was better for T1s preceding a happy T2 than those preceding a fearful T2, t(9) = 2.88, p < .05, ηp² = .48. Comparison of the detection rate of T2 in a 2 (expression: fearful, happy) x 4 (SOA) withinsubjects ANOVA showed main effects of expression, F(1, 9) = 7.58, p < .05, ηp² = .45, and SOA, F(3, 27) = 20.29, p < .001, ηp² = .69, as well as an Expression x SOA interaction, F(3, 27) = 3.45, p < .05, ηp² = .27. Pairwise comparisons between detection of fearful and happy T2s showed that at the shortest SOA (160 ms), the presence of fearful faces was detected more frequently than the presence of happy faces, t(9) = 3.58, p < .01, ηp² = .59. At the remaining SOAs, detection of the two expressions did not differ (p > .10).

The results were comparable with those of Experiment 1 in that detection of T2s was influenced by their emotional meaning; fearful faces were better detected than happy faces. This advantage in detection of fearful faces could not be attributed to an interaction with the expressions of the faces presented as T1, as these were always neutral. There was no indication that the enhanced detection of fearful faces resulted from a trade-off in attention to T1. Discrimination performance for T1s preceding fearful or happy faces was very similar, except at SOA 240 ms, but at this SOA the detection of fearful and happy T2s was not different, and T2 detection scores were conditional on correct T1 performance.

The advantage of fearful T2 over happy T2 detection suggests that the preferential detection is not simply based on the presence of an emotional expression in the face, in which case detection of fearful and happy faces would have been equivalent. Instead, preferential detection of T2s was influenced by the valence of the expression.

Although face stimuli have the advantage of being more ecologically valid than words or schematic faces, a potential risk with using naturalistic stimuli is that the observed advantage in detecting fearful faces was caused by an artifact in the pictures rather than the emotion expressed by these faces. By using six different faces, we tried to reduce the risk of artifacts having a systematic effect on detection. However, in the past, image artifacts have troubled studies into selective attention to facial expressions (e.g., Hansen & Hansen, 1988). This concern of artifacts causing the preferential detection of fearful faces was addressed in Experiment 3. If the enhanced perception of fearful faces in Experiments 1 and 2 was caused by their emotional meaning, in this case a signal of potential danger or threat, it may be possible to obtain similar results by manipulating the emotional meaning of neutral stimuli through conditioning. Experiment 3 also investigated a question that has not been examined previously: how stimuli acquire the emotional significance that allows preferential detection. Is this property of enhanced detection restricted to a limited set of stimuli that are of particular importance to humans, or can formerly neutral stimuli acquire this property through learning and experience? The reports of preferential detection of emotional words and ideograms (Anderson & Phelps, 2001; Keil & Ihssen, 2004; Ogawa & Suzuki, 2004) suggest a role of learning, through which inherently harmless symbols become associated with an emotional meaning.

Experiment 3

Fear conditioning is a simple form of emotional learning that involves associating a neutral stimulus (the conditioned stimulus; CS) with an aversive unconditioned stimulus (US), such as a loud noise. It is known that fear conditioning can modulate the direction of spatial attention (Armony & Dolan, 2002; Beaver, Mogg, & Bradley, 2005) and elicit physiological responses to conditioned faces (Esteves, Dimberg, & Öhman, 1994). These studies suggest that conditioning can modify the emotional significance of stimuli, although none reported whether fear conditioning could increase the detection of conditioned stimuli. We hypothesized that, if fear conditioning can enhance the emotional meaning of neutral stimuli, this would result in increased detection of the conditioned faces in an AB task.
Method

Participants. Twelve participants (10 women, 2 men) took part in this experiment in exchange for course credits or were paid £4 (U.S. $7). Their age ranged between 18 and 46 years (M = 24 years). All participants had normal, or corrected to normal, visual acuity and gave informed consent to participate. None of the participants had participated in the previous experiments.

Materials and procedure. All faces came from the same standard set as used in Experiments 1 and 2. Four neutral faces were chosen to serve as T2 in the RSVP task and as conditioned faces: two male and two female. Four different faces, all with happy expressions, were presented as T1 in the RSVP task: two male and two female. As in Experiments 1 and 2, faces with different identities and expressions were presented as T1 and T2. Happy expressions were chosen for T1, as these would clearly contrast with the negative meaning to be associated with the conditioned faces.

Participants started with a habituation phase during which they passively viewed the four neutral faces to be used as T2, each presented 5 times in a random order for 1 s each. This was followed by the first RSVP task. This task was similar to that used in Experiments 1 and 2, except that T1 was always a happy face, and T2 was always neutral. Again, T1 had a greenish tint, and all neutral and scrambled faces were black and white. To avoid extinction effects following conditioning, we kept the number of trials low and used only one SOA (160 ms) between T1 and T2. Experiments 1 and 2 had shown that at this SOA, the difference in detecting faces with different emotional meaning was most pronounced. Each of the four neutral faces appeared 12 times as T2. On a further 12 trials, T1, but not T2, was presented, resulting in 60 trials presented in random order. Immediately after each trial, participants reported whether T1 was male or female and whether they had seen a second face. This first RSVP task was followed by the conditioning phase. During conditioning, the four neutral faces were shown one by one for 500 ms each. Each face was presented 5 times in random order, and the interval between successive faces varied between 15 and 25 s. One neutral face (CS+) was always immediately followed by a 500-ms tone at 83 dB presented through earphones (the US), and all neutral and scrambled faces were black and white. To avoid an immediate response following the conditioning phase, we used only one SOA (160 ms) between T1 and T2. Experiments 1 and 2 had shown that at this SOA, the difference in detecting faces with different emotional meaning was most pronounced. Each of the four neutral faces appeared 12 times as T2. On a further 12 trials, T1, but not T2, was presented, resulting in 60 trials presented in random order. Immediately after each trial, participants reported whether T1 was male or female and whether they had seen a second face. This first RSVP task was followed by the conditioning phase. During conditioning, the four neutral faces were shown one by one for 500 ms each. Each face was presented 5 times in random order, and the interval between successive faces varied between 15 and 25 s. One neutral face (CS+) was always immediately followed by a 500-ms tone at 83 dB presented through earphones (the US), but nothing happened after the remaining three neutral faces (CS−).

Different participants saw different faces as CS+, but nothing happened after the remaining three neutral faces (CS−). Different participants saw different faces as CS+, and each of the four neutral faces served an equal number of times as CS+ or CS−. Participants were instructed to look at the faces but did not have to make any response during this phase. The conditioning phase was immediately followed by the second RSVP task, which was identical to the task performed before conditioning, except that the trials were presented in a different, random order. As before, participants had to report the gender of the T1 and whether they had seen a second face among the scrambled faces. The US was never presented during the RSVP tasks.

Results and Discussion

Mean false alarm rates on T2-absent trials were 4.8% (SD = 6.6) before and 2.7% (SD = 4.1) after conditioning; this difference was not significant (p > .08). For T2 detection rates, only those trials with correct responses to both T1 and T2 were included. The mean percentage of correct T1 discrimination and T2 detection before and after conditioning are shown in Figure 4. Correct sex discrimination of T1s preceding CS+ or CS− before and after conditioning was compared in a 2 (conditioning: T1 preceding CS+ or CS−) × 2 (time: before or after conditioning) ANOVA, revealing a main effect of time, F(1, 11) = 6.53, p < .05, ηp² = .37, but no effect of conditioning and no interaction (p > .30). Pairwise comparisons showed more correct responses to T1s preceding CS− after conditioning than before conditioning, t(11) = 2.32, p < .05, ηp² = .33, but no such difference for T1 preceding CS+ faces (p > .10). Analysis of the T2 detection rates in a 2 (conditioning: C+, C−) × 2 (time: before or after conditioning) ANOVA revealed main effects of conditioning, F(1, 11) = 12.35, p < .01, ηp² = .53, and time, F(1, 11) = 8.54, p < .05, ηp² = .43, as well as a significant interaction, F(1, 11) = 8.79, p < .05, ηp² = .44. Further analysis of the interaction showed a significant increase in the number of CS+ faces detected after compared with before conditioning, t(11) = 3.01, p < .05, ηp² = .42, whereas detection of CS− faces did not change, t(11) < 0.01. Comparing the detection of CS+ and CS− faces presented as T2 before conditioning revealed no difference between these two categories, t(11) < 0.30, whereas following conditioning CS+ faces were detected more frequently than CS− faces, t(11) = 3.60, p < .01, ηp² = .54.

Pairing CS+ faces with an aversive US did increase detection of these faces, and detection of CS− faces did not change, even though prior to conditioning, detection of CS+ and CS− T2s was similar. The improved detection of CS+ faces following fear conditioning could not result from reduced attention to T1s, because T1 performance on CS+ trials did not change following conditioning, and T2 detection was conditional on correct T1 discrimination. Retest effects cannot explain the improved detection of CS+ faces, because all neutral faces were presented an equal number of times during conditioning, and the RSVP tasks and detection of the CS− faces did not improve following conditioning. Each of the four neutral faces served an equal number of times as CS+ or CS−, therefore it is unlikely that the enhanced detection of CS+ faces was caused by an image artifact or by characteristics of an individual face. It is also unlikely that the improved detection of CS+ faces following fear conditioning could not result from reduced attention to T1s, because T1 performance on CS+ trials did not change following conditioning, and T2 detection was conditional on correct T1 discrimination. Retest effects cannot explain the improved detection of CS+ faces, because all neutral faces were presented an equal number of times during conditioning, and the RSVP tasks and detection of the CS− faces did not improve following conditioning. Each of the four neutral faces served an equal number of times as CS+ or CS−, therefore it is unlikely that the enhanced detection of CS+ faces was caused by an image artifact or by characteristics of an individual face. It is also unlikely that the increased detection of CS+ faces following conditioning was caused by a criterion shift, as false alarm rates before and after conditioning were not different. Finally, the increased detection rates could not result from a nonspecific sensitization in response to the US, as the increase in detection was restricted to the CS+. In sum, the critical factor distinguishing the CS+ from the CS− faces, which must underlie the increase in CS+ detection, was the presentation of the aversive US.
General Discussion

The results of three experiments were consistent in showing that detection of the presence of faces appearing as the second target (T2) in an RSVP stream was affected by their emotional meaning. First, faces were detected more frequently if they displayed an expression of fear compared with neutral or happy expressions. Second, manipulation of the emotional significance of a neutral face, through pairing with an aversive loud noise, increased subsequent detection of that face. The enhanced detection of fearful compared with neutral T2s in Experiment 1 might have been caused by the different expressions of the T1 and differences in the amount of attention allocated to fearful and neutral T1s, rather than by the expression of the T2. In Experiment 2, we eliminated this potential confound by presenting only neutral expressions as T1 and varying the expression of the T2s. Nevertheless, the results of Experiment 2 were comparable with those of Experiment 1, showing preferential detection of fearful faces. Experiment 2 also indicated that the enhanced detection was a function of the type of emotion expressed—that is, fear versus happy—and not simply of the presence or absence of emotion in the face—that is, fear versus neutral. The finding in Experiment 3, that fear conditioning selectively increased detection of the conditioned face, ruled out image artifacts or differences in familiarity with the presented faces as plausible explanations for the preferential detection, as four different faces served as the conditioned face.

Our results extend previous reports of enhanced detection of emotionally meaningful words (Anderson & Phelps, 2001; Keil & Ihssen, 2004), ideographs (Ogawa & Suzuki, 2004), and schematic objects (Mack et al., 2002; Mack & Rock, 1998) in AB tasks to more naturalistic stimuli, that is, human faces. The enhanced detection of fearful faces and conditioned faces also corroborates evidence for a late selection account of the AB (Shapiro, Caldwell, & Sorensen, 1997). Most explanations of the AB agree that the impairment in T2 detection occurs because a limited-capacity process is still occupied by T1 when T2 arrives (Jiang & Chun, 2001). Access to this limited-capacity process would be crucial for short-term consolidation to allow subsequent report of stimuli and access to awareness. Conversely, partial or complete failure of T2 to enter this process would result in the impairment in detecting the presence of T2. Although T2 may not be consciously detected, it has been shown that the semantic meaning of unreported T2 words can be accessed (Lick, Vogel, & Shaprio, 1996) and can produce semantic priming effects (Maki, Frigen, & Paulson, 1997; Shapiro, Driver, Ward, & Sorensen, 1997). The emotional meaning of stimuli falling within the AB must also be evaluated to explain the effect of emotional meaning on T2 detection. Furthermore, the fact that awareness of T2 stimuli is modulated by their emotional meaning suggests that stimuli evaluated as being emotionally meaningful have preferential access to this limited-capacity process, thus allowing availability for subsequent report (Keil & Ihssen, 2004). A slightly different explanation was suggested by Shapiro, Caldwell, and Sorensen (1997), who proposed that particularly salient stimuli (e.g., words associated with threat, one’s own name) can survive the AB because they have a lower activation threshold for recognition than less salient stimuli. Because of these low activation thresholds, salient stimuli presented as T2 could still be reported, despite reduced activation of their representations caused by the ongoing processing of T1. These two explanations, preferential access to limited-capacity process or reduced activation thresholds, are not mutually exclusive, and both could account for the enhanced detection of faces associated with danger or threat.

Which stimuli are sufficiently meaningful for preferential selection and detection? To date, most evidence points at preferential detection of negative emotional stimuli, in particular those associated with danger and threat. We found an advantage of detecting fearful over happy and neutral faces, whereas previous studies reported preferential detection of negative (i.e., threat-related) as compared with positive and neutral words or ideographs (Anderson & Phelps, 2001; Dijksterhuis & Aarts, 2003; Ogawa & Suzuki, 2004). There are reports of enhanced detection of positive compared with neutral stimuli, such as schematic happy faces (Mack et al., 2002) or one’s own name (Shapiro, Caldwell, & Sorensen, 1997), but none of these studies included negative emotional stimuli for comparison. Keil and Ihssen (2004) did find an equivalent advantage of identifying negative and positive words compared with emotionally neutral words in an AB task. However, Keil and Ihssen (2004) also showed that arousal ratings were better predictors of the preferential identification of emotional words than the words’ emotional valence. Arousal can be regarded as an integral part of the emotional response and is reflective of its intensity (Schupp et al., 2004). Therefore, the effect of arousal noted by Keil and Ihssen (2004) could indicate that, in addition to valence, the emotional intensity is a further factor in the preferential detection of emotional stimuli.

The results of Experiment 3 suggest that fear conditioning can improve detection of previously neutral faces. Although previous studies have shown that fear conditioning could modulate spatial attention (Armony & Dolan, 2002; Beaver et al., 2005), physiological responses (Esteves et al., 1994), and brain activation patterns (e.g., Morris et al., 1998, 2001) in response to conditioned faces, to our knowledge, this is the first indication that fear conditioning can modulate detection and awareness of conditioned faces. Because the increase in detection was restricted to the CS+ face, the effect must be a consequence of the US presentation during conditioning. In line with studies using fear conditioning to manipulate spatial attention or physiological responses to CS+, we assumed that the association with aversive US changed the emotional meaning of the neutral face resulting in enhanced detection in the subsequent AB task. However, an alternative possibility is that the increased detection of CS+ was due to CS+ being unique, that is, being the only face followed by a noise. Although we cannot completely rule out this possibility, existing findings do not indicate that being unique is sufficient for preferential detection in AB tasks. Numerous studies into the AB showed severe impairments in T2 detection, even though T2 was a unique letter, for example, X (Raymond et al., 1992). Furthermore, AB studies into the effect of meaning on T2 detection held uniqueness constant in the sense that detection of one’s own name was contrasted with a single other name (Shapiro, Caldwell, & Sorensen, 1997) or detection of one negative ideogram was compared with one other positive or neutral ideogram (Ogawa & Suzuki, 2004). In all cases, it was the meaning of T2 for the observer that influenced its detection. The literature on attentional blindness and capture also indicates that unique items or unusual events do not necessarily capture attention or enter awareness (e.g., Mack & Rock, 1998; Simmons, 2000).

The enhanced detection of CS+ faces is in line with reports of involvement of the amygdala in both fear conditioning and en-
hanced perception of emotional stimuli. It has been shown that the amygdala is crucial for fear conditioning in humans (Bechara et al., 1995) and that fear conditioning increases amygdala activation to conditioned faces (Morris et al., 1998, 2001). In addition, there is neuropsychological evidence that the amygdala is involved in the enhanced detection of threat stimuli. Patients with bilateral or left-sided amygdala damage did not show the advantage, seen in healthy participants, of identifying threat words better than neutral words in an AB task (Anderson & Phelps, 2001). Kapp, Whalen, Supple, and Pascoe (1992) have put forward a hypothesis, based on animal studies, that relates the amygdala with both conditioning and sensory sensitivity. Kapp et al. proposed that the central nucleus of the amygdala is essential for associating a neutral stimulus with a negative or positive unconditioned stimulus and that subsequent responses to the conditioned stimulus are characterized by increased attention and arousal that would serve to enhance sensory processing and sensitivity. A comparable process might underlie the increased detection of CS+ faces observed here, as fear conditioning is known to increase arousal levels for conditioned stimulus in humans (Öhman & Soares, 1998) and to modulate attention toward conditioned faces (Armony & Dolan, 2002; Beaver et al., 2005). Indeed, Keil and Ihssen (2004) demonstrated a relationship between arousal ratings and the preferential selection of emotional words.

In summary, using faces with different emotional expression, we showed enhanced detection of faces associated with threat or danger compared with neutral or happy faces, even though expression recognition was implicit in the detection task. These results provide further evidence that selection for awareness is influenced by the significance of stimuli to the observer. This property of preferential selection seems not restricted to a limited, fixed set of emotionally salient stimuli, as neutral faces could also acquire this property following presentation with an aversive unconditioned stimulus.

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