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Does Emotion Processing Require Attention? The Effects of Fear Conditioning and Perceptual Load

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Abstract

This study examined the impact of perceptual load on the processing of unattended threat-relevant faces. Participants performed a central letter-classification task while ignoring irrelevant face distractors, which appeared above or below the central task. The face distractors were graded for affective salience by means of aversive fear conditioning, with a conditioned angry face (CS+), an unconditioned angry face (CS–), and a neutral control face. The letter-classification task was presented under conditions of both low and high perceptual load. Results showed that fear conditioned (i.e., CS+) angry face distractors interfered with task performance more than CS– angry or neutral face distractors but that this interference was completely eliminated by high perceptual load. These findings demonstrate that aversively conditioned face distractors capture attention only under conditions of low perceptual load.

Keywords

attention; fear-conditioning; threat; perceptual load; emotion processing

It is often assumed that our visual system performs high-speed preliminary analysis of salient or affective visual features, before the operation of selective attention (e.g., Anderson, 2005; Eastwood, Smilek, & Merikle, 2003; Fox, Lester, Russo, Bowles, Pichler, & Dutton, 2000). However, the extent to which threatening features in the face of others can be processed outside the focus of attention and impact on behavioral response is an ongoing debate. The perception of a primitive social threat such as an angry facial expression is clearly an important skill essential to human survival and as such, is likely to occur automatically. However, there are contrasting views concerning the extent to which the preferential processing of emotional information takes place at a preattentive level.

Some argue that preferential processing of emotional stimuli is “automatic” and does not require focused attention (Dolan & Vuilleumier, 2003; Vuilleumier, Armony, Driver, & Dolan, 2001). In support of this view, neuroimaging research has demonstrated amygdala activation in response to fear arousing facial expressions that are presented under conditions of inattention (Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003; Vuilleumier et al., 2001). Strong evidence also comes from findings that patients with visual extinction can detect emotional expressions presented in their neglected visual field to a much greater extent than neutral faces (Fox, 2002; Lucas & Vuilleumier, 2008; Vuilleumier & Schwartz, 2001a, 2001b), implying that emotional stimuli are being processed in the absence of attention since they can be detected even in the “extinguished” visual field. Similarly,

pictures of spiders are noticed in the neglected field more frequently than pictures of flowers (Vuilleumier & Schwartz, 2001a). These findings are consistent with a subcortical neural route via the amygdala that can initiate an immediate fear response to affective stimuli, without extensive cortical analysis (LeDoux, 1996, 2000).

In contrast, because the human attention system has capacity limits, it has been argued that emotion processing requires attention (Pessoa, 2005). Support for this view has been shown in a behavioral experiment that used multiple levels of processing load (Erthal et al., 2005). Participants had to indicate the orientation of a target bar under varying conditions of processing load. Emotionally laden distractors such as photographs of mutilated bodies produced interference under easy and intermediate conditions, but these effects were eliminated under a hard condition. Thus, emotional images did not produce distraction under high load conditions indicating that they had not been processed. Research using the attentional blink paradigm has also shown that emotional faces are subject to the effects of perceptual load (Fox, Russo, & Georgiou, 2005). For instance, even though fearful facial expressions were detected more frequently than happy expressions showing that they can break through the attentional blink to some extent, they still produced a significant “blink” effect suggesting that attention was required for their detection (Fox et al., 2005). Neuroimaging studies have also demonstrated the complete suppression of amygdala activity in response to unattended fearful faces as a result of increasing the perceptual demands placed on focal attention by a cognitive task (Lim, Padmala, & Pessoa, 2008; Pessoa, Kastner, & Ungerleider, 2002; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002; Pessoa, Padmala, & Morland, 2005).

This line of argument has drawn upon the theoretical insights of the perceptual load theory (Lavie, 1995; Lavie & Tsai, 1994) as well as the biased competition model of attention (Desimone & Duncan, 1995). Taken together the assumption is that attention can be biased either by preattentive processes relating to the salience (e.g., affective significance) of a stimulus, or attentional control operations relating to task performance. However, the assumption is that processing of unattended distractors will be eliminated or at least severely reduced if the perceptual load of an attended task exhausts capacity limits. Similar to Lavie’s (2005) proposal, Pessoa and colleagues argue that studies claiming that the processing of unattended fearful faces occurs without attention did not take the perceptual load of the target task into account. In other words, it is likely that distractor processing was because of attention resources left over from the primary task.

The extent to which affective stimuli, such as emotional expressions, compete more efficiently for attention remains an interesting phenomenon, particularly in light of reports that sensory processing can take place without attention and subsequently guide selection in difficult visual search tasks (e.g., Fox, 2002; Lucas & Vuilleumier, 2008; Vuilleumier & Schwartz, 2001a, 2001b; for review see Driver & Vuilleumier, 2007). Studies using functional MRI (fMRI) have also given hints that sensory processing of affective stimuli might occur without attention. For example, there was evidence of increased activity in the visual cortex when presented with fearful relative to neutral face distractors under high perceptual load even when activity in the amygdala was reduced (Mitchell et al., 2007). Likewise, Holmes, Kiss, and Eimer, (2006) observed enhanced neural activity as indexed by event-related potentials during a house-face matching paradigm regardless of whether participants attended or did not attend to emotional facial expressions. Even though this response was transient and extinguished within 220 ms the findings are consistent with the view that affectively salient distractor stimuli can be analyzed in the absence of attentive resources (Chun & Wolfe, 2001; Driver, 2001).

To summarize, in a typical natural scene, not all objects or locations are equally important; thus, attention can be guided both, by the bottom-up influence of preattentive processes and affective saliency of stimuli as well as by top-down influences such as task instruction or spatially directed attention. Competition among multiple stimuli must be considered in the context of preattentive sensory processing and top-down user driven control, where both components would be powerful. Thus, it is possible that previous studies showing that emotion processing requires attention were robust in augmenting the perceptual demands of a target task, without being equally robust in augmenting the affective saliency of competing distractor stimuli. Taking this into account, the elimination of emotion processing under high load may be because the distractor was not salient enough. As noted by Lavie (1995) there is no “gold standard” for determining “high” perceptual load without being circular and the same of course goes for affective saliency. Given this, it seems important to manipulate the affective saliency of distractors, so that the influence of distractor intrusion is manipulated in addition to perceptual load.

The Present Study

In a version of the Eriksen flanker paradigm (Eriksen & Eriksen, 1974) the present behavioral study investigated whether increasing the affective salience of an angry face distractor would make them more resistant to modulation by perceptual load. To increase the affective salience of an angry face we used a fear-conditioning procedure. Fear conditioning is a simple form of associative learning that manifests across species and provides a powerful model for understanding affective processing (LeDoux, 1996, 2000). We presented angry faces that were either conditioned with a burst of white noise (CS+) or not conditioned (CS-) as well as a neutral face that was not accompanied by the aversive white noise. Perceptual load was manipulated by varying the demands of a central letter classification task, by presenting nontarget letters that were either similar (low perceptual load) or dissimilar (high perceptual load) to each other (Lavie, 1995). Experiment 1 demonstrated that an aversive noise could modulate a conditioned response as measured by a change in skin conductance responses (SCRs). This result provided psychophysiological evidence that the aversive noise increased the affective salience of the CS+ angry face relative to the CS- angry face.

Two competing hypotheses were examined: the load hypothesis and an alternative affective salience hypothesis. The load hypothesis predicts that distractor interference *always* occurs under conditions of low perceptual load and *never* occurs under conditions of high perceptual load, irrespective of distractor salience. This is because under low-load unattended face distractors should be fully processed, since there are spare attentional resources. However, under high-load the demands of the target task will consume most, if not all, of one's attention, leaving insufficient resources for the processing of face distractors. Thus, distractor interference effects should occur in the low-load trials, but not in the high load trials supporting the view that attentional resources are necessary for emotion perception.

The affective salience hypothesis argues that the demands of a visual search task may affect distractor processing not because of limitations in perceptual processing capacities, but rather because of the relative weakness of distractor saliency. Thus, it is the prepotency of the facial expression that determines if distractor processing will occur, rather than the perceptual load of a target task. This hypothesis suggests that if the distractor is not particularly salient it will not receive preferential processing during high-load trials resulting in reduced or no interference. The affective salience hypothesis promotes the idea that increasing the affective significance of an angry face distractor via fear conditioning should facilitate that stimulus's capacity to produce interference irrespective of the degree of

difficulty or perceptual load of the central task. The affective salience hypothesis therefore predicts that interference effects from the CS+ angry face will be resistant to modulation by perceptual load.

Experiment 1

In the present experiment we tested the assumption that conditioning would successfully modulate the affective salience of an angry expression. Two angry faces were presented, one of which was paired with an aversive noise (CS+), while the other was not (CS−). A neutral face was also presented, which was never accompanied by aversive noise. First, SCRs were recorded for angry face A, angry face B, and the neutral face before conditioning during a habituation phase. The acquisition phase presented the two angry faces, one of which was accompanied by the aversive noise and the neutral face. Following the acquisition phase, SCRs were recorded for the CS+ angry face, CS− angry face, and the neutral face during an extinction phase. The prediction was that SCRs to angry face A and angry face B should be equivalent before conditioning. After the acquisition phase, in contrast there should be increased SCRs to the CS+ angry facial expressions relative to the CS− angry face.

Method

Participants—Nine participants (7 women) with a mean age of 19.2 years ($SD = 1.67$) were recruited for the experiment. Participants were undergraduates randomly recruited from the Psychology Department at the University of Essex. One participant was Italian, 1 was Polish, and 7 were British nationals. All participants in this study had normal or corrected-to-normal vision and were naïve to the purpose of the experiment. Participation was rewarded with payment of £3 or course credits. All participants taking part in this study scored midrange (35–44) on a measure of trait anxiety (Spielberger, Gorsuch, Lushene, & Vagg, 1983). The University of Essex Ethics Committee approved the study and participants gave written informed consent.

Apparatus and stimuli—The experiment was presented on a Macintosh iMac4 computer with the screen set at a resolution of $1,680 \times 1,050$ pixels. Stimulus presentation and data collection were controlled by SuperLab Version 4 software (Cedrus Corporation, 1997). Response times were collected by means of a USB-based RB-834 response pad with a built in timer that allows data to be collected at 1 ms resolution (Cedrus Corporation). The aversive auditory stimulus of ~90db was delivered binaurally through Sennheiser HD 495 digital headphones connected to a sound card in the iMac computer.

Skin conductance responses were recorded by means of a “SC-FLEX/PRO” [SA9309M] encoder unit (Thought technology LTD, Canada) and two silver/silver-chloride Triode electrodes, filled with 0.05 molar sodium chloride (NaCl) electrode paste, fastened by surgical adhesive tape to the palmar sides of the phalanges of the first and second fingers of the nondominant hand. SCR was amplified and sampled at 250 Hz (8 data points per second) and the analysis of waveforms was conducted using polygraph (SA7900 Version 2.0.1 [2004], BioGraph infinity software system, Thought technology LTD, Canada).

The target faces were three black and white photographs selected from the Ekman Pictures of Facial Affect set (Ekman & Friesen, 1976). These included 2 angry faces (A) and (B) (codes; WF3-01, and JJ3-12, respectively) and one neutral face (code; EM2-04). All stimuli had the hair and nonfacial areas removed in Adobe Photoshop (Adobe systems, Incorporated, San Jose, CA [www.adobe.com]), so that only the central face area was visible. The location of each target face subtended a visual angle of 10.23° vertically and 8.17° horizontally (450×350 pixels) and were positioned in center of the screen. Each face was presented on a black background.

Design and procedure—There were three experimental phases to the SCR experiment: habituation, acquisition, and extinction. The intertrial intervals varied between 15 and 25 s, with a mean of 20 s and were presented equiprobably to mitigate anticipatory and habituation effects. Across the habituation, acquisition, and extinction phases target faces were presented in randomized order with the restriction that only two successive presentations of each face were presented. All stimuli were presented at a viewing distance of 56 cm from the screen, which was positioned at eye-level.

The habituation phase exposed the participants to two nonreinforced presentations of angry face A, angry face B and the neutral face stimuli. Each trial began with a fixation cross presented for 500 ms, upon offset of the fixation cross one nonreinforced face was presented for 100 ms followed by a blank screen. Each face stimuli was presented twice resulting in a total of 6 habituation trials.

The acquisition phase consisted of 3 event types; CS+, CS−, or N−. During acquisition trials, the conditioned stimulus (CS+) was counterbalanced across participants, with half of the participants conditioned to angry face (A) and the other half conditioned to angry face (B), to rule out any confounding artifacts in the faces. For the CS+, the presentation of the appropriate angry face was immediately followed by the delivery of an auditory unconditioned stimulus (US), which was a 500 ms burst of white noise. Each trial began with a fixation cross presented for 500 ms, upon offset of the fixation cross the CS+, CS−, or the N− was presented for 100 ms followed by either a blank screen for 500 ms or an aversive noise (CS+). Participants were instructed to press one of two response buttons to indicate whether they liked or disliked the face in the photograph. During the acquisition phase each of the three faces was presented 20 times, resulting in a total of 60 acquisition trials.

The extinction phase proceeded as follows. Stimulus-onset-asymmetries (SOA) for trials were exactly the same as the acquisition phase. Participants were instructed to stay still and remain focused on the computer screen and to respond verbally whether they liked or disliked each face. This ensured that participants were actually processing expressive features within each face while SCRs were recorded. During the extinction phase participants were presented with 36 extinction trials (12 CS+, 12 CS−, and 12 neutral faces) presented in a randomized order.

SCR data was investigated with a repeated measure ANOVA with 3 (Face; CS+ angry face vs. CS− angry face vs. N− neutral face) $\times$ 2 (Trial: First vs. Second) as within subject factors for the habituation phase; and with 3 (Affective salience: CS+ Angry vs. CS− Angry vs. N− Neutral) $\times$ 12 (Trial: Trials 1–12) as within subject factors for the extinction phase. The minimal response criterion was 0.05 microsiemens (μ S). Before statistical analysis, the SCR data underwent a correction range to reduce variation not related to psychological processes and a subsequent square-root transformation to normalize the distribution (Lykken, 1972). Separate analyses were performed on the habituation and extinction phase. No analysis was performed on the acquisition data given that US reinforcement would alter the SCR response to the CS+ angry face, but not the CS− angry face. The dependent variable was the SCRs measured as the maximal amplitude in conductance initiated in a 1–4 second latency window following the onset of each face (Prokasy & Kumpfer, 1973).

Results and Discussion

Habituation phase—A 3×2 (face $\times$ trial) within-subjects factorial ANOVA was conducted on SCRs. The main effect of face was nonsignificant, $F(2, 16) = 2.9, p > .05$. However, there was a significant main effect for trial ($F(1, 8) = 5.9, p < .05$). Post hoc tests revealed significant decrements in SCR from Trial one to Trial two for both angry face A

(Mean SCR = 0.37 μ S vs. 0.32 μ S), and angry face B (Mean SCR = 0.36 μ S vs. 0.31 μ S). The decrement in SCR from Trial one to Trial two for the neutral face was not significant. There was no interaction between face and trial (see Figure 1), showing that SCR responding during the habituation phase did not discriminate between the two angry faces. This similarity between the two angry faces during habituation is important because it confirms that both angry face A and angry face B was equally threatening before conditioning.

Extinction phase—A 3×12 (affective salience $\times$ trial) within-subjects factorial ANOVA was conducted on the SCR data presented in Figure 1. There was a significant main effect for trial ($F(11, 88) = 6.86, p < .001$), demonstrating a general SCR decrease across trials. There was also a main effect of affective salience ($F(2, 16) = 18.9, p < .001$) such that the CS+ angry face elicited larger SCRs ($M = 0.27, SD = 0.10$) than the CS- angry face ($M = 0.23, SD = 0.09$) and the N- neutral face ($M = 0.19, SD = 0.07$), during the extinction phase. No interaction was found between affective salience and trials ($F(22, 176) = .341, p > .05$), indicating that an affective salience effect was maintained across the extinction phase. As depicted in Figure 1, these results indicated that aversive noise increased the affective salience of angry expressions as measured by SCR.

Experiment 2

In Experiment 2 we sought to examine whether CS+ angry face distractors capture attention to a greater extent than CS- angry face distractors during low-load flanker trials and whether CS+ angry face distractors are resistant to modulation by perceptual load. Irrelevant face distractors (CS+, CS-, N) were presented while participants' speeded choice responses to a central task were recorded. The extent to which a face distractor is processed is indicated by the degree of interference caused on the central task. The load hypothesis predicts that distractors will be processed and thus cause interference in the low-load, but not the high-load condition, irrespective of the affective salience of the face distractor. The affective salience hypothesis predicts that a CS+ angry face distractor should capture attention, regardless of perceptual load.

Method

Participants—Fourteen participants (10 women) with a mean age of 27 years ($SD = 6$) were recruited for the flanker experiment. One participant was removed from the analysis because of an error rate of more than 3 SD s from the mean, leaving 13 participants in the study. Participants were preselected from a database of 240 people who were screened at the beginning of the academic year. All participants were right-handed and had normal or corrected-to-normal vision. Participants were naïve to the purpose of the experiment and received payment (£3) or course credits. All participants taking part in this study scored midrange (35–44) on a measure of trait anxiety (Spielberger et al., 1983). The University of Essex Ethics Committee approved the study protocol and participants gave written informed consent.

Apparatus and stimuli—The apparatus and stimuli used in the present experiment were exactly the same as those used in Experiment 1. Face distractor stimuli were presented with their center either 3.8° above or below fixation and subtended a visual angle of 3.82° vertically and 2.87° horizontally (142 $\times$ 201 pixels). The distance between the face distractor and the nearest target or nontarget letter was ~1.2 cm (1.23° of visual angle). Targets consisted of the lowercase letter 'x' or 'z.' The targets appeared at one of six positions in the center of the computer screen along with either the nontarget letter 'o' in the low load condition or with five nontarget letters 'k,' 's,' 'm,' 'v,' and 'n' in the high load condition.

The targets and the nontargets subtended a visual angle of 0.4° vertically and 0.4° horizontally and were separated by $\sim 0.2^\circ$ nearest edge to edge from any adjacent letters in the same row (see Figure 2). Consequently, face distractors were clearly presented in the periphery segmented from the letter classification task, providing a strong test of automaticity.

Design and Procedure—There were two sections to Experiment 2; an initial acquisition phase and the main flanker task. Full instructions were presented on the computer screen at the beginning of each phase. The acquisition phase was exactly the same procedure as the acquisition phase in Experiment 1. All stimuli were presented at a viewing distance of 56 cm from the screen, which was positioned at eye-level.

After completion of acquisition, using a 7-point Likert scale, participants reported levels of anxiety (1 = *no anxiety*, 7 = *extreme anxiety*), fearfulness (1 = *not at all fearful*, 7 = *extremely fearful*), perceived valence (1 = *not at all unpleasant*, 7 = *extremely unpleasant*), and levels of arousal (1 = *not at all aroused*, 7 = *extreme arousal*) elicited by CS+ and CS− angry faces. The flanker task immediately followed the conditioning phase. Each trial in the flanker task began with a central fixation cross presented at the center of the computer screen for 500 ms. Upon offset of the fixation cross, a target display of letters appeared at the center of the screen with a distractor face presented equiprobably above or below the letters for 100 ms. Thus, both the letter display and the face distractor appeared for the full duration of the stimulus trial. The participants were required to respond to one of two response buttons to indicate which target letter appeared in the central display ‘x’ or ‘z’ (see Figure 2). The two response buttons were switched for handedness on half the participants. The participants were instructed to concentrate on the task at hand and make their responses as quickly and accurately as possible, while ignoring the irrelevant distractor. A blank screen was then presented until response. After response a blank screen was maintained for 500 ms until the beginning of the next trial. The computer emitted a 500-Hz feedback tone when participants made an error.

One concern with this design was the expected extinction or habituation that was likely to occur during the flanker experiments. Accepting that a CS+ angry face might quickly lose its aversion if it was repeatedly presented alone without a noise during each experimental block (see Figure 1), it was important to reduce the likelihood of such extinction. To do this, a reinforcement acquisition phase consisting of 12 (4 CS+, 4 CS−, and 4 N−) trials was added before each experimental block, using the same design as the initial conditioning phase. The use of reinforcement trials have previously been used to good effect in a study showing aversively conditioned stimuli are prioritized and modulate attention during an attentional blink experiment (Smith, Most, Newsome, & Zald, 2006).

The ordering of the target and nontarget letters in the primary letter classification task were randomized and counterbalanced across participants and the distractor face was equally likely to be the CS+, the CS−, or the neutral expression, either above or below the letter display. Perceptual load was presented in two different testing sessions in a repeated-measures block design. The acquisition phase/conditioning procedure was repeated on the second testing session. Half the participants completed the low load condition first followed by the high load condition, while the other half had the reverse order. The three distractor faces were presented 24 times in each block, creating a total of 72 trials in each block. There were four blocks in the experiment, making 288 trials for each perceptual load condition, which resulted in total of 576 trials. The testing session was split into two parts (~1 week apart). Each session took ~30 min.

The dependent variables were mean reaction times (RTs milliseconds) and accuracy scores, which were investigated using 2×3 repeated measures ANOVAs, with Perceptual Load (high load vs. low load) and Distractor Salience (neutral faces vs. CS– angry face vs. CS+ angry face) as within subject factors. Paired t test comparisons with Bonferroni adjustments at alpha level $p < .05$ were conducted where appropriate.

Results and Discussion

RTs—RTs (milliseconds) on error trials and RTs more than 3 SD s from the mean were removed from the data before analysis, and accounted for $<2\%$ of the trials. Analysis of the RTs (milliseconds) revealed a main effect of load ($F(1, 12) = 35.13, p < .001$), with responses for the low load condition (Mean RT = 563 ms) being faster than the high load condition (Mean RT = 679 ms), confirming that perceptual load modulation was successful in increasing task difficulty (see Figure 3). There was also a main effect of distractor salience ($F(2, 24) = 10.12, p < .01$), with responses for the CS+ (Mean RT = 647 ms) being slower than the CS– (Mean RT = 617 ms) and the neutral (Mean RT = 598 ms), that was qualified by an interaction with load ($F(2, 24) = 11.34, p < .01$). This interaction indicated that the high load condition eliminated distractor salience interference effects.

To investigate this interaction, separate one-way analyses were conducted for the low load and high load conditions. A one-way analysis on the low load condition revealed a main effect of distractor salience ($F(2, 24) = 18.7, p < .001$). Paired t tests showed that RT was slower for the CS+ angry face compared to the CS– angry face (Mean RTs = 608 ms vs. 564 ms, $t(13) = 2.9, p < .05$), and to the neutral face ($M = 608$ ms vs. 516 ms, $t(13) = 7.1, p < .001$). The response times on CS– trials were slower than on the neutral face trials (Mean RTs = 564 ms vs. 516 ms, $t(13) = 2.9, p < .05$).

These results suggest that angry distractor faces capture attention to a greater extent than neutral nonthreatening faces, at least when the perceptual demands of an ongoing task are low. It is of interest that the aversive noise boosted response interference to the same extent as the difference between the neutral and the CS– angry face, that is, [CS+ > CS– (40 ms); CS– > neutral (50 ms); CS+ > Neutral (90 ms)]. A separate one-way analysis on the high load condition revealed no main effect of distractor salience ($F < 1$), thus contrary to the affective salience hypothesis the strong interference effect by the CS+ angry face distractor under the low load condition was completely eliminated in the high perceptual load condition, extending previous findings that high perceptual load eliminates distractor processing (Erthal et al., 2005; Lavie, 1995; Lavie & Fox, 2000; but see Lavie, Ro, & Russell, 2003, for contrasting results).

Errors—Analysis of the error rates revealed a main effect of load ($F(1, 12) = 8.95, p < .05$), with error rates for the low load condition being lower than the high load condition (3.0 vs. 7.0%), indicating that our paradigm effectively modulated task difficulty without confounding attentional capacity limits. There were no further effects on error rate for distractor salience and load, or their interaction (all F s < 1).

Reported subjective measures—A Wilcoxon's Signed-ranks test indicated that subject levels of anxiety were greater for the CS+ angry face than the CS– angry face ($Z = 3.11, p < .05$). The CS+ angry face was also judged to be more unpleasant ($Z = -2.51, p < .05$), more arousing ($Z = -2.98, p < .05$), and threatening ($Z = -2.86, p < .05$) than the CS– angry face, indicating that fear-conditioning was occurring during acquisition.

Experiment 3

The result of Experiment 2 showed that perceptual load was the primary determinant of whether fear conditioned angry face distractors are processed and cause interference on task performance. The design of Experiment 2 meant that perceptual load was varied between experimental blocks across two separate testing sessions. Therefore, the possibility remains that demand effects or attentional set might have affected the results. The aim of Experiment 3 was to determine whether fear-conditioned face distractors would produce interference in a paradigm with less predictable demand expectations. Therefore, the design and procedure of Experiment 3 was identical to that of Experiment 2 except that perceptual load was now randomized *within* experimental blocks and all testing was completed in a single session. The hypotheses and all other aspects of the design and procedure remain the same as in the previous experiment.

Method

Participants—Twenty experimentally naïve participants (12 women) with an average age of 29.4 years ($SD = 7.88$) were recruited for the experiment from the University of Essex. Participants were preselected from the same population as the previous two experiments. All participants scored midrange (35–44) on a measure of trait anxiety (Spielberger et al., 1983), were right-handed, had normal or corrected-to-normal vision and were paid £5 for taking part in the experiment. The data of two participants were removed from the analysis because of error rates of more than 3 SD s from the mean, leaving 18 participants in the study.

Apparatus and stimuli—The apparatus, face stimuli, target, and nontarget letters were exactly the same as Experiment 2.

Design and procedure—There were two experimental sections to the flanker experiment, an initial fear conditioning (acquisition) phase and the main flanker task. The acquisition phase was exactly the same as the previous experiments, and the flanker task with exactly the same stimuli as Experiment 2 immediately followed the acquisition phase. This phase consisted of 36 practice trials followed by 8 blocks of 72 trials, which resulted in a total of 576 trials. The entire experiment lasted about 45 min for each participant. The only difference from the previous experiment was that both levels of perceptual load (low and high) were randomized in the same experimental block. A reinforcement acquisition phase consisting of 12 (4 CS+, 4 CS–, and 4 N–) trials was added before each experimental block to ensure that habituation did not occur.

Results and Discussion

RTs—RTs (milliseconds) on error trials and RTs more than 3 SD s from the mean were removed from data before analysis, and accounted for <2% of the trials. The mean correct RTs are shown in Figure 4. As in Experiment 2 analysis of the RTs revealed a main effect of load ($F(1, 17) = 65.5, p < .01$), with responses for the low load condition (Mean RT = 552 ms) being faster than the high load condition (Mean RT = 685 ms). Also as before, there was a main effect of distractor salience ($F(2, 34) = 5.7, p < .01$), with responses for the CS+ ($M = 631$ ms) being slower than the CS– (Mean RT = 616 ms) and the neutral (Mean RT = 608 ms), that was qualified by an interaction with load ($F(2, 34) = 10.2, p < .001$). As before, this interaction indicated that the high perceptual load condition eliminated distractor processing.

To investigate this interaction, separate one-way analyses were conducted for the low load and high load conditions. The one-way analyses on the low load condition revealed a main effect of distractor salience ($F(2, 34) = 13.7, p < .001$). Subsequent paired t tests showed that

RT was slower for the CS+ angry face compared to the CS- angry face (Mean RTs = 580 ms vs. 550 ms, $t(17) = 2.9$, $p < .05$) and the neutral face (Mean RTs = 580 ms vs. 526 ms, $t(17) = 4.6$, $p < .01$) trials. The CS- trials also differed from the neutral face trials (Mean RTs = 550 ms vs. 526 ms, $t(17) = 2.7$, $p < .05$). This indicated that the aversive noise boosted response interference to approximately the same extent as the difference between the neutral and CS- angry face, that is, [CS+ > CS- (30 ms), CS- > Neutral (24 ms) and CS+ > Neutral (64 ms)]. A one-way analysis on the high load condition revealed no significant effect of distractor salience ($F < 1$), indicating that the affective salience hypothesis was only supported during conditions of low load with the CS+ face showing greater interference relative to the CS- face. The prediction that the CS+ face would successfully compete for limited attentional resources and cause interference in the high load condition was not supported, replicating the pattern of results shown in Experiment 2. This shows that both the CS+ and the CS- angry face distractor modulated differential response patterns relative to the neutral face when sufficient attention resources were available under low load. However, when spare attentional resources were constrained by the perceptual demands of the flanker task this response pattern was eliminated, suggesting that attention does have a role to play in the perception of emotion (Pessoa et al., 2002).

Errors—An ANOVA on error rates revealed a main effect of load ($F(1, 17) = 33.7$, $p < .001$), with greater errors for high load compared to the low load condition (15.0 vs. 5.0%). The error rate in Experiment 3 (5 vs. 15%, for the low and high load condition, respectively) was ~50% greater than the error rate in Experiment 2. There are two possible reasons for this finding: First, participants in Experiment 3 may have found the relevant letter discrimination task less predictable than the subjects in Experiment 2. Second, the less predictable randomization order of perceptual attentional load in Experiment 3 may have diluted anticipatory or strategy-based differences that might have had an effect on performance in the flanker task. Either way, the increased error rates across perceptual load conditions in Experiment 3 indicated that the present paradigm effectively modulated task difficulty, without confounding attentional resource limitations, or the perceptual operations necessary to elaborate them. A third possible reason for the higher error rate in Experiment 3 might be that both low- and high-load conditions were completed in one sitting, resulting in a longer experiment and potentially greater participant fatigue. However, as in Experiment 2 there were no further effects on error rate for distractor salience and load or their interaction (all F s < 1), this was also the case for when error rate for the experimental blocks 1–4 was subsequently compared with error rate for experimental blocks 5–8.

Reported subjective measures—A Wilcoxon's Signed-ranks test indicated that subject levels of anxiety were greater for the CS+ angry face than the CS- angry face, $Z = -3.59$, $p < .001$. The CS+ angry face was also judged to be more unpleasant ($Z = -2.75$, $p < .05$), more arousing ($Z = -3.35$, $p < .001$), and threatening ($Z = -3.26$, $p < .001$) than the CS- angry face, indicating that fear-conditioning was occurring during acquisition.

General Discussion

The present behavioral study used a fear-conditioning procedure to investigate whether angry face distractors are resistant to modulation by perceptual load. Experiment 1 established that during extinction participants showed significantly greater SCR activity to a CS+ angry face relative to a CS- angry face, providing psychophysiological evidence that aversive noise can induce a conditioned response. Thus, we were able to increase the strength of distractor salience by means of a straightforward fear conditioning procedure. This result is consistent with other studies that have effectively modulated the affective salience of the CS+ angry face, over an angry face not associated with an aversive event (Boschen, Parker, & Neumann, 2007; Pischek-Simpsona, Boschen, Neumann, & Watersa,

2009), providing strong evidence that fear-conditioning can play a crucial role in the development of attentional bias for aversive stimuli (see also Beaver, Mogg, & Bradley, 2005, for similar results with snakes and spiders). Combining fear-conditioning procedures with manipulations of perceptual load also allowed us to provide a strong test of the hypothesis that emotion processing requires attention.

The results from Experiments 2 and 3 were quite clear. Under conditions of low perceptual load, reliable fear-conditioning effects demonstrated a graded pattern of interference such that conditioned angry faces produced more interference than nonconditioned angry faces, which in turn produced more interference than neutral facial expressions. This demonstrates that despite their identical physical features participants were more distracted by CS+ angry face distractors than by CS- angry face distractors, and both were more distracting than neutral expressions. Such robust differential interference effects from CS+ distractors was used here to provide a strong test of distractor interference under conditions of high perceptual load. Across two experiments there was no hint of differential response interference by fear-conditioned face distractors under high load conditions. This finding is important as it suggests that the processing and perceptual discrimination of threatening angry face distractors is indeed determined by capacity limits, extending and giving strong support to the perceptual load theory (Lavie, 1995).

The present research showed that the processing of unattended and highly salient face distractors do capture attention, but only when attentional resources are available to guide attention to unattended face distractors. This account of attention processing is consistent with other studies that have eliminated distractor processing under situations of high perceptual load (e.g., Erthal et al., 2005; Forster & Lavie, 2008; Lavie, 1995; Lavie & Fox, 2000). The present results are important, however, in extending previous findings to show that even aversively conditioned and highly salient stimuli require attentive resources to be processed. These results complement both fMRI and electrophysiological evidence demonstrating that early effects of preferential threat processing are influenced by perceptual load (e.g., Bishop, Jenkins, & Lawrence, 2006; Doallo, Holguin, & Cadaveira, 2006; Holmes, Vuilleumier, & Eimer, 2003; Ishai, Pessoa, Bickle, & Ungerleider, 2004; Pessoa et al., 2005; Schupp et al., 2007). Related fMRI findings have also revealed that fear arousing irrelevant faces evoked stronger responses in the amygdala and fusiform gyrus relative to nonarousing fear faces during low-load attentional conditions, but not during high-load conditions (Lim, Padmala, & Pessoa, 2008; Pessoa, McKenna et al., 2002; Pessoa et al., 2005). Taken together, our results along with other evidence, indicates that emotion processing only occurs when perceptual resources are available. When the perceptual load of a task is high, even highly salient fear-conditioned faces are not processed to a sufficient extent to produce interference.

Our results, however, are not consistent with those reported by Lavie et al. (2003), showing that interference effects from irrelevant face distractors were resistant to modulation by perceptual load. These authors argued that stimuli of sociobiological significance such as faces play a special role in attention and therefore do not depend on general capacity limits. The explanation for the different results is not clear. However, one possibility is that the duration of stimulus presentation in the Lavie et al. (2003) study may have allowed rapid shifts of attention. For instance, their experimental trials consisted of congruent or incongruent target names with distracting faces and these displays were presented until response with no time constraints placed on stimulus exposure. As such, there can be no guarantee that attentional resources were withheld from the distractor face, or indeed that load modulation without stimulus exposure limits, is sufficient to completely exhaust attentional resources. Thus, interference associated with the face distractors in Lavie et al. (2003) might not necessarily reflect attentional modulation by face stimuli, but rather reflect

the time it took to move attention back and forth from the distractor to the flanker task. The present experiments tried to rule out the potential confound of shifts of attention or eye movements toward the distractor stimuli by limiting the exposure of the flanker task to 100 ms and presenting distractors in a separate spatial location. We argue that this represents an exceptionally strong test of the perceptual load hypothesis. Our results are consistent with Lavie's (1995) original premise that perceptual load determines selective attention. We have shown that this is the case even when the distractor stimuli are highly salient emotionally relevant items and support the view that emotion perception does indeed require attention (e.g., Pessoa, 2005).

We conclude that perceptual load is a major determinant of whether unattended face distractors are processed, supporting and extending the perceptual load hypothesis (Lavie, 1995) and not supporting findings that face processing is immune to capacity limitations (Lavie et al., 2003). Our affective salience hypothesis was only supported during conditions of low load, with subtle patterns of graded response interference effects being found. Thus, the CS+ angry face did have a competitive edge over a CS- angry face or a neutral face in drawing attention away from a central task. However, this capacity of aversive stimuli to capture attention only occurred under conditions of low perceptual load. The contrast between our results and those reported by Lavie et al. (2003) is interesting and deserving of further research. Our sample size was relatively small, and we tested more female than male participants, all of which might limit the degree to which we can generalize our results. We also did not measure skin conductance responses in Experiments 2 and 3 and so it is possible that the degree of aversive conditioning was not as extensive as we found in Experiment 1. We feel that this is unlikely, however, given the results of the first experiment and the fact that fear-conditioning did have significant effects on interference under low load conditions. Nevertheless, future research could focus on larger sample sizes with equal numbers of male and female participants perhaps using psychophysiological measures along with the flanker task to ensure adequate fear conditioning. The potential impact of individual differences in emotion processing using the current paradigm would also be an interesting focus for future research on the nature of the complex interactions among perception, attention, emotion, and personality.

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References

- Anderson AK. Affective influences on the attentional dynamics supporting awareness. *Journal of Experimental Psychology: General*. 2005; 134:258–281. [PubMed: 15869349]
- Anderson AK, Christoff K, Panitz D, De Rosa E, Gabrieli JDE. Neural correlates of the automatic processing of threat facial signals. *Journal of Neuroscience*. 2003; 23:5627–5633. [PubMed: 12843265]
- Beaver JD, Mogg K, Bradley BP. Emotional conditioning to masked stimuli and modulation of visuospatial attention. *Emotion*. 2005; 5:67–79. [PubMed: 15755220]
- Bishop SJ, Jenkins R, Lawrence AD. Neural processing of fearful faces: Effects of anxiety are gated by perceptual capacity limitations. *Cerebral Cortex*. 2006; 17:1595–1603.
- Boschen MJ, Parker I, Neumann DL. Changes in implicit associations do not occur simultaneously to Pavlovian conditioning of physiological anxiety responses. *Journal of Anxiety Disorders*. 2007; 21:788–803. [PubMed: 17184968]
- Chun, MM.; Wolfe, J. Visual attention. In: Goldstein, EB., editor. *Blackwell's handbook of perception*. Blackwell; Oxford, UK: 2001. p. 272-310.

- Desimone R, Duncan J. Neural mechanisms of selective visual attention. *Annual Review of Neuroscience*. 1995; 18:193–222.
- Doallo S, Holguin SR, Cadaveira F. Attentional load affects automatic emotional processing: Evidence from event-related potentials. *Neuroreport*. 2006; 17:1797–1801. [PubMed: 17164667]
- Dolan RJ, Vuilleumier P. Amygdala automaticity in emotional processing. *Annual New York Academy of Sciences*. 2003; 985:348–355.
- Driver J. A selective review of selective attention research from the past century. *British Journal of Psychology*. 2001; 92:53–78.
- Driver J, Vuilleumier P. Perceptual awareness and its loss in unilateral neglect and extinction. *Cognition*. 2001; 79:39–88. [PubMed: 11164023]
- Eastwood JD, Smilek D, Merikle PM. Negative facial expression captures attention and disrupts performance. *Perception & Psychophysics*. 2003; 65:352–358. [PubMed: 12785065]
- Ekman, P.; Friesen, WV. *Pictures of facial affect*. Consulting Psychologists; Palo Alto, CA: 1976.
- Eriksen BA, Eriksen CW. Effects of noise letters upon the identification of a target letter in a non search task. *Perception and Psychophysics*. 1974; 16:143–149.
- Erthal FS, de Oliveira L, Mocaiber I, Pereira MG, Machado-Pinheiro W, Volchan E, Pessoa L. Load-dependent modulation of affective picture processing. *Cognitive Affective & Behavioral Neuroscience*. 2005; 5:388–395.
- Forster S, Lavie L. Failures to ignore entirely irrelevant distractors: The role of load. *Journal of Experimental Psychology*. 2008; 14:73–83. [PubMed: 18377168]
- Fox E. Processing emotional facial expressions: The role of anxiety and awareness. *Cognitive, Affective, & Behavioral Neuro-science*. 2002; 2:56–63.
- Fox E, Lester V, Russo R, Bowles RJ, Pichler A, Dutton K. Facial expressions of emotion: Are angry faces detected more efficiently? *Cognition and Emotion*. 2000; 14:61–92. [PubMed: 17401453]
- Fox E, Russo R, Georgiou G. Anxiety modulates the degree of attentive resources required to process emotional faces. *Cognitive, Affective, & Behavioral Neuroscience*. 2005; 5:396–404.
- Holmes A, Kiss M, Eimer M. Attention modulates the processing of emotional expression triggered by foveal faces. *Neuroscience Letters*. 2006; 394:48–52. [PubMed: 16257119]
- Holmes A, Vuilleumier P, Eimer M. The processing of emotional facial expression is gated by spatial attention: Evidence from event-related potentials. *Cognitive Brain Research*. 2003; 16:174–184. [PubMed: 12668225]
- Ishai A, Pessoa L, Bickle C, Ungerleider LG. Repetition suppression of faces is modulated by emotion. *Proceedings of the National Academy of Sciences, USA*. 2004; 101:9827–9832.
- Lavie N. Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception and Performance*. 1995; 21:451–468. [PubMed: 7790827]
- Lavie N. Distracted and confused? Selective attention under load. *Trends in Cognitive Sciences*. 2005; 9:75–82. [PubMed: 15668100]
- Lavie N, Fox E. The role of perceptual load in negative priming. *Journal of Experimental Psychology: Human Perception and Performance*. 2000; 26:1038–1052. [PubMed: 10884008]
- Lavie N, Ro T, Russell C. The role of perceptual load in processing distractor faces. *Psychological science*. 2003; 14:510–515. [PubMed: 12930485]
- Lavie N, Tsal Y. Perceptual load as a major determinant of the locus of selection in visual attention. *Perception and Psychophysics*. 1994; 56:183–197. [PubMed: 7971119]
- LeDoux, JE. *The emotional brain: The mysterious underpinnings of emotional life*. Simon & Schuster; New York: 1996.
- LeDoux JE. Emotion circuits in the brain. *Annual Review of Neuroscience*. 2000; 23:155–184.
- Lim SL, Padmala S, Pessoa L. Affective learning modulates spatial competition during low-load attentional conditions. *Neuropsychologia*. 2008; 46:1267–1278. [PubMed: 18206186]
- Lucas N, Vuilleumier P. Effects of emotional and non-emotional cues on visual search in neglect patients: Evidence for distinct sources of attentional guidance. *Neuropsychologia*. 2008; 46:1401–1414. [PubMed: 18289616]
- Lykken DT. Range correction applied to heart rate and to GSR data. *Psychophysiology*. 1972; 9:373–379. [PubMed: 5034126]

- Mitchell DG, Nakic M, Fridberg D, Kamel N, Pine DS, Blair RJ. The impact of processing load on emotion. *Neuroimage*. 2007; 34:1299–1309. [PubMed: 17161627]
- Pessoa L. To what extent are emotional visual stimuli processed without attention and awareness? *Current opinion in neurobiology*. 2005; 15:188–196. [PubMed: 15831401]
- Pessoa L, Kastner S, Ungerleider LG. Attentional control of the processing of neutral and emotional stimuli. *Cognition and brain Research*. 2002; 15:31–45.
- Pessoa L, McKenna M, Gutierrez E, Ungerleider LG. Neural processing of emotional faces requires attention. *Proceedings of the National Academy of Sciences, USA*. 2002; 99:11458–11463.
- Pessoa L, Padmala S, Morland T. Fate of unattended fearful faces in the amygdala is determined by both attentional resources and cognitive modulation. *NeuroImage*. 2005; 28:249–255. [PubMed: 15993624]
- Pishek-Simpsona LK, Boschen MJ, Neumann DL, Watersa AM. The development of an attentional bias for angry faces following Pavlovian fear. conditioning. *Behaviour Research & Therapy*. 2009 doi:10.1016/j.brat.2009.01.007.
- Prokasy, WF.; Kumpfer, KL. Classical conditioning. In: Prokasy, WF.; Raskin, DC., editors. *Electrodermal activity in psychological research*. Academic Press; New York: 1973. p. 157-202.
- Schupp HT, Stockburger J, Bublatzky F, Junghofer M, Weike AI, Hamm AO. Explicit attention interferes with selective emotion processing in human extrastriate cortex. *BMC Neuroscience*. 2007; 8
- Smith SD, Most SB, Newsome L, Zald DH. An “emotional blink” of attention elicited by aversively conditioned stimuli. *Emotion*. 2006; 6:523–527. [PubMed: 16938093]
- Spielberger, CD.; Gorsuch, RL.; Lushene, R.; Vagg, PR. *Manual for the state-trait anxiety inventory*. Consulting Psychologists Press; Palo Alto, CA: 1983.
- Vuilleumier P, Armony JL, Driver J, Dolan RJ. Effects of attention and emotion on face processing in the human brain: An event-related fMRI study. *Neuron*. 2001; 30:829–841. [PubMed: 11430815]
- Vuilleumier P, Schwartz S. Beware and be aware: Capture of spatial attention by fear-related stimuli in neglect. *NeuroReport*. 2001a; 12:1119–1122. [PubMed: 11338176]
- Vuilleumier P, Schwartz S. Emotional facial expressions capture attention. *Neurology*. 2001b; 56:153–158. [PubMed: 11160948]

Figure 1. Mean first-interval anticipatory responses (FAR) to CS+ angry face, CS- angry face and the neutral face as a function of habituation and extinction trials (square root transformation).

Figure 2. Example display of angry distractor face (A) and angry distractor face (B) in the high perceptual load condition. In this flanker task participants were instructed to ignore irrelevant distractor faces presented either above or below fixation and attend to the central letter classification task.

Figure 3.

Mean reaction times (in milliseconds) for the correct responses in Experiment 2. As can be seen mean reaction times were slower as a function of perceptual load (low vs. high). CS+, CS-, and neutral distractor interference was only observed during the low load condition. Participants were slower to respond to the relevant visual search task when the CS+ (black bar) face was presented as a distractor as opposed to the CS- (gray bar) and the neutral face (white bar) in the low load condition. During the high load condition times did not differ whether the CS+, CS-, and neutral distractors were presented. Error bars indicate the *SEMs*.
 * $p < .05$.

Figure 4.

Mean reaction times (in milliseconds) for the correct responses in Experiment 2. As can be seen mean reaction times were slower as a function of perceptual load (low vs. high). CS+, CS-, and neutral distractor interference was only observed during the low load condition. Participants were slower to respond to the relevant visual search task when the CS+ (black bar) face was presented as a distractor as opposed to the CS- (gray bar) and the neutral face (white bar) in the low load condition. During the high load condition times did not differ whether the CS+, CS-, and neutral distractors were presented. Error bars indicate the *SEMs*. * $p < .05$.