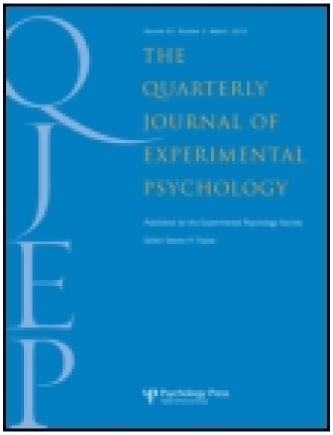

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Negative emotional stimuli reduce contextual cueing but not response times in inefficient search

Melina A. Kunar[a], Derrick G. Watson[a], Louise Cole[a] & Angeline Cox[a]

[a] Department of Psychology, The University of Warwick, Coventry, UK

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Negative emotional stimuli reduce contextual cueing but not response times in inefficient search

Melina A. Kunar, Derrick G. Watson, Louise Cole, and Angeline Cox
Department of Psychology, The University of Warwick, Coventry, UK

In visual search, previous work has shown that negative stimuli narrow the focus of attention and speed reaction times (RTs). This paper investigates these two effects by first asking whether negative emotional stimuli narrow the focus of attention to reduce the learning of a display context in a contextual cueing task and, second, whether exposure to negative stimuli also reduces RTs in inefficient search tasks. In Experiment 1, participants viewed either negative or neutral images (faces or scenes) prior to a contextual cueing task. In a typical contextual cueing experiment, RTs are reduced if displays are repeated across the experiment compared with novel displays that are not repeated. The results showed that a smaller contextual cueing effect was obtained after participants viewed negative stimuli than when they viewed neutral stimuli. However, in contrast to previous work, overall search RTs were not faster after viewing negative stimuli (Experiments 2 to 4). The findings are discussed in terms of the impact of emotional content on visual processing and the ability to use scene context to help facilitate search.

Keywords: Visual search; Emotion; Contextual cueing.

In everyday life, people search the world for objects. For example, we may search for a pen on a messy desk or look for a friend in a crowd. The process of how people attend to their visual environment is complex and can be influenced by many factors. For example, previous studies have shown that emotional stimuli can affect our search behaviour and that our attention can rapidly orientate to threats (e.g., Flykt, 2006; Fox, Griggs, & Mouchlianitis, 2007; Öhman, Flykt, & Esteves, 2001). Scientists can investigate visual search processes in the laboratory by asking participants to search for a prespecified target among distractors and record their reaction times (RTs) and/or error rates. From these studies we know that the visual system has a number of mechanisms that can be used to filter out irrelevant information and prioritize important and relevant information (e.g., Abrams & Christ, 2003, 2005; Klein, 1988; McLeod, Driver, & Crisp, 1988; Treisman & Gelade, 1980; Watson & Humphreys, 1997, 1998; see also Wolfe & Horowitz, 2004). Recent research has also shown that the surrounding context of a task can influence the search process. Chun and Jiang (1998) first demonstrated this by asking participants to search for a target letter T, among rotated distractor letter Ls. Unlike standard visual search experiments, half of the displays were repeated whilst the rest were seen only once within the experiment (unrepeated displays). The results

Correspondence should be addressed to Melina A. Kunar, Department of Psychology, The University of Warwick, Coventry, CV4 7AL, UK. E-mail: m.a.kunar@warwick.ac.uk

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showed that although participants demonstrated little explicit memory for repeated displays, RTs were nevertheless faster for the repeated displays than the unrepeated ones. This facilitation was called "contextual cueing" (CC; Chun & Jiang, 1998) and occurred because target presence became associated with the repeated layout of a display (Brady & Chun, 2007; Kunar & Wolfe, 2011).

There have been two main theories proposed to explain why contextual cueing occurs. One theory states that the context guides attention to the target location (Chun & Jiang, 1998). That is, the configuration of the distractors in the display guides attention to the target so that it was found faster (see also Johnson, Woodman, Braun, & Luck, 2007, for evidence of this theory using event-related potentials, ERPs, and Peterson & Kramer, 2001, for evidence using eye movements, although see Kunar, Flusberg, & Wolfe, 2008a, for an alternative hypothesis of these latter results). However, a benefit in guidance should also have a measurable impact on improving search efficiency in contextual cueing (measured by a decrease in the RT × Set Size function, or search slopes, across time), yet this was not observed (Kunar, Flusberg, Horowitz, & Wolfe, 2007; see also Kunar, Flusberg, & Wolfe, 2008b, and Wolfe, Klempen, & Dahlen, 2000, who showed that search slopes for repeated displays did not decrease across time). From this, Kunar et al. (2007) proposed a second theory, hypothesizing that the context instead speeds the response selection process (see also Schankin & Schubö, 2009, for further evidence of this theory using ERPs). That is, the amount of information that needs to accumulate before a person commits to a response is reduced in a familiar context where participants expect to see the target at a learned location. These theories differ in their explanation for how the attended context facilitates the search process. However, please note that both of these theories require participants to attend the context for learning to occur.

Brady and Chun (2007) recently investigated whether a contextual cueing effect occurs if only the immediately surrounding distractors of the target remained invariant. In their experiments they retained the configuration of the distractors within the quadrant of the target but randomly generated the distractor configurations in the remaining three quadrants. In this case, the total configuration of the display was altered but the configuration surrounding the target remained the same. Their results showed that a robust contextual cueing effect remained provided that the distractors nearest the target predicted its location (see also Olson & Chun, 2002). Please note, however, that this immediate context needed to be attended and processed in order to obtain a beneficial effect. Jiang and Chun (2001) showed that when the predictive context was not selectively attended, RTs to find the target did not differ from those of unrepeated displays. These results suggest that the context needs to fall within the focus of attention for a contextual cueing effect to occur.

Along with context, other work has shown that the emotional valence of a stimulus has a powerful effect on visual processing. We examine the effects of emotional stimuli on attention further in this paper using two methods of investigation. First, we investigate the effect of emotional stimuli on the processing of a display's context (using a contextual cueing task), and, second, we investigate the effect of emotional stimuli on response times using an inefficient visual search task. Taking the first point, previous research has suggested that negative emotions lead to diminished processing of peripheral items and a narrowing of attention (Easterbrook, 1959; Fenske & Eastwood, 2003; Fredrickson, 1998, 2001, 2004; Wadlinger & Isaacowitz, 2006; Wells & Matthews, 1994). This focusing or narrowing of attention could occur in a number of situations including inducing social stress (Huguet, Galvaing, Monteil, & Dumas, 1999; Sanders, Baron, & Moore, 1978), creating ego-threatening and time-pressured situations (Chajut & Algom, 2003), threatening participants with electric shocks (Wachtel, 1968), and presenting people with faces demonstrating negative emotions (Fenske & Eastwood, 2003). Fredrickson (2004) suggested a "broaden-and-build" account to explain the data stating that while positive emotions widen the focus of attention to peripheral areas, negative emotions tend to reduce it. Furthermore, Chajut and Algom (2003) suggested that the data could be explained by an "attention view" account whereby relevant and irrelevant stimuli undergo differential processing under negative conditions. In this case, negative emotions lead to fewer resources to process task-irrelevant peripheral stimuli and a narrowing of attention to only focus on local task-relevant stimuli. That is, if negative emotional stimuli automatically capture attention, this would leave fewer attentional resources available to attend to peripheral stimuli leading to an impairment in search.[1]

Gable and Harmon-Jones (2010) recently investigated the narrowing of attention using emotional stimuli by asking participants to respond to either the global or local letters of a Navon stimulus after they had viewed a negative image. Navon letters consist of a large global letter (e.g., a letter H) composed of many smaller local letters (e.g., letter Fs) and is typically used to measure attentional breadth (Navon, 1977). Gable and Harmon-Jones found that after viewing high-intensity negative stimuli (e.g., stimuli that promoted fear or disgust), participants responded faster to the local stimuli than to the global stimuli compared with when participants viewed neutral stimuli. The present study develops Gable and Harmon-Jones's findings to investigate whether viewing negative emotional stimuli can narrow attention within a contextual cueing task and thus impair the processing of a display's context to help find relevant information. Gable and Harmon-Jones's work suggests that following a negative image, individual stimuli were prioritized over global context. This leads to an interesting prediction. If attention becomes narrowed after viewing negative stimuli, then participants are less likely to attend the context of a particular display when processing it. As individual items are prioritized rather than their relationships with neighbouring distractors, then, if the emotional stimuli produced strong enough effects, even the benefit of a target having invariant nearby distractors (Brady & Chun, 2007) would be disrupted. It follows that viewing negative emotional stimuli should lead to a reduction in contextual cueing compared with viewing neutral stimuli. We investigated this in Experiment 1, in which we had participants search for a target letter T among distractor letter Ls in a contextual cueing task. In this task, half of the displays were repeated across the experiment (providing the target with a consistent predictive context) while the rest of the displays were novel.

The second aim of this paper was to test the general effect of emotional stimuli on visual search tasks—namely, the prediction that presenting negative emotional stimuli prior to a visual search task speeds RTs overall. Previous studies have shown that when searching through emotional stimuli, people are faster at searching for negative faces among positive ones (e.g., Blagrove & Watson, 2010; Frischen, Eastwood, & Smilek, 2008) and faster at responding to fear-relevant pictures (e.g., spiders and snakes) than to fear-irrelevant stimuli (e.g., flowers and mushrooms, Öhman et al., 2001; see also Flykt, 2006, and Fox et al., 2007). Using a different attentional paradigm, Olatunji, Ciesielski, Armstrong, and Zald (2011) investigated whether showing emotional stimuli prior to a nonemotional visual search display influenced response time (see also Becker, 2009). Phelps and LeDoux (2005) have suggested that showing participants threatening stimuli leads to increased arousal levels and increases a participant's vigilance (see also Kapp, Whalen, Supple, & Pascoe, 1992). From this it has been hypothesized that showing people fearful stimuli may lead to an overall improvement in perception and attention. One reason for this may be because fearful stimuli are thought to increase amygdala activation, which feeds back information to the visual cortex and other attentional regions in the brain to enhance perceptual processing (Phelps, Ling, & Carrasco, 2006; see also Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003; Vuilleumier, Armony, Driver, & Dolan, 2001, for evidence of an interaction between fearful faces,

[1] We would like to thank Anders Flykt for this suggestion.

the amygdala, and attention). If these regions of the brain have been primed by the amygdala, then it follows that they may be faster to respond to other subsequent stimuli (even if the subsequent stimuli have no emotional valence, per se; Phelps et al., 2006). Based on these findings, Olatunji et al. predicted that showing people pictures of fearful faces (taken from the Karolinska Directed Emotional Faces, KDEF, database; Lundqvist, Flykt, & Öhman, 1998) prior to a search display would increase overall arousal levels and decrease overall RTs in a visual search task. Their results concurred with this hypothesis and showed that participants responded more quickly to the target after being presented with a fearful face than with other emotional expressions.

Note that in the task used by Olatunji et al. (2011) the facilitation effect was relatively small, and participants were looking for a target that was uniquely salient in the display (the target was the only red circle present). This search task was distinctive in that with the presence of both the salient bottom-up colour cue and the strong top-down knowledge of the target colour, guided search theories predict that the target would already be highly activated on a visual saliency map (e.g., Wolfe, 2007; Wolfe, Cave, & Franzel, 1989). Here the emotion of fear may have acted to further boost bottom-up processes, producing faster RTs. However, this effect might not occur in displays where the target does not already produce strong activation by either bottom-up or top-down guidance. If instead a difficult search task was presented, then any additional beneficial effect of fear may be lost in the "noisy" process of actively searching the display. We investigated this possibility here by asking participants to search for a letter T among Ls—an inefficient search task known to afford little guidance (Wolfe, 2007; see Kunar, Humphreys, Smith, & Hulleman, 2003, for examples)—after being presented with fearful stimuli. If the effect of fear is only apparent in searches where the target is already highly activated (i.e., for salient targets) then we would not expect to see a benefit.

Experiment 1 examined the effect of preexposure to negative and neutral emotional stimuli (faces and scenes) on contextual cueing. In this experiment, a set of 20 emotional stimuli were presented prior to the search task to set up an emotionally negative or emotionally neutral context in which to perform the search task (see also Pacheco-Unguetti, Acosta, Callejas, & Lupiáñez, 2010, who manipulated emotion in this manner before the experimental task). According to Fredrickson's (2004) "broaden-and-build" account, showing participants negative stimuli prior to the search task should change people's search strategy, causing them to have a narrower focus of attention throughout the experiment. Participants were shown negative or neutral stimuli taken from either the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2001; see Most, Chun, Widders, & Zald, 2005; Most & Wang, 2011; Olivers & Nieuwenhuis, 2006, for previous studies using these stimuli) or the KDEF database (Lundqvist et al., 1998; see Olatunji et al., 2011, for examples) prior to the contextual cueing task,[2] in which they had to search for a target T among distractor letter Ls. Crucially, in this experiment half of the search displays were repeated while the other half were not. The results showed that the contextual cueing effect was reduced after participants viewed the negative stimuli compared to the neutral stimuli, consistent with the hypothesis that negative stimuli reduced the focus of attention. However, in contrast to the work of Olatunji et al. (2011), there was no benefit to overall RTs after participants were shown negative stimuli.

Experiments 2 and 3 replicated the conditions of Olatunji et al. (2011) but used an inefficient search task where participants were asked to search for a target T among distractor letter Ls

[2] Past work in the literature has used either scene or face pictures to investigate the effect of emotion on attention (e.g., Pacheco-Unguetti et al., 2010, and Olatunji et al., 2011, respectively). Therefore, we used both types of stimuli in Experiment 1.However, as the results suggest that there was no difference in the type of negative stimuli used, in Experiments 2 to 4 we used only face stimuli to manipulate emotion.

(which had a high degree of similarity to the target) rather than look for a uniquely salient target. In both experiments, participants viewed an emotional face before each trial (following the methodology of Olatunji et al., 2011). In Experiment 2, participants performed a target discrimination response task, whilst in Experiment 3 participants performed a target localization task (similar to that used by Olatunji et al., 2011). Again, in contrast to the work of Olatunji et al., the results showed that there was no decrease in overall RTs after viewing fearful stimuli.

In Experiments 2 and 3, negative and neutral stimuli were presented directly before each search display. In contrast, in Experiment 4 we tested whether setting up a negative context before a series of inefficient search trials (as in Experiment 1) influenced participants' search performance. If participants' attentional focus was narrowed after viewing negative stimuli they may be less able to process multiple stimuli in one glance—leading to a greater number of shifts in attention before finding the target. This would have the effect of decreasing search efficiency (as measured by the RT × Set Size function). As in Experiments 2 and 3, there was no benefit to overall response times after participants had been shown fearful stimuli. However, there was now a change in search efficiency such that people were *less* efficient at finding a target after viewing negative stimuli than when they viewed neutral stimuli. Taking the results of all four experiments together suggest that the RT advantage obtained after viewing fearful stimuli did not occur when using an inefficient search task.

EXPERIMENT 1

Method

Participants

Eighty-five participants (44 female, mean age = 23.1 years) took part in the experiment. All had normal or corrected-to-normal visual acuity. Given that each experimental condition lasted approximately 1 hour, to avoid effects of fatigue, a between-participants design was used, with participants divided between four conditions. There were 19 participants in the "negative scene" condition, 24 participants in the "negative face" condition, 18 participants in the "neutral scene" condition, and 24 participants in the "neutral face" condition.

Apparatus and stimuli

Displays were generated and responses recorded using custom programs running on a PC attached to a 19″ CRT monitor. The distractor items were white L shapes presented randomly in one of four orientations (0°, 90°, 180°, or 270°) on a black background. The target item was a white T, rotated 90° left or right with equal probability. Each L contained a small offset (~0.3°) at the line junction to make search more difficult. All stimuli subtended 1.7° × 1.7°, at a distance of 57.4 cm. Each display had a set size of 12 items (11 distractors and 1 target) with individual stimuli positioned within a 6 × 6 invisible matrix.

Procedure

Participants completed a block of 448 trials divided into seven epochs of 64 trials. Within each epoch, half of the trials were repeated; four displays were each repeated eight times per epoch. Thus, over seven epochs, each repeated display was shown 56 times. In a repeated display, the locations of both the target and the distractors remained constant across trials; however, similar to previous work, the orientation of each distractor and target was not assigned within a trial and could change across repeated displays. In the remaining trials (unrepeated displays), the configuration of the distractors was generated at random on each trial. In order to ensure that participants were not simply learning the absolute target location in repeated displays, in the unrepeated displays, targets appeared equally often in four locations, selected randomly at the beginning of the experiment, similar to previous work (e.g., Chun & Jiang, 1998; Kunar et al., 2007, 2008b; Kunar & Wolfe, 2011). However, these were not correlated with any of the distractor configurations. On each trial, participants responded to the orientation of the T by pressing "m" if the bottom of the T pointed to

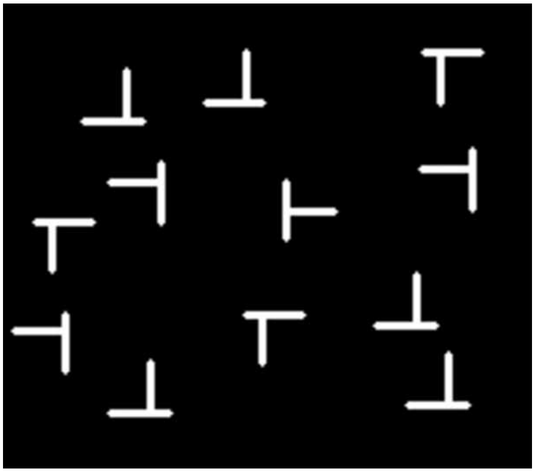

Figure 1. *An example visual search display for the contextual cueing task. The target is a T among rotated Ls.*

the right and "z" if the bottom of the T pointed to the left. Figure 1 shows an example display.

In the negative scene condition, after a short practice session, participants were shown 20 negative stimuli taken from the IAPS (Lang et al., 2001). Each image was shown for 3 seconds and had a mean rating of 3.46 for pleasantness and 4.95 for arousal on the IAPS scale. Immediately following the picture presentation, participants completed the experimental block of contextual cueing trials. Participants were then shown a presentation of 20 positive images (all taken from the IAPS database) to counter any potential effects of having viewed the negative stimuli and were given a debriefing with the experimenter to discuss the negative pictures if they wished in case they found the pictures too distressing; none of the participants did.

The negative face condition was similar, except that 20 fearful faces from the KDEF database (Lundqvist et al., 1998) were shown prior to the visual search displays. Stimuli were also presented for the shorter duration of 2 seconds each.[3] In the neutral scene condition, participants saw 20 neutral IAPS stimuli (Lang et al., 2001) before the contextual cueing task. Each image was shown for 3 seconds and had a mean rating of 5.22 for pleasantness and 2.66 for arousal on the IAPS scale. Finally, in the neutral face condition, 20 neutral faces from the KDEF database (Lundqvist et al., 1998) were shown prior to the visual search displays.

Results and discussion

The data from two participants were not analysed due to high error rates (over 90% in one condition) leaving data from 83 participants remaining. To examine the contextual cueing effect, RTs less than 200 ms (see also Kunar et al., 2007, 2008a; Kunar, Flusberg, & Wolfe, 2006; Kunar & Wolfe, 2011) and RTs greater than 3 standard deviations above the mean of each cell (per condition for each participant) were removed as outliers. This led to the removal of 2.7% of the data. Mean correct RTs were entered into a mixed analysis of variance (ANOVA) with within-participant factors of condition (repeated versus unrepeated) and epoch, and between-participant factors of stimuli (scene versus face) and emotional valence (negative versus neutral). The results showed that there was no difference in overall RTs depending on whether participants viewed the IAPS or KDEF stimuli before the contextual cueing experiment ($F < 1$). Neither were any of the interactions significant (all Fs < 1.7, ps $> .18$). As a result we pooled the RTs across stimulus type into a negative stimulus group and a neutral stimulus group. Figure 2a shows the mean correct RTs across epochs for the repeated and unrepeated trials in the negative stimulus group, and Figure 2b shows the mean correct RTs across epochs for the repeated and unrepeated trials in the neutral stimulus group.

A 2 (emotional valence: negative group vs. neutral group) × 2 (condition: repeated vs. unrepeated) × 7 (epoch) mixed ANOVA with between-participant factor of emotional valence was conducted to determine whether the valence of the emotional stimuli previously viewed

[3] Two seconds was still more than enough time for participants to process each stimulus. Previous studies have shown that emotional effects of negative stimuli can occur with presentation durations as short as 100 ms for each negative stimulus (e.g., Olatunji et al., 2011).

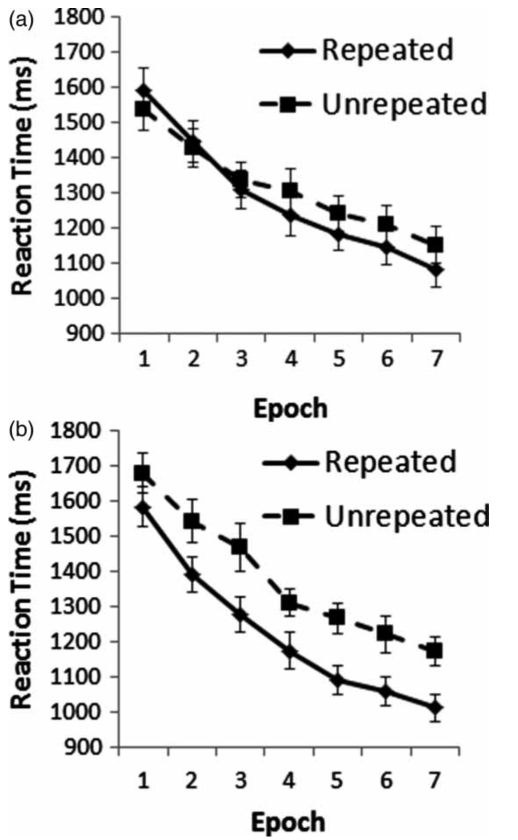

Figure 2. *Mean correct reaction times (RTs; ms) across epoch for the (a) negative stimulus group and (b) neutral stimulus group for repeated and unrepeated trials in Experiment 1. Error bars represent the standard error.*

influenced contextual cueing. Participants responded faster in repeated displays than in unrepeated displays, $F(1, 81) = 13.8$, $p < .01$, $\eta_p^2 = .146$, and RTs decreased with epoch, $F(6, 486) = 147.6$, $p < .01$, $\eta_p^2 = .646$. There was also a Condition × Epoch interaction, $F(6, 486) = 3.2$, $p < .01$, $\eta_p^2 = .038$; RTs became faster over epoch for repeated displays than for unrepeated displays. This shows that an overall contextual cueing effect was obtained. Please note that RTs decreased overall across epoch. This occurred for both the repeated trials and the unrepeated trials. RTs for unrepeated trials are thought to become faster across the experiment due to perceptual learning of the task and because participants become faster with practice. Crucially, however, RTs for the repeated trials showed a greater facilitation across the experiment. This occurred because participants had learned the context in the displays, which benefitted search by facilitating attentional guidance to the target (Chun & Jiang, 1998) and/or facilitating response selection (Kunar et al., 2007).

Of most importance, examining the effect of the emotional stimuli on contextual cueing, there was a significant interaction between Condition × Emotional Valence, $F(1, 81) = 6.2$, $p < .05$, $\eta_p^2 = .071$. The benefit of repeating a display was greater following neutral images than following negative images. There was no main effect of emotional valence, $F < 1$. However there was a significant Epoch × Emotional Valence interaction, $F(6, 486) = 2.3$, $p < .05$, $\eta_p^2 = .028$, in which RTs decreased more across epoch in the neutral condition than in the negative condition. None of the other interactions was significant (all *F*s < 1).

There have been many ways to measure contextual cueing in the literature, with some studies showing a difference in RTs between the repeated and unrepeated trials across the first few and the last few epochs (e.g., Olson & Chun, 2002) and others determining whether there was a difference in the last three epochs, where the contextual cueing effect was strongest (given that participants learned the context of the repeated displays in the preceding epochs, e.g., Chun & Jiang, 1998; Kunar et al., 2006, 2007, 2008a; Kunar & Wolfe, 2011). We conducted both of these additional analyses to further investigate the effect of negative stimuli on contextual cueing. To preview the results, both of these measures showed a decreased contextual cueing effect in the negative condition compared to the neutral condition.

First, we averaged RTs over the first three epochs and compared them to RTs averaged over the last three epochs in a 2 (emotional valence: negative group vs. neutral group) × 2 (condition: repeated vs. unrepeated) × 2 (first epochs vs. last epochs) mixed ANOVA with emotional valence as a between-participants factor. Similar to the above analysis, participants responded faster in repeated displays than in unrepeated displays,

$F(1, 81) = 12.4$, $p < .01$, $\eta_p^2 = .133$, and RTs were faster in the last three epochs than in the first three epochs, $F(1, 81) = 308.3$, $p < .01$, $\eta_p^2 = .792$. There was also a Condition × Epoch interaction, $F(1, 81) = 7.5$, $p < .01$, $\eta_p^2 = .085$, whereby the difference between RTs in the repeated and unrepeated trials was greater in the last three epochs than in the first three epochs. Again this demonstrates the presence of an overall contextual cueing effect. Post hoc t tests showed that there was no difference between repeated and unrepeated RTs in the first epochs, $t(82) = 0.5$, $p = .58$; however, there was a difference between repeated and unrepeated RTs in the last epochs, $t(82) = 4.4$, $p < .01$. Of most importance, there was a significant interaction of Condition × Emotional Valence, $F(1, 81) = 6.6$, $p < .05$, $\eta_p^2 = .076$. The benefit of repeating a display was greater following neutral images than following negative images. There was no main effect of emotional valence, $F < 1$. However, there was a significant Epoch × Emotional Valence interaction, $F(1, 81) = 5.1$, $p < .05$, $\eta_p^2 = .059$, in which RTs decreased more across epoch (the last three epochs vs. the first three epochs) in the neutral condition than in the negative condition. None of the other interactions was significant (all Fs < 1).

Second, we calculated the difference between repeated and unrepeated RTs collapsed across Epochs 5 to 7 as contextual cueing is said to have occurred if participants were faster in the repeated than in the unrepeated displays in the last three epochs (see Chun & Jiang, 1998; Kunar et al., 2006, 2007, 2008a; Kunar & Wolfe, 2011). The results are shown in Figure 3. A 2 (emotional valence: negative vs. neutral) × 2 (condition: repeated vs. unrepeated) mixed ANOVA with between-participant factor of emotional valence was conducted to examine the difference in contextual cueing across the mean of the last three epochs depending on the valence of the stimuli viewed. There was no significant main effect of emotional valence, $F < 1$; however, there was a main effect of condition, $F(1, 81) = 21.5$, $p < .01$, $\eta_p^2 = .210$, where RTs for repeated trials were faster than RTs for unrepeated trials. Of most importance, the Condition × Emotional Valence interaction was significant, $F(1, 81) = 4.4$, $p < .05$, $\eta_p^2 = .051$. Post hoc t tests showed that there was a marginally significant difference between the repeated and unrepeated trials over the last three epochs in the negative condition, $t(41) = 2.0$, $p = .053$, and that there was a significant difference between the repeated and unrepeated trials over the last three epochs in the neutral condition, $t(40) = 4.4$, $p < .01$. However, the contextual cueing effect was smaller after participants had viewed a series of negative stimuli (63 ms) than when they had seen neutral stimuli (167 ms).

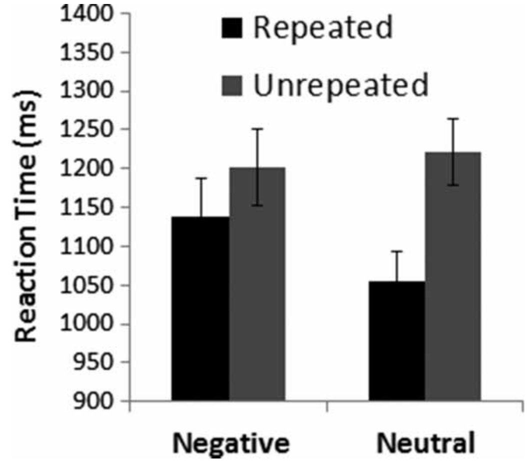

Figure 3. *Mean correct reaction times (RTs; ms) averaged over the last three epochs for the negative stimulus group and neutral stimulus group for repeated and unrepeated trials in Experiment 1. Error bars represent the standard error.*

Overall error rates were low at 2.0%. A mixed ANOVA on errors with within-participant factors of condition and epoch and between-participant factors of stimuli and emotional valence showed that there was no significant main effects of condition, epoch, stimuli, or emotional valence (all Fs < 1.7, ps $> .13$). The Condition × Emotional Valence interaction was significant, $F(1, 79) = 4.1$, $p < .05$, $\eta_p^2 = .049$, with error rates in the unrepeated condition being higher than those in the repeated condition for the neutral stimuli (2.1% vs. 1.9% for unrepeated and repeated trials, respectively) and vice versa for the negative stimuli conditions (1.8% vs. 2.2% for unrepeated and repeated trials, respectively). As this pattern of data follows that of the RT data, there was no sign of a speed–accuracy trade-off. The Stimuli × Emotional Valence interaction was significant, $F(1, 79) = 5.0$, $p < .05$, $\eta_p^2 = .059$; more errors were made after negative than after neutral faces were shown (2.9% vs. 1.7%, respectively) but this was opposite for scene stimuli (1.2% vs. 2.4%, for negative and neutral stimuli, respectively). There was also a significant three-way interaction of Condition × Epoch × Stimuli, $F(6, 474) = 2.6$, $p < .05$, $\eta_p^2 = .031$. None of the other interactions was significant (all Fs < 1.2). As error rates were low overall, we do not discuss them further.

There were two main findings. First, the size of the contextual cueing effect was reduced after viewing negative emotional stimuli compared with viewing neutral stimuli. Pooling data over the last three epochs, we see that the contextual cueing effect was over 100 ms greater in the neutral condition than in the negative condition. This concurs with our hypothesis that negative affective stimuli restrict the focus of attention so that the context of the display (even the neighbouring context) was no longer processed. Second, the results showed that there was no overall difference in RTs depending on whether participants viewed negative stimuli or neutral stimuli, prior to the contextual cueing task. These results contrast with those of Olatunji et al. (2011) who found an RT advantage when participants had viewed negative stimuli prior to searching for a unique red circle target. With more complex search stimuli, producing highly inefficient search, the presentation of fearful stimuli does not appear to speed responses.

Of course there were many differences between the contextual cueing task in Experiment 1 and the visual search task presented by Olatunji et al. (2011). In the first instance, some of the displays were repeated in Experiment 1 but not in Olatunji et al.'s experiments. Furthermore, the emotional stimuli were presented before each condition in Experiment 1, whereas in Olatunji et al.'s experiments an emotional face was presented prior to each trial for either 100 ms or 500 ms (with the 500-ms exposure time producing faster RTs in the fearful face condition). Olatunji et al. also had participants respond using a target localization task in which participants used a mouse to click on the position of the target rather than the two-alternative forced-choice (2AFC) task used in Experiment 1. Finally, Experiment 1 used a fixed set size of 12 display elements. It is possible that with more difficult search tasks, RT differences might depend on set size. For example, a small set size in a difficult search task might be equivalent to a larger set size in an easier search task. Given these variations, to ensure the differences in methodology were not driving the differences in fear-facilitation results, we replicated the experiment of Olatunji et al. (2011) using inefficient search stimuli in Experiments 2 and 3. Here we presented negative and neutral emotional faces (taken from the KDEF) for either 100 ms or 500 ms prior to a T versus L letter search task and had participants respond using a 2AFC task (Experiment 2) or a target localization task (Experiment 3).

EXPERIMENT 2

Method

Participants

Twenty-three participants (13 female, mean age = 20.4 years) took part in the experiment. All had normal or corrected-to-normal visual acuity.

Apparatus and stimuli

The apparatus and stimuli were similar to those of Experiment 1 except that set sizes of 4, 8, and 12 were used. Please note that Olatunji et al. (2011) only used set size 12 in their experiments. We extended the set sizes to calculate a measure of search efficiency in each condition.

Procedure

Thirty fearful faces and 30 neutral faces from the KDEF database (Lundqvist et al., 1998) were used as emotional stimuli, replicating the procedure used by Olatunji et al. (2011). Participants completed four experimental blocks of 90 trials (30 trials per set size). Each block corresponded to four conditions: a 500-ms negative condition, a 500-ms neutral condition, a 100-ms negative condition, and a 100-ms neutral condition. In the 500-ms negative condition, participants were shown a fixation cross for 500 ms followed by a fearful face that was presented for 500 ms. The search display was then presented, and participants were asked to respond to the orientation of the T, as quickly but as accurately as possible, by pressing "m" if the bottom of the T pointed to the right and "z" if the bottom of the T pointed to the left. The 500-ms neutral condition was similar except that participants were shown a neutral facial expression before the search stimuli appeared. In the 100-ms negative condition, participants were again shown the fixation dot for 500 ms before being presented with the negative face for 100 ms. A blank screen was then presented for 400 ms (so that the total time between the onset of the faces and the onset of the search stimuli equalled 500 ms in all conditions) before the search stimuli appeared. The 100-ms neutral condition was similar except that neutral faces were presented instead of negative ones. Participants completed a short practice session before each block, and the presentation order of the blocks across participants was randomized.

Results and discussion

RTs less than 200 ms and RTs greater than 3 standard deviations above the mean (for each cell) were

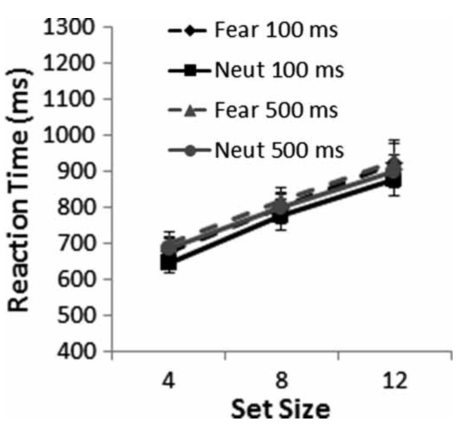

Figure 4. *Mean correct reaction times (RTs; ms) for all conditions in Experiment 2 across set size. Fear = fearful; Neut = neutral. Error bars represent the standard error.*

removed as outliers. This led to the removal of 1.7% of the data. Mean correct RTs are shown in Figure 4. A 2 (time: 500 ms vs. 100 ms) × 2 (emotional valence: negative vs. neutral) × 3 (set size: 4, 8, or 12) ANOVA of mean correct RTs showed there to be a main effect of set size, $F(2, 44) = 122.2$, $p < .01$, $\eta_p^2 = .053$, in which RTs increased with set size. However, there was no main effect of emotional valence, $F(1, 22) = 2.6$, $p = .12$, nor a main effect of time, $F(1, 22) = 1.2$, $p = .35$. The Emotional Valence × Set Size interaction was not significant, and neither were any of the other interactions (all Fs < 1, ps $< .4$).

Overall error rates were low at 2.4%. A 2 (time: 500 ms vs. 100 ms) × 2 (emotional valence: negative vs. neutral) × 3 (set size: 4, 8, or 12) ANOVA of error rates showed that there was no main effect of time or of set size, (all Fs < 1). The main effect of emotional valence approached significance, $F(1, 22) = 3.7$, $p = .07$, $\eta_p^2 = .143$; however, the difference in error rates between emotion conditions was small (2.7% and 2.0% for the negative and neutral conditions, respectively). None of the other interactions was significant (all Fs < 1.9, ps $> .17$). As error rates were low overall we do not discuss them further.

The results showed that presenting people with fearful faces before an inefficient search task did not lead to faster RTs than when participants were presented with neutral stimuli. Neither did it lead to more efficient search. These results contrast with those of Olatunji et al. (2011) who found that when using a search task for a more distinct target there was a fear-facilitation effect, at least when the stimuli were presented for 500 ms prior to the search display. Olatunji et al. (2011) report there being a 55.6-ms benefit in RTs for fearful compared to neutral conditions when they were presented for 500 ms; however, when the experimental conditions were replicated using inefficient search stimuli this difference was no longer significant. Indeed, overall RTs in the fearful conditions were numerically longer than those in the neutral condition (815 ms vs. 797 ms, respectively). Taking the results from Experiments 1 and 2 together, it seems that the fear-facilitation effect on response times does not extend to conditions of inefficient search at either relatively small or larger set sizes. One possible reason for the difference in findings could be due to the type of response required. In Experiments 1 and 2, participants performed a 2AFC target discrimination task, whereas Olatunji et al. had participants perform a localization task in which participants used the mouse to click on the target location. It could be that this change in response type affected people's search behaviour (for example, see Kunar & Wolfe, 2011, who showed that changing response type affects search behaviour in contextual cueing). Experiment 3 examined this by having participants use the mouse to respond to the target location in an inefficient search task, after viewing negative or neutral stimuli.

EXPERIMENT 3

Method

Participants

Twelve participants (7 female, mean age = 19.6 years) took part in the experiment. All had normal or corrected-to-normal visual acuity.

Apparatus and stimuli

The apparatus and stimuli were similar to those of Experiment 2.

Procedure

The procedure was similar to that of Experiment 2, except that participants used the mouse to click on the location of the target, as in the procedure of Olatunji et al. (2011). In each trial when the search display appeared, a mouse cursor was presented in the centre of the screen. Participants were instructed to move the cursor and to click on the location of the target. In all conditions, participants were asked to respond as quickly and as accurately as possible. In order for the response to be counted as a correct response, participants had to make sure that they clicked within a radius of 2.4° of the centre of the target item. Participants completed a short practice session before each block, and the presentation order of the blocks across participants was randomized.

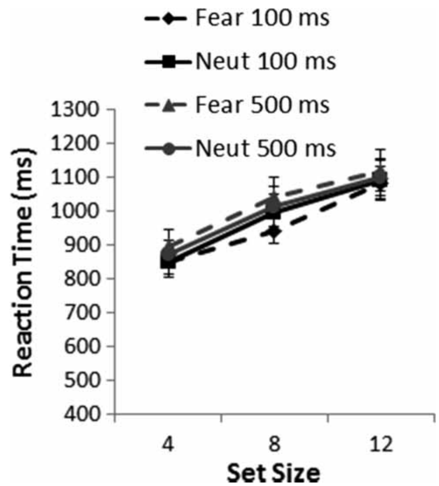

Figure 5. *Mean correct reaction times (RTs; ms) for all conditions in Experiment 3 across set size. Fear = fearful; Neut = neutral. Error bars represent the standard error.*

Results and discussion

RTs less than 200 ms and RTs greater than 3 standard deviations above the mean (for each cell) were removed as outliers. This led to the removal of less than 1% of the data. Mean correct RTs are shown in Figure 5. A 2 (time: 500 ms vs. 100 ms) × 2 (emotional valence: negative vs. neutral) × 3 (Set size: 4, 8, or 12) ANOVA of mean correct RTs showed there to be a main effect of set size, $F(2, 22) = 98.9$, $p < .01$, $\eta_p^2 = .900$, where RTs increased with set size. However, there was no main effect of emotional valence, $F < 1$. The main effect of time approached significance, $F(1, 11) = 4.1$, $p = .07$, $\eta_p^2 = .272$; RTs were slightly faster in the 100-ms condition (RT = 970 ms) than in the 500-ms condition (RT = 1008 ms). The Emotional Valence × Set Size interaction was not significant, $F(2, 22) = 1.3$, $p = .28$; neither were any of the other interactions significant (all Fs < 2.1, ps > .15).

Overall error rates were low at 1.2%. A 2 (time: 500 ms vs. 100 ms) × 2 (emotional valence: negative vs. neutral) × 3 (set size: 4, 8, or 12) ANOVA of error rates showed that there was no main effect of time, set size, or emotion (all Fs < 1). The three-way interaction approached significance, $F(2, 22) = 2.8$, $p = .08$, $\eta_p^2 = .202$; however, none of the other interactions was significant (all Fs < 2.4, ps $> .12$). As error rates were low overall we do not discuss them further.

Experiment 3 replicated the localization response type of Olatunji et al. (2011) by having participants use a mouse to click on the target location. Despite this, the results were similar to those of Experiment 2 and contrast with those of Olatunji et al. Presenting people with negative faces before each trial did not lead to a benefit in response times compared to presenting them with neutral faces. Neither did it lead to more efficient search. Experiment 1 showed that presenting all the faces before the visual search task changed people's search strategy and narrowed their focus of attention in a contextual cueing task. Experiment 4 investigates whether presenting all the faces before an inefficient search task also affects people's search behaviour.

EXPERIMENT 4

Method

Participants

Sixteen participants (12 female, mean age = 20.6 years) took part in the experiment. All had normal or corrected-to-normal visual acuity.

Apparatus and stimuli

The apparatus and stimuli were similar to those of Experiment 2.

Procedure

The procedure was similar to that of Experiment 2, except that participants saw all the affective faces before the visual search task started (similar to Experiment 1). For the negative condition, participants saw 20 negative stimuli taken from the KDEF database (Lundqvist et al., 1998) prior to the visual search displays. In the neutral condition, participants saw 20 neutral stimuli taken from the KDEF database (Lundqvist et al., 1998) prior to the visual search displays. Each stimulus was presented for 2 seconds. Participants completed a short practice session before each block, and the presentation order of the blocks across participants was randomized.

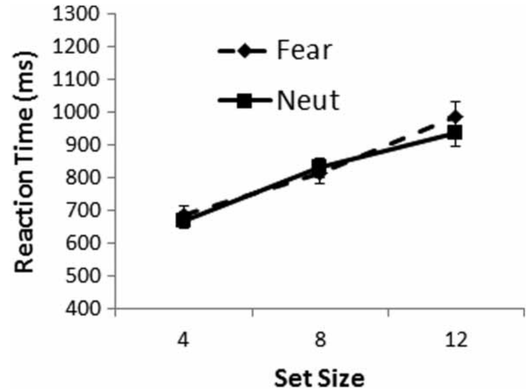

Figure 6. *Mean correct reaction times (RTs; ms) for all conditions in Experiment 4 across set size. Fear = fearful; Neut = neutral. Error bars represent the standard error.*

Results and discussion

The data from one participant were removed due to high error rates (over 50% errors). RTs less than 200 ms and RTs greater than 3 standard deviations above the mean (for each cell) were removed as outliers. This led to the removal of less than 1% of the data. Mean correct RTs are shown in Figure 6. A 2 (emotional valence: negative vs. neutral) × 3 (set size: 4, 8, or 12) ANOVA of mean correct RTs showed there to be a main effect of set size, $F(2, 28) = 137.7$, $p < .01$, $\eta_p^2 = .908$, where RTs increased with set size. However, there was no main effect of emotional valence, $F(1, 14) = 0.6$, $p = .46$. Participants were not faster to respond after viewing the negative faces than with the neutral faces. The Emotional Valence × Set Size interaction was significant, $F(2, 28) = 4.7$, $p < .05$, $\eta_p^2 = .250$. However, this was in the opposite direction to what would be predicted on the basis of Olatunji et al.'s (2011) fear-facilitation results; RTs in the negative condition increased more with set size than RTs in the neutral condition.

Overall error rates were low at 4.0%. A 2 (emotional valence: negative vs. neutral) × 3 (set size: 4, 8, or 12) ANOVA of error rates showed that there was no main effect of set size or emotion (both Fs < 2.1, ps $> .14$). Neither was the Emotional Valence × Set Size interaction significant ($F < 1$). As error rates were low overall, we do not discuss them further.

Interestingly, in this experiment there was a difference in search efficiency dependent on the emotional valence of the stimuli that were viewed. However, it was in the opposite direction to that predicted by Olatunji et al. (2011) where search was *less* efficient after viewing negative faces than after neutral faces. Similarly, in contrast to the results provided by Olatunji et al., response times, overall, were not quicker after viewing negative faces. We discuss this further in the General Discussion.

GENERAL DISCUSSION

Previous work has suggested that viewing negative stimuli narrows the focus of attention and leads to an overall decrease in RTs. This study first examined the effect of negative images on contextual cueing and second whether there was a general speeding of RTs after viewing negative stimuli using an inefficient search task. Taking the first point, Experiment 1 showed that a smaller CC effect was obtained after showing participants negative images than when they viewed neutral stimuli. This was particularly true across the latter epochs of the experiment where contextual cueing should be at its maximum (e.g., Chun & Jiang, 1998; Kunar et al., 2006, 2007, 2008a; Kunar & Wolfe, 2011). Fredrickson (2004) suggested that negative emotions lead to a narrower focus of attention (see also Easterbook, 1959; Fenske & Eastwood, 2003). Our results support this. If the focus of attention was sufficiently narrowed to process only individual items rather than the relationship between the stimuli (e.g., target and adjacent distractors) in the negative condition then the surrounding context would not be learned. Gable and Harmon-Jones (2010) found that a similar pattern occurred in the Navon task, in which negative emotion biased the processing of individual letters at the expense of the global figure. Our results extend this to contextual cueing. In both, negative emotional stimuli disrupted the ability to use the context of a scene in visual processing.

An alternative theory predicting a reduced contextual cueing effect after viewing negative stimuli would be that the presence of emotional stimuli interfered with memory. If the negative images led to impairment in memory processes then the learning of the repeated contexts would be, and CC would be reduced. Although possible, we believe this to be unlikely. Previous research has found that, if anything, the effect of viewing negative emotional stimuli on memory leads to enhanced performance in terms of both the quantity of information remembered (e.g., Buchanan & Adolphs, 2002; Hamann, 2001) and the quality of information remembered (e.g., Dewhurst & Parry, 2000; Ochsner, 2000). This also occurs for implicit memory tasks where emotional stimuli show improved performance in priming tasks (e.g., Burton et al., 2004; Collins & Cooke, 2005; LaBar et al., 2005; Michael, Ehlers, & Halligan, 2005). On this basis one would predict that implicit memory for the configuration would be stronger in the negative emotion condition leading to an increased CC effect. This did not happen. Instead we propose that negative emotional stimuli narrowed the focus of attention so the surrounding distractor context was not learned.

Experiment 1 showed that viewing negative stimuli disrupted contextual cueing. However, Gable and Harmon-Jones (2010) recently showed that attentional performance may also depend on the motivational intensity of negative stimuli used. In their study they found that negative stimuli that are high in motivational intensity (e.g., fear and disgust) narrow the focus of attention whereas negative stimuli that are low in motivational intensity (e.g., sadness) do not have the same effect. The stimuli in our studies used images that were high in motivational intensity (e.g., fearful faces and scenes with a high arousal rating). This led to a reduction in

CC. However, if participants were instead shown negative images of low intensity a contextual cueing effect might still be observed. It is up to future work to investigate this.

Let us now turn our attention to the second point. Olatunji et al. (2011) found that RTs to find a unique red circle in a visual search task were faster following the presentation of negative emotional stimuli. In contrast, using an inefficient T versus L letter search task, we found no benefit in RTs after participants had viewed negative stimuli. This difference did not occur due to discrepancies in methodology because Experiments 2 and 3 replicated and extended Olatunji et al.'s conditions and also failed to find an overall RT effect. This occurred using a target discrimination task (Experiment 2) and a 2AFC target localization task (Experiment 3). Experiment 4 also showed that there was little difference in response times after preexposure to the negative stimuli prior to the search task (similar to the methodology of Experiment 1). Furthermore, in this condition, search efficiency was actually worse after viewing negative stimuli than after neutral stimuli.

One of the main differences between Olatunji et al.'s (2011) work and the work presented here was the type of visual search stimuli used. With more complex inefficient search stimuli the fear-facilitation effect did not occur. Given that the fear-facilitation effect observed in Olatunji et al.'s work was relatively small (55.6 ms), it may be that with the increased noise and variability witnessed in a more inefficient search task any facilitation effect was lost[4] (see Watson, Maylor, & Bruce, 2005, for an analogous finding on the effects of old age on enumeration and search performance). Furthermore, the target in Olatunji et al.'s work was likely to have had a high activation on a visual saliency map, given that its colour could guide attention using both bottom-up and top-down processes (e.g., Wolfe, 2007; Wolfe et al., 1989). If fear increased arousal in this condition this could boost the already strong bottom-up signal, leading to a visible increase in RT. In contrast, in order to determine the location of a T in Ls (for example, in Experiments 2 to 4), each stimulus would need to be fixated in turn as the target would have a relatively low activation in the saliency map. Any arousal facilitation effect was likely to be lost as people laboriously searched through the display.

Interestingly, with preexposure to the negative stimuli before the visual search task, search was less efficient (as measured by the RT × Set Size function) than when participants viewed the neutral stimuli (Experiment 4). This did not occur in Experiments 2 and 3 when participants were presented with the valenced face before each trial. The results suggest that presenting all of the emotional stimuli at the start of the experiment led to a change in attentional strategy throughout the experiment, narrowing the focus of attention (supporting evidence of this comes from the lack of a significant Condition × Epoch × Emotional Valence three-way interaction in Experiment 1, showing that the effect of emotional valence did not change across time). This change in strategy affected search performance overall (see also Smilek, Enns, Eastwood, & Merikle, 2006, for evidence of strategy effects in visual search). For example, in Experiment 1 with a narrower focus of attention, the repeated context was processed to a lesser degree, leading to a reduction in contextual cueing, whereas in Experiment 4, with a narrower focus of attention fewer items could be processed in one glance. This meant that, with less peripheral processing, participants needed to serially search the display more before finding the target item.

Our results suggest that the fear-facilitation effect shown by Olatunji et al. (2011) is dependent on the difficulty of the visual search task. Becker (2009) also found that the presence of a fearful face improved search efficiency for an image of a house among other pictures. However, we suggest that the search task presented by Becker (2009) was easier than that presented here for two reasons. First the set sizes used by Becker (2009) were lower than those presented here. Despite

[4] As an objective measure of variation, the standard deviation in the 500-ms fear condition (set size 12 to match that of Olatunji et al.'s, 2011, work) here was 256 ms versus 120 ms in Olatunji et al.'s work.

this, even at our low set sizes we did not see an RT benefit. Second, the house image used as a target by Becker (2009) was perceptually different to the rest of the distractor stimuli. According to Duncan and Humpheys (1989), this would have the effect of creating an easier search task, allowing the fear-facilitation effect to have impact. Nevertheless, in more complex search, using highly inefficient search stimuli, the fear-facilitation effect of viewing negative stimuli, prior to a visual search task, was no longer apparent. Instead viewing negative emotional stimuli removed the RT advantage of presenting repeated displays. Our results add to the growing literature that emotional stimuli affect visual processing—in particular, viewing negative stimuli impairs our ability to process important contextual information.

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