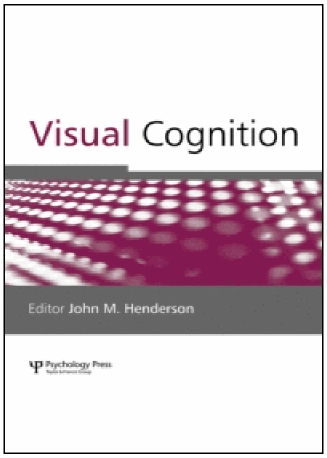

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The effect of emotional faces on eye movements and attention

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The present study investigated the nature of attention to facial expressions using an oculomotor capture paradigm. Participants were required to make a speeded saccade toward a predefined target and ignore distractors. The valence (happy or angry) and orientation (upright or inverted) of the target and distractors varied. We found evidence that irrelevant happy and angry face distractors did capture attention, but only when emotions were the target of search. Eye movements were not directed toward angry distractors any more often than toward happy distractors, and saccades to angry face targets were no faster than to other targets. The results provide evidence that emotion information can be used as a feature to voluntarily select targets and direct attention, suggesting attention is not necessary for the identification of emotional expression. There was no evidence, however, that angry face stimuli have a special priority for reflexively orienting attention.

As we scan the environment for a specific item, voluntary visual attention enables selection of specific types of information to the exclusion of those items that are irrelevant to current task goals or intentions (e.g., Folk, Remington, & Johnston, 1992). For example, if you are looking for your friend in a crowd, your attention might be drawn to people who have similar characteristics to your friend, such as a similar jacket or hair colour. Your

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attention might also be directed to certain kinds of events, even when they are irrelevant, because of intrinsic meaning or salience (e.g., Yantis & Jonides, 1984). Thus the reflection of sunlight off a shiny object might catch your attention, simply because it is bright, and not because it is in any way relevant to your intention to find your friend. The latter "reflexive" orienting system has been conceptualized as a "circuit-breaker" of voluntary attention, serving to interrupt ongoing voluntary attention in order to alert the system of a potentially important event (Corbetta & Shulman, 2002).

The notion that reflexive attention serves as an alerting system has led to the question of what kinds of events are able to summon attention reflexively. If reflexive attention is an adaptive system that prevents behaviourally relevant but unexpected events from escaping notice, one might predict that emotional or threatening events would have the power to attract attention reflexively. One approach to addressing this issue has been to measure the attentional effects of fear-inducing stimuli that are associated with phobias, such as snakes and spiders.[1] Öhman, Flykt, and Esteves (2001a) found faster reaction time to detect fear-inducing target (snakes and spiders), among neutral items (mushrooms and flowers) than to find a neutral target among fear-inducing items. This effect was more pronounced among participants with a specific snake or spider phobia. They suggest that fear-inducing stimuli are processed preattentively, that is, the threatening information can be extracted from a visual object without allocating attention to it. In comparison, in order to detect a neutral stimulus, attention must be allocated to each item in the display in a serial fashion in order to determine whether or not it is the target.

A serious problem with this interpretation of their results is pointed out by Tipples, Young, Quinlan, Broks, and Ellis (2002), who note that snakes and spiders are animals, and flowers and mushrooms are not. Thus the difference between snakes/spiders and flowers/mushrooms may be due to an animate/inanimate difference rather than a threatening/nonthreatening difference. In support of their interpretation, Tipples et al. replicated the effect that reaction time is faster when detecting an animal among plants than when detecting a plant among animals, but also showed across several studies that reaction time to detect a threatening animal target among neutral animals is no faster than to detect a neutral animal among threatening animals. They suggest that the subjective sense that attention is preferentially allocated to threatening events may arise not because attention is attracted to these stimuli, or because they are processed more

[1] Visual stimuli commonly associated with threat (e.g., snakes, spiders, angry faces) are often termed "threatening" in an experimental context, even though they pose no actual threat to the participant. The underlying assumption is that if orienting to threatening-looking stimuli really is reflexive, it should be invariant even in these extremely artificial contexts.

quickly, but because once attention has been directed to a threatening stimulus, it is harder to disengage from it than from neutral events.

Fox, Russo, Bowles, and Dutton (2001) make a similar distinction between the power to *attract* attention, and the power to *hold* attention. Using face stimuli, they observed that the time to detect a target presented in a location previously occupied by a threatening versus a neutral stimulus was the same, even for highly anxious individuals. When the target appeared at a different location than the threatening or neutral stimulus, reaction time to detect the target was delayed more for threatening than for neutral stimuli. This result suggests that attention is slower to disengage from a threatening stimulus than a neutral one. However, this pattern was only consistently observed among highly anxious individuals. Among those participants who scored low on an anxiety scale, slower disengagement of attention from threatening stimuli occurred only in a limited set of conditions. They suggest that anxiety increases the attentional dwell-time on threatening stimuli, rather like the "freezing" response to danger observed in other animals. They imply that this response is particular to highly anxious individuals, representing an orienting abnormality rather than a norm.

Other research has explored the effect of facial expression on visual search, because faces convey emotional information such as threat and affiliation very quickly and efficiently (e.g., Ekman & Friesen, 1975). Hansen and Hansen (1988) were the first to introduce emotional expressions to a visual search task. Their logic was that if an angry or threatening face draws attention automatically, then reaction time to detect an angry face in a crowd of happy faces should be faster than to detect a friendly face in an angry crowd. This is indeed what they observed. However, subsequent researchers have pointed out that the faces used by Hansen and Hansen in their experiment contained a critical confound, in that their versions of photographs of facial expressions (adapted from Ekman & Friesen, 1975) had high-contrast black patches on the angry faces, but not on the happy faces. When this perceptually salient feature was removed from the photographs, a priority for angry faces in visual search was no longer observed (Purcell, Stewart, & Skov, 1996).

Subsequent studies have explored the effect of emotion on attention using schematic faces instead of photographs. Schematic faces present an advantage over photographs because they convey emotional information efficiently and unambiguously, and can be more carefully controlled for contrast artifacts and other low-level perceptual differences such as those pointed out by Purcell et al. (1996). Eastwood, Smilek, and Merikle (2001) examined the reaction time to detect an angry or happy schematic face embedded among from 7 to 19 neutral faces. An increase in the number of distractors is typically associated with an increase in reaction time to detect a target. This increase across the search display size, known as the search slope, can be used as an index of how quickly attention can filter out the distractors and home in on the target. Eastwood et al. reasoned that if attention gives priority to angry faces, the search slope to detect an angry face among neutral distractors should be shallower than the search slope to detect a happy face among neutral distractors. The results confirmed this prediction: negative faces were detected faster than positive ones, and search slopes were slightly but consistently steeper for happy faces than for angry faces. When faces were inverted, negative faces were still detected faster than positive ones, but there was no difference in slope. This result suggests that it was indeed the facial expressions causing the decrease in reaction time and slope for angry faces, and not a difference in detection of a lower level stimulus property such as a down-curved line (if it were, there would be a reversal of the effect when the faces were inverted). Öhman, Lundqvist, and Esteves (2001b) also observed a very small but significant effect of emotional expression of faces on visual search, with faster reaction times to detect an angry target than to detect a happy target. There was no interaction of emotion with set size (from 4 to 25 items), however, in contrast to the findings of Eastwood et al.

One common feature of the studies above is that attention is typically measured using speeded detection responses. The locus of covert attention must therefore be inferred based on a nondirectional detection or discrimination response. Slower reaction times are usually interpreted in these experiments as evidence that attention was delayed from being deployed to the target location, but no direct measure of the locus of attention is possible. Other factors besides attention could slow responses in the presence of threatening distractors, such as changes in strategy to detect the target, slower discrimination of the target features, and increased competition between possible responses. The mutually contradictory results produced with regard to whether or not threatening stimuli capture attention might be the result of differences in how other factors besides selective attention influence manual discrimination and detection responses. By measuring visual search using eye movements instead of manual responses, a richer and more direct measure of attention can be obtained. Given that covert attention and eye movements tend to move together (e.g., Hoffman & Subramanian, 1995; Kowler, Anderson, Dosher, & Blaser, 1995; McPeek, Maljkovic, & Nakayama, 1999; Sheperd, Findlay, & Hockey, 1986), eye movements may be slower and more error-prone when attention is distracted by task-irrelevant events. There is also evidence from the oculomotor capture literature (e.g., Theeuwes, Kramer, Hahn, & Irwin, 1998) that salient events that occur during visual search can "capture" eye movements, even when the events are irrelevant to the current task. If threatening or emotional events attract attention reflexively, and therefore slow reaction time, one would therefore also predict that a highly emotional event would capture eye movements more than emotionally neutral events.

Several studies have measured the effect of threatening events on eye movements. Hermans, Vansteenwegen, and Eelen (1999) and Miltner, Krieschel, Hecht, Trippe, and Weiss (2004) both used similar flower/mushroom/spider stimulus sets as Öhman et al. (2001a). As such, their findings are subject to the same criticism levelled by Tipples et al. (2002) that the threatening/unthreatening manipulation is confounded with an animate/inanimate distinction. It is interesting to note, however, that Miltner et al. observed that both eye movements and manual responses were actually faster for mushroom than spider stimuli, showing the opposite pattern from the original Öhman et al. (2001a) study. Miltner et al. also observed that both manual responses and eye movements toward neutral stimuli were slowed by the presence of spiders among spider-phobics, but not among nonphobics. This result is similar to Fox et al. (2001) in that the attentional bias toward threatening stimuli is a unique characteristic of phobic individuals, and does not represent a typical attentional orienting response. A similar conclusion was also reached by Bradley, Mogg, and Millar (2000), who observed that eye movement biases towards threatening faces were correlated with manual reaction time biases to detect probe stimuli faster when shown over threatening faces than over nonthreatening faces. The bias to orient toward threatening stimuli was again particular to high-anxiety, but not low-anxiety, individuals.

To summarize the above results, the evidence that attention prioritizes emotionally negative or threatening events is suggestive, but not compelling, with some studies finding evidence in favour of this conclusion (e.g., Eastwood et al., 2001; Öhman et al., 2001a) and others finding evidence that if threatening events do interfere with search, they do so consistently only among people with anxiety or a specific phobia (e.g., Bradley et al., 2000; Tipples et al., 2002; Fox et al., 2001, Miltner et al., 2004).

The present study explored the effect of emotional faces on visual search, using eye movements to resolve the question of whether attention is attracted or held by negative emotional events. A single face target was shown among five distractors, equidistant from fixation, and the task was fixate the target face as quickly as possible. On half the trials, the five distractors were all neutral, but on the other half, one of the five distractors was a unique positive, negative, or neutral face. Using this method, four questions can be simultaneously addressed.

1. Will eye movements be directed towards angry face targets faster than happy or neutral face targets? If so, this result would support the conclusions of Öhman et al. (2001b), who suggested that attention is automatically allocated to threatening events.

2. Will erroneous eye movements towards a distractor (that is, oculomotor capture) be more frequent when the distractor displays anger than when it is positive or neutral? This would provide converging evidence that attention is reflexively attracted to threatening events.
3. Will an angry face distractor slow eye movements to a target more than a positive or neutral face distractor? Distraction effects could occur for several reasons. If the answer to Questions 1 and 2 above is "yes", then the distraction effect likely occurs because attention is reflexively drawn to angry distractors. If the answer to Questions 1 and 2 above is "no", however, it is more likely that the distraction effect is due to slower disengagement of attention from negative distractors, or some other factor such as target discriminability or strategy.
4. When eye movements are erroneously directed towards irrelevant items, are they slower to disengage and redirect to the target when the distractor is an angry face than when it is positive or neutral? If so, this would provide the most direct evidence to date that disengagement from a threatening stimulus is slower than from positive or neutral stimuli.

In the first experiment, the emotion and orientation of both target and distractor varied between participants. In the second experiment, the target type was always emotionally neutral, and the distractor emotion and orientation varied within participants. The results of these two experiments together will shed light on the relative power of negative face stimuli to both attract and hold attention.

EXPERIMENT 1

Methods

Forty participants were randomly assigned to one of four groups. For all four groups, the display was composed of a central fixation surrounded by six 3.7° black outlines of circles, equally spaced on a white background (see Figure 1). Each circle contained the same elements, but in different configurations and orientations (see Figure 2). The distance from the fixation point to the centre of each circle was 12.5°.

Groups were based on the emotion of the target to which participants were instructed to move their eyes. In the "happy" group, for example, each trial began with six upright neutral faces (see Figure 1). After 1000 ms, one of the faces changed from neutral to a happy face. On half the trials, a second face changed from neutral to angry. The task was to move the eyes from the central fixation crosshair to the happy face as quickly as possible, and the angry face was always irrelevant to this task for the participants in

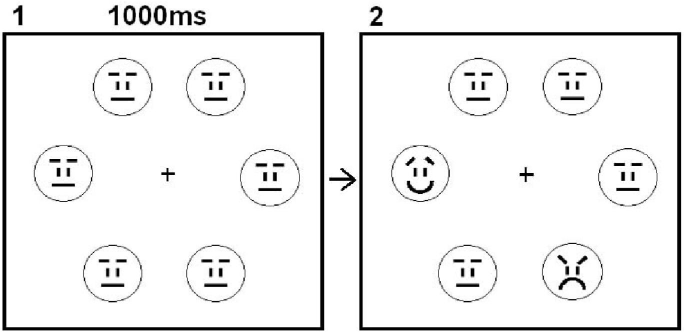

Figure 1. A typical distractor-present trial from the "happy" group from Experiment 1. Each trial began with six neutral faces, which appeared when the participant pressed the spacebar and a stable fixation was detected. After 1000 ms, one of the neutral faces became the target (for example, a happy face). On half the trials, the target face was displayed among only neutral faces, and on the other half of trials, an additional neutral face became a unique distractor (as shown above, an irrelevant angry face is shown along with the happy face). The task was to saccade to the target as quickly as possible, ignoring the other faces.

the happy group. The "angry" group participants were instructed to look towards the angry face among upright neutral faces, and on half the trials an irrelevant upright happy face was shown. The target and distractor appeared equally often at each of the possible locations, creating 30 possible configurations. The order of trials was randomly determined for each subject. Each trial ended 1600 ms after the onset of the target. Each participant completed a single block of 60 trials.

The other two groups provided a control condition, in which the displays shown to the "happy" and "angry" groups were inverted, including the neutral face distractors. The display was inverted in order to reduce the emotional content of the items without changing their perceptual features. Although inverting faces does disrupt normal face processing (e.g., Yin, 1969) and inverted emotional faces are detected more slowly than their upright counterparts (Prkachin, 2003) the emotional information is still communicated, albeit not so well. Thus it was necessary to disguise the stimuli's emotional content. To accomplish this, participants were instructed to search for the "mushroom" or "goblet" among "tables" (see Figure 2). In order to reinforce this interpretation of the display, participants were given 10 practice trials before the experimental block in which extra lines were added to the display to enhance their resemblance to nonemotional objects. During the experimental block, these additional lines were removed. After the experiment, participants filled out a questionnaire about the task and the resemblance of the objects to faces. Only two of the 20 participants in the inverted groups noticed that the objects in the display were actually inverted faces.

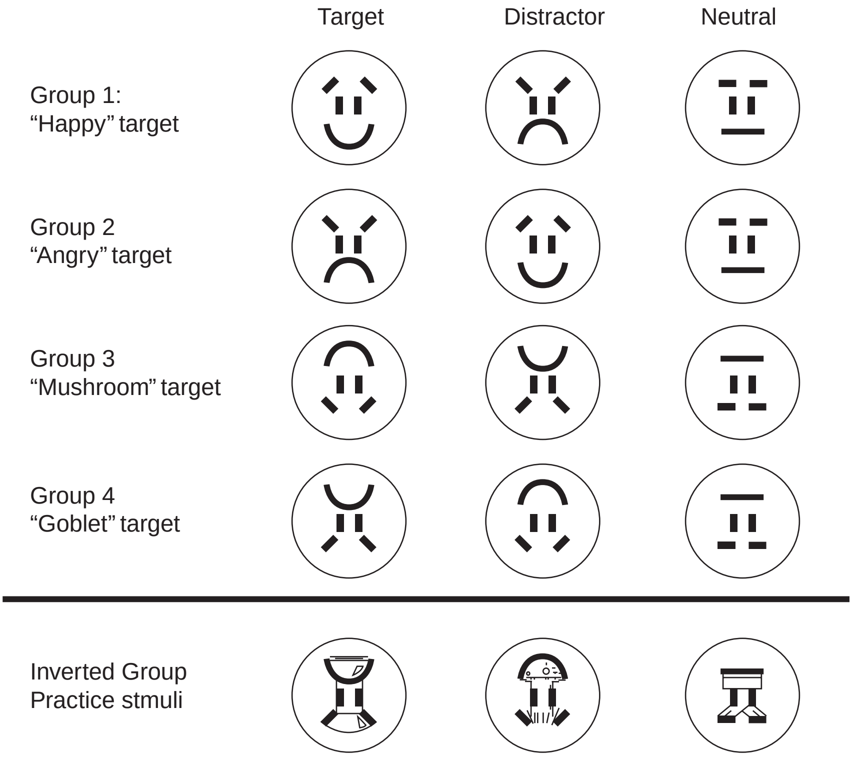

Figure 2. The stimuli used as the target, the unique distractor, and the neutral distractors in the four groups included in Experiment 1. The task was to fixate the target as quickly as possible, ignoring both neutral distractors and unique distractors. In the "mushroom" and "goblet" groups, participants were given practice trials prior to the experiment in which they were shown the inverted stimuli with extra lines included, in order to reinforce the interpretation of these stimuli as objects rather than faces.

Each participant was seated alone in a small room, with their heads resting in a chinrest 57 cm from a 17-inch 80 Hz monitor. The experimenter monitored performance from a display situated in an adjacent room. Eye movements were monitored using an EyeLink eye monitoring system (SMI research). Before the block began, participants underwent a nine-point calibration sequence. The position of the left eye only was recorded every 4 ms, and saccades were detected with a velocity criterion of at least 30° per second. Only the first saccade following the onset of the target to exceed a distance of 22.5 pixels in any one direction was analysed. Saccadic latency was recorded as the time from the onset of the target to the initiation of this first saccade. The landing position of the saccade was classified as (1) on the target if it landed within 30° (in polar coordinates) of the target; (2) on the unique distractor if it landed within 30° of the unique distractor, or (3) an error if it went elsewhere in the display. Only correct trials were included in saccade latency analyses. Trials were excluded from analysis when blinks occurred before the first eye movement, and when the eyes were not at the centre of the display when the target appeared.

Participants with less than 60% correct or useable trials were discarded from analysis and replaced. Five participants were rejected for not meeting this criterion: Two each from the inverted happy and upright angry groups, and one from the inverted angry group.

Results

The analyses were designed to address the four questions posed in the introduction. A mixed ANOVA with distractor (present or absent) as a within-subjects factor and emotion (angry or happy) and orientation (upright and inverted) as between-subjects factors was used to assess the effect of target and distractor type on reaction time. A between-subjects ANOVA examined the proportion of saccades directed toward the distractor as a function of the emotion and orientation of the target and distractor. Finally, a third between-subjects ANOVA examined the duration of fixation on the distractor, also as a function of emotion and orientation.

The results of the reaction time analysis are shown in Table 1. There was a main effect of the distractor on saccadic reaction time, with faster saccades to the target when the distractor was absent than when it was present, $F(1, 36) = 42.91$, $p < .001$. There was also a significant interaction of orientation and distractor, $F(1, 36) = 18.18$, $p < .001$, because the effect of the distractor was larger for upright faces than for inverted faces. When the reaction time to saccade to the target in the absence of a distractor was analysed as a function of the target type, there was no significant effect of the target emotion, $F(1, 36) < 1$, or target orientation, $F(1, 36) < 1$.

TABLE 1

The reaction time of saccades directed towards the four target types in the presence or absence of a unique distractor and duration of fixation on distractor in Experiment 1

	Distractor condition			
Target type	*Absent*	*Present*	*Distractor type*	*Distractor fixation duration*
Inverted angry	322.6 (13.7)	344.9 (17.2)	Inverted happy	181.1 (15.6)
Inverted happy	319.6 (23.6)	332.5 (20.6)	Inverted angry	185.6 (23.5)
Upright angry	319.1 (32.9)	394.5 (46.7)	Upright happy	231.1 (34.2)
Upright happy	343.4 (21.5)	434.3 (34.1)	Upright angry	220.6 (24.2)

Values are in milliseconds. Standard errors are given in parentheses.

The analysis of the proportion of saccades erroneously directed towards the irrelevant distractor was similar to the reaction time analysis, and is displayed in Figure 3. Saccades were misdirected towards the irrelevant distractor on 26.2% of the trials in which it appeared, so attention was clearly drawn to the unique irrelevant items. The important question is whether the emotional content of the faces influenced the degree to which eye movements were captured. There was no evidence that this was the case, with no significant effect of orientation, $F(1, 36) = 2.35$, $p > .1$, or emotion, $F(1, 36) < 1$, or an interaction, $F(1, 36) < 1$. There was a numerical increase in capture to 32.0% when the angry face was the target and the happy face was the distractor, but this was not sufficiently consistent across participants to be significant.

Finally, the duration of fixation of trials in which the eyes went to the distractor was analysed as a function of distractor type (see Table 1). The fixation duration was timed from the end of the saccade that landed on the distractor to the onset of the following saccade. There was no main effect of orientation, $F(1, 36) = 2.88$, emotion, $F(1, 36) < 1$, or an interaction, $F(1, 36) < 1$. In the introduction it was predicted that if threatening stimuli hold

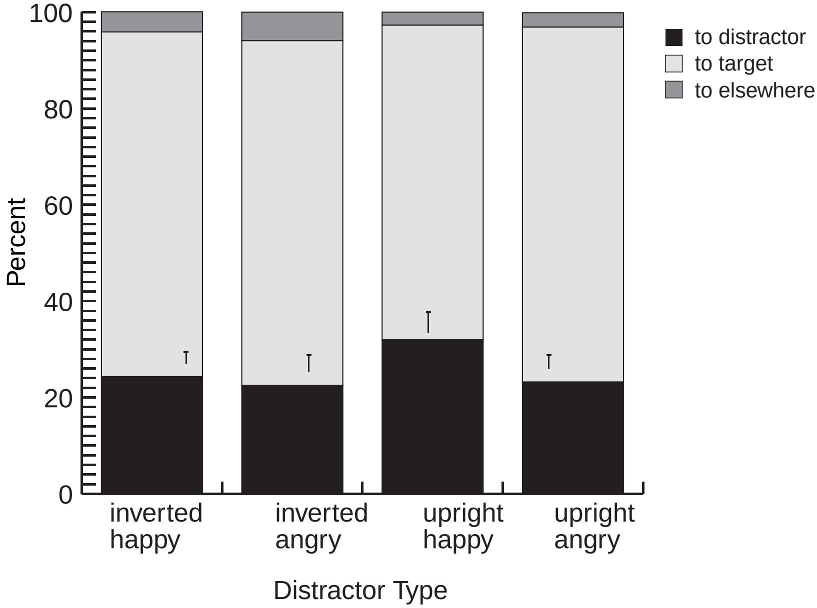

Figure 3. The proportion of saccades directed towards the unique distractor, the target, or to some other locations on the screen is shown as a function of the distractor type. Only distractor-present trials are shown. Error bars are the standard error of the mean proportion of saccades directed towards the distractor. The eyes were not directed towards angry faces more than other types of stimuli.

attention longer than other kinds of stimuli, that there would be longer fixations when the eyes land on the angry face than on happy or inverted faces. This result does not support that prediction.

Discussion

In response to the four questions posed in the introduction:

1. There was no evidence that eye movements were directed towards negative emotional faces faster than positive or neutral faces. This result is consistent with Bradley et al. (2000), Fox et al. (2001), Miltner et al. (2004), and Tipples et al. (2002), in showing no attentional bias associated with threatening stimuli among nonanxious individuals.
2. Eye movements were frequently captured by the unique distractors, but the eyes were not directed towards the negative emotional distractors any more than other kinds of distractors. This converges with the reaction time evidence above to suggest that attention is not preferentially allocated to threatening emotional stimuli.
3. Upright distractors slowed reaction time to saccade to a target to a greater extent than inverted distractors. Recall that Fox et al. (2001) concluded that threatening distractors hold, but do not draw, attention. A similar conclusion could be drawn based on the current findings, but with two caveats: First, both positive and negative expressions of emotion can hold attention relative to a neutral distractor. Second, in the current study, unlike in Fox et al., the emotion of the target was a relevant feature to the task being performed. We will return to this point in a moment.
4. There was no evidence that the eyes fixate upright or angry faces longer than neutral faces, arguing against the notion that attention is slower to disengage from emotional events. This result does not support the interpretation that attention is slower to disengage from negative distractors.

This experiment has shown that saccades are not faster or more accurate to move towards angry faces than neutral and happy face targets. Evidence for the hypothesis that negative emotions hold attention for longer (Fox et al., 2001) is less clear-cut. On the one hand, emotional faces, happy and angry alike, interfere with detection of the target more than nonface distractors. On the other, the eyes were not slower to disengage from negative distractors than from positive or inverted distractors.

EXPERIMENT 2

Experiment 1 showed that search for a target is slower in the presence of emotional distractors, which previous research interpreted as evidence that attention is slower to disengage from these kinds of event (Fox et al., 2001). However, fixation duration was similar for all types of distractors, arguing against this interpretation. An alternative possibility for why emotional distractors would slow saccades to the target is that search for a target that is defined based on a specific emotion is slower when another emotional face appears in the search display. In other words, observers use emotional content as the feature that defines the target, and this is the most efficient strategy for detecting the target when all the distractors are neutral. When one of the distractors is also emotional, search is slower because additional time is required to discriminate the emotional target from the emotional distractor.

Experiment 2 was designed to measure the effect of emotional and neutral distractors when emotion is not the defining attribute of the target. If the effects in Experiment 1 are due to the attention-grabbing properties of emotional face distractors, upright faces will interfere with search regardless of the target type. This experiment also allows for the comparison of distractor effects within participants instead of between participants, which will increase power to detect potential differences between distractors.

Methods

In this experiment, 10 participants completed eight blocks of 60 trials. The display and series of events were similar to that of Experiment 1, except in the following respects. Each participant experienced all four distractor types. The distractor type was constant within a block of trials (to match the conditions of Experiment 1), and could be an upright happy, inverted happy, upright angry, or inverted angry face (see Figure 2). In four consecutive blocks (one block for each distractor type), the target was a neutral face among inverted neutral faces, and in the other four consecutive blocks, the target was an inverted neutral face among upright neutral faces (see Figure 4).

The order of inverted/upright targets was counterbalanced, and within each run of four blocks, the order of distractor conditions was randomized. The individual trial sequence was similar to Experiment 1, and a unique distractor was shown on half the trials. The two different types of target (inverted and upright neutral faces) were used because when both the target and unique distractor are upright, or both are inverted, they are more similar. This was expected to increase capture relative to when one is upright and the other is inverted. Both inverted and upright targets were included in the experiment to balance out this potential effect. In the analyses of the reaction

TABLE 2
The reaction time (ms) of saccades directed towards the four target types in the presence or absence of a unique distractor and duration of fixation on distractor in Experiment 2

	Distractor condition		
Distractor type	*Absent*	*Present*	*Distractor fixation duration*
Inverted angry	328.5 (14.3)	380.2 (16.9)	135.0 (7.6)
Inverted happy	319.1 (19.2)	375.7 (16.1)	147.7 (7.8)
Upright angry	349.8 (12.4)	401.2 (15.2)	152.1 (10.8)
Upright happy	335.3 (10.8)	396.0 (19.4)	168.9 (10.7)

Values are in milliseconds. Standard errors are given in parentheses.

time, proportion capture, and duration of fixation, there was no main effect of target orientation and no interaction of either the distractor type or the distractor status (present or absent) with target orientation. For simplicity, target orientation was therefore not included as a factor in further analyses.

Results

Reaction time results were submitted to a three-way within-subjects ANOVA, with distractor status (absent or present), distractor orientation (upright or inverted), and distractor emotion (angry or happy) as factors. The results are shown in Table 2. There was a main effect of the distractor status, with slower reaction times when the distractor was present than when it was absent, $F(1, 9) = 30.04$, $p < .001$, and a main effect of distractor orientation, with faster responses to the target in blocks with inverted distractors than blocks with upright distractors, $F(1, 9) = 10.24$, $p < .05$. There were no significant interactions, including the interaction of the distractor orientation and the presence or absence of the distractor, $F(1, 9) < 1$, which is the interaction that was significant in the reaction time results from Experiment 1. In Experiment 2, upright face distractors slowed reaction time to fixate the target more than inverted face distractors, but this occurred whether or not the distractor was actually presented.

The proportion of saccades directed to the distractor ("capture") was submitted to a 2×2 ANOVA, with distractor orientation (inverted or upright) and distractor emotion (angry or happy) as factors. The proportion of capture was larger when the distractor was happy than when it was angry, $F(1, 9) = 5.98$, $p < .05$ (see Figure 5), but there was no effect of orientation and no interaction of distractor emotion and orientation (both Fs < 1).

Finally, the duration of fixation on the distractor following capture was also analysd in a 2×2 within-subjects ANOVA with distractor orientation

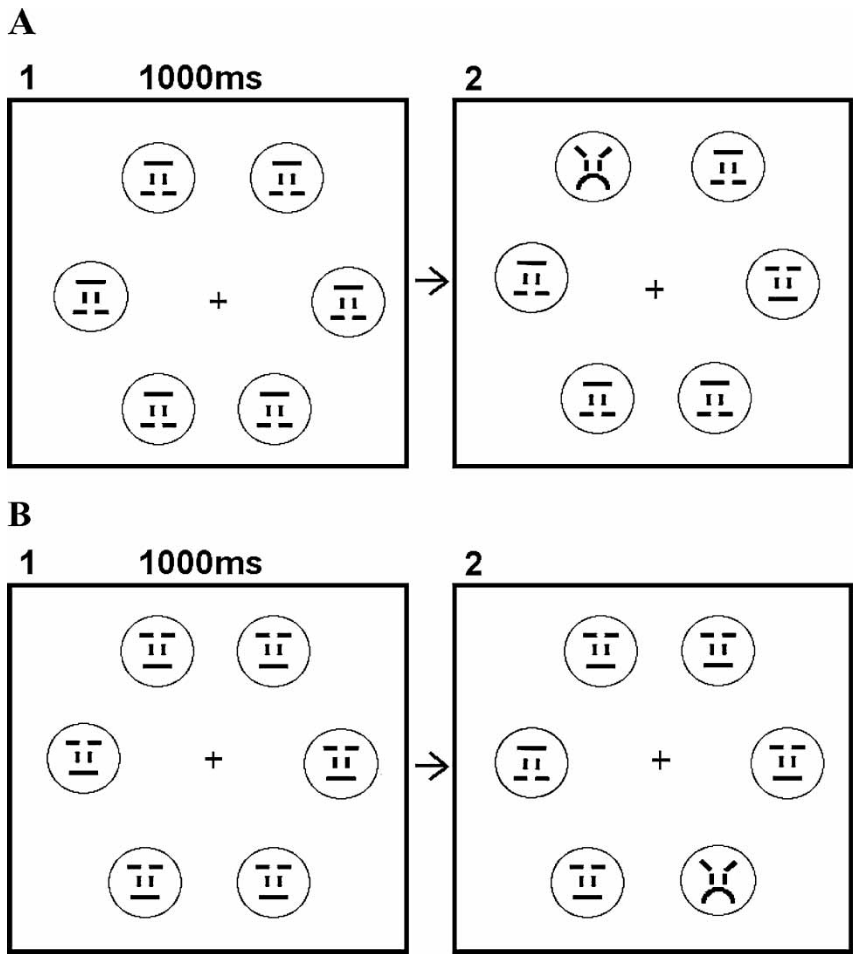

Figure 4. The two types of target trial used in Experiment 2 are shown. In A, the trial begins with six inverted neutral faces. After 1000 ms, one face becomes upright (the target). On half the trials, a unique distractor appears (in this case, an upright angry face). In B, the trial is similar, except the display begins with six upright neutral faces, and one of the upright faces becomes an inverted neutral face that is displayed at the same time as a unique distractor on half the trials.

and emotion as factors (see Table 2). One participant was omitted from this analysis because her very low capture rate (5.8%; the rest of the participants had a mean of 21.2% capture) meant she had very few observations per cell. The results of the ANOVA were similar to the proportion capture data, with a significant main effect of emotion, $F(1, 8) = 5.37$, $p < .05$, but no effect of orientation, $F(1, 8) = 3.09$ and no interaction, $F(1, 8) < 1$. This result supports the proportion analysis above in showing that not only are the eyes

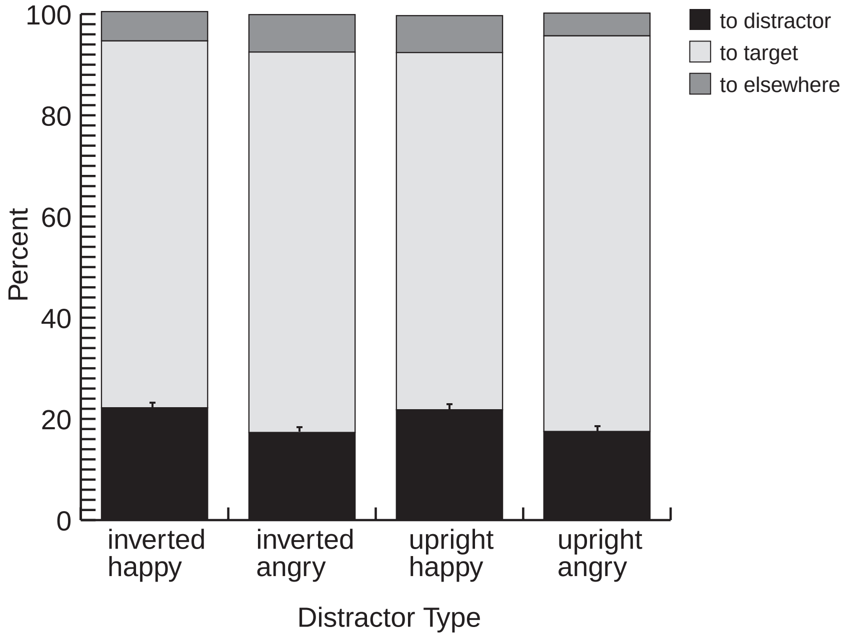

Figure 5. The proportions of saccades directed towards the distractor, the target, and to other locations are shown as a function of the distractor type.

more likely to be captured by a happy face, but they are also likely stay on a happy face for longer before moving to the target.

Discussion

In Experiment 2, in which the target type was constant and the distractor varied as a within-subjects variable, reaction time was slower overall when upright face distractors were expected but not especially distracted by the presence of an upright face when it actually occurred. There was also an increase in the proportion of capture for happy faces, and an increase in the duration of fixation on happy face distractors.

The current experiments highlight an important distinction between a default or pre-existing bias to orient to emotional events, and the ability to use emotion to guide attention voluntarily. The presence of emotional faces had a significantly larger effect on reaction time than inverted faces in Experiment 1, but this result was not replicated in Experiment 2, in which the target was defined based on orientation instead of emotion. The upright emotional faces may have been especially distracting in Experiment 1 because participants were voluntarily attending to emotional stimuli as a strategy for detecting the target. In Experiment 2, in contrast, emotion was never relevant to the task goals, and therefore the presence of upright emotional faces did not interfere with search for a neutral stimulus any more than inverted faces. Instead, there was a main effect of orientation, with slower responses overall in blocks where the upright faces appeared, regardless of whether or not a distractor was actually presented. Perhaps the costs associated with emotional distractors are incurred because there is a more effortful strategy (or filter, e.g., Kahneman, Treisman, & Burkell, 1983) employed to select the target in blocks in which the distractors are consistently emotional. The selection strategy used in these blocks slows performance whether or not the emotional distractor actually appears. Together with the results from Experiment 1, this result suggests that emotion can be used as a feature to guide attention, and also that it may be more difficult to impose a strategy to ignore emotional stimuli relative to conditions where the distractors are emotionally neutral. In other words, emotional face stimuli have an observable consequence for visual search. However, the term "capture" in the current context may be misleading, in that there is no literal capture of attention by irrelevant emotional items, but rather a more effortful process involved in ignoring them.

Search strategy is a recurring issue in studies of attentional capture. There is no question that the presence of certain kinds of stimuli impedes performance even when they are not directly relevant to the task (e.g., Yantis & Jonides, 1984). What is in question is the exact underlying reason for this interference effect. On one end of the spectrum are explanations that emphasize the inherent properties of the stimulus itself (e.g., Theeuwes, 1992). These explanations suggest that attention is initially allocated to these irrelevant locations based purely on their inherent salience. On the other end of the spectrum is the notion that attention is allocated purely on the basis of voluntary goals of the observer, and capture by irrelevant distractors will occur only insofar as the distractors conform to the selection strategy being employed by the observer to detect the target (e.g., Folk et al., 1992). Most observations, however, remain somewhere in between these two claims, suggesting that attentional control is usually able to override stimulus-driven factors, but sometimes an inefficient search strategy or sudden-onset event can tip the balance in favour of stimulus-driven factors (e.g., Bacon & Egeth, 1994). In the literature on emotional valence and attentional orienting, the underlying assumption is that the putative "capture" of attention by threatening events is an invariant mechanism shaped by evolutionary pressures (e.g., Öhman et al., 2001b). The current study suggests that it instead reflects search strategies induced by the demands of the current task and specific stimulus configurations.

Another interesting observation from Experiment 2 is that the happy faces interfere with search for a neutral target more than angry faces, regardless of whether or not they are inverted or not.[2] The finding that happy expressions are detected more quickly than angry ones is not unprecedented; Purcell et al. (1996) obtained a similar pattern. In their experiment, a photograph of a happy face among photographs of angry faces was detected more quickly than the reverse. They, like us, could not offer an explanation for this effect, except as an intriguing counterpoint to Hansen and Hansen's original (1988) claim of a special status for angry faces in the orienting of attention. At first glance, an orienting preference for happy targets seems consistent with recent research showing that happy faces are recognized faster than other expressions (e.g., Leppänen & Hietanen, 2004). However, it should not be assumed that a more easily recognized stimulus would serve as a more powerful distractor. In fact, one could as easily predict the opposite result, that an easily identified feature should serve as a less powerful distractor. The relationship between the distracting effect of the happy face we observed here, and the relative ease of recognition of happy expressions observed previously, is not known, but would be a fruitful area for future research.

One important consideration for the distracting effect of happy faces in the current study is that a "neutral" face does still have facial features that communicate an expression, although it does not have the strong emotional valence that the happy and angry faces have. If the quality of the neutral expression were closer to a happy face than to an angry face, the eyes might be captured and held more by happy than angry distractors when neutral faces are the target of search. To explore this possibility, we collected questionnaire data administered to a naïve group of participants. The questionnaire asked participants to rate the three faces on a 7-point scale for the degree to which they appeared to be happy, angry, scared, surprised, disgusted, and sad. The happy face was rated highest on the "happy" scale, and the angry face was rated highest on the "angry" scale. Most importantly, the neutral face was seen as slightly more happy than angry. This result occurred despite the fact that the geometric difference between happy and angry relative to neutral was identical, with the eyebrows and mouth simply inverted to form happy and angry. Thus the bias in the eyes to move to, and stay longer on, the happy face, may be due to a greater conceptual similarity between happy and neutral faces that might make happy faces more distracting than angry faces when neutral faces are the object of search. This converges with the point made

[2] It is interesting, but not unprecedented, that the orientation of the face was not a critical factor. Öhman et al. (2001b) also found effects for both upright and inverted faces (although, as described in the introduction, they found an advantage for angry faces rather than happy). This is an important point because researchers routinely use inverted faces as a control, but this may not be an appropriate control condition when measuring attention to emotion. This point also further justifies our use of "goblets" and "mushrooms" to disguise our stimuli in Experiment 1.

earlier that voluntary search strategies play an important role in determining what kinds of distractors will be distracting.

For the purposes of the present study, the fact that angry faces did not have any special status for orienting attention or the eyes in either experiment can be taken as evidence against the hypothesis that negative emotional stimuli have a reflexive attentional priority relative to positive stimuli. Together with the results of several experiments conducted by Fox et al. (2000), Purcell et al. (1996), and Tipples et al. (2002), none of whom found an effect of threatening events on attentional orienting in nonanxious observers, the present study poses a serious challenge to the notion of attentional capture by threat as a component of normal orienting. On the other hand, results from previous studies of anxious or phobic individuals have been much more consistent in showing biases toward phobia-inducing or anxiety-provoking stimuli. The causes and effects of this attentional bias will be a fruitful area to explore for a better understanding of both anxiety disorders and attention to emotional stimuli.

The suggestion that threatening faces do not have the power to capture attention goes against the intuition that when one encounters a snake or a snarling dog or an angry face in a crowd, that there is a sense of being drawn to it automatically, and of recognizing and reacting to it immediately. However, there are many ways that threatening events could influence behaviour besides through reflexive attention, any one of which would result in the experience of heightened awareness that was initially attributed to preferential attentional orienting by Hansen and Hansen (1988). Some of these alternatives are that people may be faster to process the identity of emotionally charged stimuli, more sensitive to their details, faster to react to them, or more likely to remember them later. Further research is needed to shed light on how these processes contribute to our subjective experience of having our gaze drawn to, and held by, threatening events.

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