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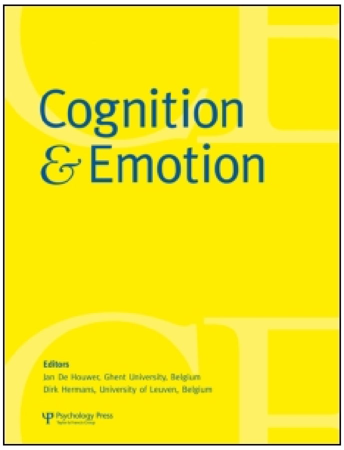

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Visual search for schematic emotional faces risks perceptual confound

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Visual search for schematic emotional faces risks perceptual confound

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Several studies have used a visual search task to demonstrate that schematic negative-face targets are found faster and/or more efficiently than positive ones, with these findings taken as evidence that negative emotional expression is capable of guiding attentional allocation in visual search. A common hypothesis is that these effects should be disrupted by face inversion; however, this has not been consistently demonstrated, and raises the possibility of a perceptual confound. One candidate confound is the feature of "closure" (see Wolfe & Horowitz, 2004) caused by the down-turned mouth adjacent to edge of the face. This was investigated in the present series of experiments. In Experiment 1, the speed advantage for upright negative faces was replicated. In Experiment 2, the effect was *not* disrupted with inversion, and an efficiency advantage emerged, suggesting that perceptual features could be causing the advantage. In Experiment 3, speed and efficiency effects were seen when this perceptual characteristic remained but face features were scrambled. Taken together, these findings suggest that visual search using schematic faces containing a curved-line mouth feature cannot provide a valid test of guided search by negative facial emotion unless this confound is controlled.

Keywords: Emotion; Attention; Faces; Facial expression; Visual search.

Visual search is a paradigm used for measuring the speed and efficiency with which visual information can be strategically processed. It has been argued that certain stimulus attributes or stimulus types may be processed automatically or "pre-attentively" (i.e., prior to awareness; Treisman & Gelade, 1980), and may be capable of guiding attention in a visual search paradigm (Elder &

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Zucker, 1993, 1994; and see Wolfe & Horowitz, 2004, for a review). The contribution of this guidance in visual search paradigms is inferred by faster search times and a reduction in the impact of set size (i.e., number of distractors) on search performance. The latter measure is referred to as "efficiency" of search, where reaction times are compared against set size, yielding a linear function. Conventionally, linear functions with slopes less than 10 ms/item have been considered efficient (Wolfe, 1998). Slopes for different targets embedded within the same distractor context have also been compared to measure "relative efficiency" of search for one target versus another (Smilek, Eastwood, & Merikle, 2000).

Recently, this paradigm has been used with stimuli of emotional significance, specifically schematic faces depicting positive and negative facial expressions, to investigate the hypothesis that emotionally significant (particularly threatening or negative) information may be capable of guiding selective attention (Eastwood, Smilek, & Merikle, 2001; Fox et al., 2000; Horstmann, 2006; Öhman, Flykt, & Esteves, 2001a; Öhman, Lundqvist, & Esteves, 2001b; Tipples, Atkinson, & Young, 2002). The capacity for faster or more efficient processing of emotionally significant information arguably confers a survival advantage, particularly if the allocation of attention permits a more complex and subtle response than simply "fight or flight" (Eastwood & Smilek, 2005). Many researchers have argued that schematic faces of emotional expression are a better stimulus choice for visual search research than real faces (e.g., Öhman et al., 2001b) because they can effectively communicate meaning (e.g., McKelvie, 1973), appear to elicit the same or similar neural responses as real faces (Sagiv & Bentin, 2001; Tong, Nakayama, Moscovitch, Weinrib, & Kanwisher, 2000), and, importantly, allow for tighter control of physical features than photographs (Purcell, Stewart, & Skov, 1996; but see Calvo & Nummenmaa, 2008; Horstmann & Bauland, 2006). Such studies have demonstrated "search asymmetries" for faces with a negative emotional expression (e.g., anger, fear) such that negative faces are found faster when embedded in positive (i.e., happy) distractor faces, than the reverse arrangement of positive-face targets embedded in negative face distractors. In addition, a speed advantage has been found for negative faces as compared to positive faces when both are embedded in neutral face distractors (e.g., Fox et al., 2000; Öhman et al., 2001b). In addition, Eastwood et al. (2001) demonstrated a relatively more efficient search for negative schematic faces compared to positive-face targets in neutral distractors.[1]

There has been debate about the theoretical interpretation of how this processing advantage for negative schematic faces arises (i.e., whether emotional information can be processed pre-attentively or not; see Cave & Batty, 2006; Frischen, Eastwood, & Smilek, 2008), and the underlying mechanism (i.e., whether emotional expressions are processed holistically or whether certain stimulus attributes carry emotional significance; e.g., Fox & Damjanovic, 2006; Larson, Aronoff, & Stearns, 2007; Tipples et al., 2002). However, researchers seem to agree that a processing advantage does exist for negative or threat-related schematic emotional faces, and that this can be used to guide visual search (Cave & Batty, 2006).

From these results, this type of visual search paradigm seems to offer promise as an index of typical processing for stimuli of emotional significance, and could therefore be used to investigate alterations or abnormalities in this processing. For example, a visual search task has been used to investigate emotional processing in individuals with anxiety (Juth, Lundqvist, Karlsson, & Öhman, 2005). Such a task could therefore be used with other clinical populations where researchers may hypothesise that processing of significant emotional information may be altered (e.g., patients who have sustained a

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[1] the stimuli used in these studies all contain a schematic representation of the outside of the face, and internal features of eyes, nose and mouth. However, the stimuli used by Öhman et al. (2001b) also included eyebrows, angled up for positive faces and angled down for negative faces.

traumatic brain injury; see Green, Turner, & Thompson, 2004). It was for this reason that we became interested in this paradigm. However, pilot testing with healthy controls prompted closer investigation of the published studies, and a lack of consistency was noted in the critical control condition of face inversion.

Inversion of the search arrays has been used in many studies as a control condition, to rule out a perceptually-based explanation of the speed advantage for negative faces. Upside down, perceptual features are held constant, but configural relationships necessary for processing of facial identity are disrupted (e.g., Farah, Tanaka, & Drain, 1995, Tanaka & Sengco, 1997; Yin, 1969). McKelvie (1995) also showed that inversion disrupted correct identification of emotional expression, and later work suggests that configural processing is also important for processing of emotional expression (e.g., Calder & Jansen, 2005; Calder, Young, Keane, & Dean, 2000; White, 2000). Based on this argument, many researchers have reasoned that the speed/efficiency advantage for negative faces should be lost when face stimuli are inverted. However, results from the inverted condition have been mixed, and there remains debate surrounding this issue (Lipp, Price, & Tellegen, 2009; Öhman et al., 2001b).

One study did, indeed, show the elimination of the speed effect in the inverted condition (Fox et al., 2000). However, in other studies such as Öhman et al. (2001b) and Eastwood et al. (2001), the speed advantage of negative over positive-face targets was not disrupted in the inverted condition. In the Eastwood et al. (2001) study, the *efficiency* advantage—that is, the relatively reduced impact of set size increases—was disrupted as predicted, but the authors did not discuss the lack of disruption of the overall reaction-time effect. Additionally, in a replication experiment by Horstmann (2006) using the same stimuli as Fox et al. (2000), the efficiency advantage was not disrupted by inversion, as evidenced by significantly shallower slopes for search for an inverted negative-face target.

Some researchers have argued that failure to eliminate search advantages for inverted negative targets may mean that inversion is not sufficient to disrupt processing of the emotional expression of the face (e.g., Lipp et al., 2009; Öhman et al., 2001b). However, without consistent findings from the inversion control condition, a perceptual explanation for the results also remains a possibility. Other studies have investigated possible perceptual inequalities between the two types of face targets. Fox et al. (2000) found no difference in reaction time to find a downward-curved line target (the mouth in a negative face) compared to an upward-curved line (the mouth in a positive face) when presented alone. Similarly, Tipples et al. (2002) found no advantage for search for downward angled eyebrows (seen, for example, in the angry faces used by Öhman et al., 2001b) when presented alone or with other, non face-like elements. These studies, therefore, argue against a perceptual explanation for the negative face stimulus. However, there remains a perceptual feature that has not been addressed by any of the previous studies: "closure" is a basic stimulus feature that is capable of guiding visual search (Elder & Zucker, 1993, 1994; Wolfe & Horowitz, 2004). Inadvertently, this feature is manifested in the negative schematic face because the proximity of the down-turned mouth to the line delineating the perimeter of the face, causing an appearance of a closed structure that does not exist in either the neutral or happy faces. Closure does not depend on orientation and so would not be disrupted when faces are inverted. Fox et al. (2000) only tested upward and downward curved "mouths" in isolation, but not inside the boundary of the circular "face".

Given the increasing use of the visual search paradigm with schematic faces for examining automatic facial emotion perception and its potential application in clinical populations, the overall aim of this study was to examine the possibility of closure as a perceptual confound, in schematic face stimuli containing a curved-line mouth feature, before considering it for use as an index of typical processing for emotionally salient information.

The goal of Experiment 1 was to replicate the findings of a search advantage for negative over positive schematic faces, when each is embedded respectively among neutral schematic distractors. The goal of Experiment 2 was to assess whether face inversion would eliminate any advantage observed. Evidence for preservation of the advantage would allow for the possibility that facilitated processing of the negative faces was attributable to a factor other than emotion. The goal of Experiment 3 was to test the existence of the closure confound using scrambled faces. Here, the relationships between facial features conveying emotional expression were explicitly disrupted, but the feature of closure was retained in one condition and compared to an otherwise balanced no-closure condition. If significantly faster reaction times and/or greater efficiency were obtained for the negative faces (or faces with closure) in all three experiments, this would provide strong evidence of a perceptual contribution to effects seen in this and other paradigms using similar schematic stimuli.

EXPERIMENT 1

Introduction

The goal of Experiment 1 was to replicate the findings from Fox et al. (2000), Öhman et al. (2001b) and Eastwood et al. (2001), that negative emotional faces are found faster and more efficiently than positive emotional faces when embedded in displays of neutral face distractors. The paradigm and stimuli from the Fox et al. (2000) study were used because it was the only study to show a significant search advantage for the upright negative face that was successfully eliminated by inversion. Using the Fox et al. (2000) stimuli would increase the chances of finding an emotion-based rather than perceptually-based (i.e., confounded) speed/efficiency advantage. The following minor changes from the Fox et al. (2000) study were made: An additional intermediate set size of 6 was added to the set sizes of 4 and 8 used by Fox et al. (2000) to provide more stability for the calculation of the slope of the search function. Also, the size of the display was increased to allow for 16 possible locations rather than 8. In Fox et al. (2000), a set size of 8 items filled all 8 possible locations of the search array, thus creating a perfect circle of stimuli. This characteristic was unique to the largest set size, and also could disproportionately promote the use of a circular, serial, search strategy in this condition. In the present study, a larger search array was used so that no condition would completely fill the array. Also, fewer conditions were examined: positive targets and negative targets appeared in the context of neutral distractors; however, neutral faces never appeared as targets, and emotional faces never appeared as distractors.

Based on the literature, we predicted a processing advantage of negative faces over positive faces. This would be evidenced by (1) an overall main effect of valence in favour of negative faces, and/or (2) more efficient processing of negative faces as indicated by an interaction between valence and set size and a shallower average slope (for the function of reaction time versus set size) for negative versus positive-face targets.

Methods

Participants. Nineteen participants were recruited from the staff of the Toronto Rehabilitation Institute (TRI). The participants were blind to the purposes and hypotheses of the study until follow-up debrief. Approval for the study was granted by the Research Ethics Boards of the TRI and University of Toronto. The sample comprised 17 females and 2 males, with an average age of 30.14 years (range = 19–51, *SD* = 8.84).

Apparatus. Visual displays were presented on a ViewSonic G75F+ 17-inch CRT monitor or a ViewSonic 19-inch LCD monitor, controlled by E-Prime programming software, which initiated trials and recorded reaction times. Participants were assigned approximately equally to the two monitors (10 vs. 9 in Experiment 1, 10 vs. 9 in Experiment 2, 9 vs. 10 in Experiment 3). Participants indicated responses by pressing two different keys on the keyboard, equidistant from centre and affixed with labels reading “Y” and

"N", with their left and right index fingers respectively.

Stimuli and experimental design. The stimuli, shown in panel (a) of Figure 1, were the same schematic emotional faces used in Fox et al. (2000). Displays consisted of 4, 6 or 8 faces arranged around the circumference of an imaginary circle with 16 possible locations equidistant from a central fixation point. Displays were drawn in black against a white background. On each trial, the faces were randomly distributed to the 16 locations, with the constraint that targets appeared equally as often in each of the 4 quadrants of the visual display. Figure 2 shows a sample display of 6 faces, with a negative target. Each face had a vertical visual angle of 1.81 degrees and a horizontal visual angle of 1.52 degrees. The distance from fixation to the centre of each face was 7.15 degrees, at a viewing distance of approximately 60 cm. The experiment was a 2 (target present vs. target absent) by 2 (positive vs. negative target) by 3 (set size of 4, 6 or 8) repeated-measures design. Ninety-six trials were s*ame* displays, consisting of all neutral faces; 96 trials were *different* displays, consisting of neutral face distractors plus one discrepant target, for a total of 192 trials. Half of the *different* display trials contained a positive-face target, and half contained a negative-face target. The purpose of the *same* displays was to prevent guessing as to the location of the target, and performance on these trials was not relevant to the purpose of the experiment. Thus, reaction time and accuracy data from *same* trials were not analysed. For all trials, subjects were asked to respond via key press whether all of the items were the same or different (Y or N).

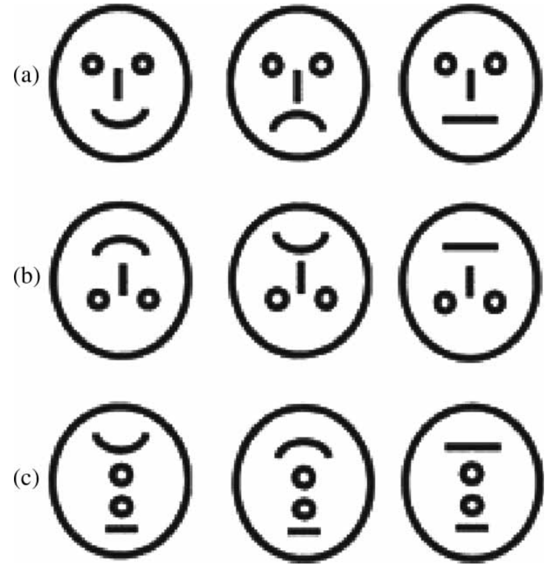

Figure 1. *Schematic face stimuli used for: (a) Experiment 1; (b) Experiment 2; (c) Experiment 3. Stimuli for Experiments 1 and 2 used with permission from Fox et al. (2000).*

Procedure. Participants were tested in a quiet room, seated in front of the computer. Instructions were presented visually on the computer screen and simultaneously read aloud by the experimenter. Participants were told that they would see a display of many items on the screen. Either all of the items would be the same or one of them would be different from the rest. Their goal on each trial was simply to respond to the prompt question, "Are all of the items the same?" by pressing the "Y" key, if the items were the same, or by pressing the "N" key, if one was different from the rest. Participants were also told to bring their eyes back to a central fixation point, which would appear on the screen prior to each trial, but eye movements were not constrained in this experiment.

Participants were told that reaction time would be measured. They were encouraged to respond as quickly as possible, but not to sacrifice accuracy for speed. Each trial consisted of a fixation cross (+) presented at the centre of the screen for 1000 ms, immediately followed by the search display. The display remained on the screen until a response was given, and was then followed by a blank screen for 2000 ms. Participants were presented with 16 practice trials followed by 192 experimental trials.

Results

Reaction time results are shown in Figure 3a. Incorrect trials were not analysed (4.8%). Outliers were removed per participant per condition, if

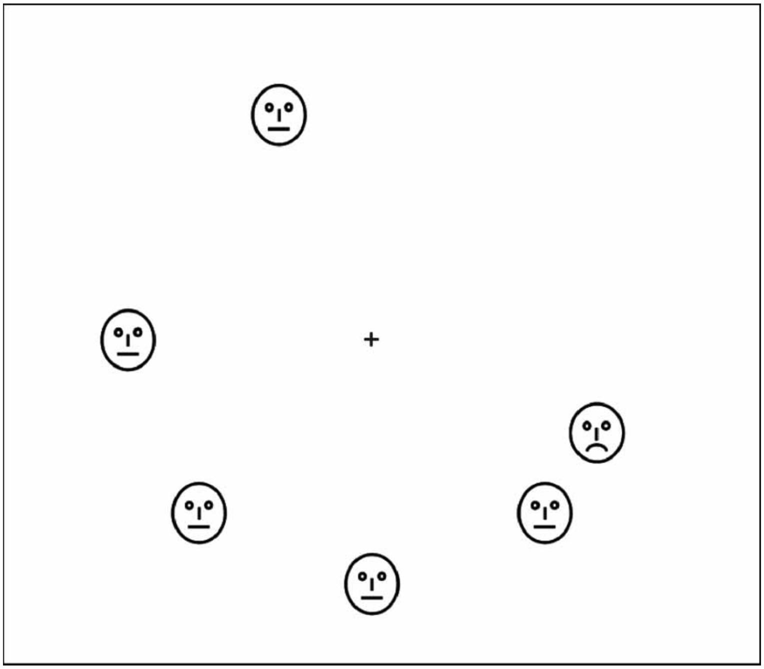

Figure 2. *Sample search array of six faces, including a negative-face target.*

they were greater than three standard deviations away from the participant's mean reaction time for that condition. This analysis resulted in the removal of three data points (0.16%), one from each of from three different participants.

Reaction-time data were subjected to a 2 (Valence) × 3 (Set Size) repeated-measures analysis of variance (ANOVA). As predicted, results showed a significant main effect of Valence, $F(1, 18) = 46.79$, $p < .001$, $\eta_p^2 = .72$, with negative target faces significantly faster overall. The main effect of Set Size was also significant, $F(2, 36) = 28.82$, $p < .001$, $\eta_p^2 = .62$, demonstrating that all targets are harder to find when the size of the search array is increased. Neither the interaction of Valence by Set Size nor the t-test of the slopes was significant, $F(2, 36) = 0.06$, $p = .94$, *ns*, and $t(18) = 0.86$, $p = .41$, *ns*, although the slope of the function for negative targets ($S = 127.59$ ms/item) was shallower than for positive targets ($S = 147.12$ ms/item). Faster reaction times for the negative target were significant at each set size: 4 items, $t(18) = 5.34$, $p < .001$; 6 items, $t(18) = 6.62$, $p < .001$; and 8 items, $t(18) = 5.21$, $p < .001$.

With regard to accuracy data, the average number of incorrect trials was computed for each condition of the experiment for each participant. These data are shown in Figure 3b. A 2 × 3 ANOVA revealed a significant main effect of Valence, $F(1, 18) = 41.28$, $p < .001$, $\eta_p^2 = .70$. Neither the main effect of Set Size, $F(2, 36) = 0.20$, $p = .82$, *ns*, nor the interaction, $F(2, 36) = 0.36$, $p = .69$, *ns*, were significant. Greater errors for the positive target were significant at each set size: 4 items, $t(18) = 4.75$, $p < .001$; 6 items, $t(18) = 4.03$, $p < .001$; and 8 items, $t(18) = 5.90$, $p < .001$.

Discussion

Consistent with the results of Fox et al. (2000), Öhman et al. (2001b) and Eastwood et al. (2001), an overall advantage of search speed for the negative-face targets was demonstrated. This

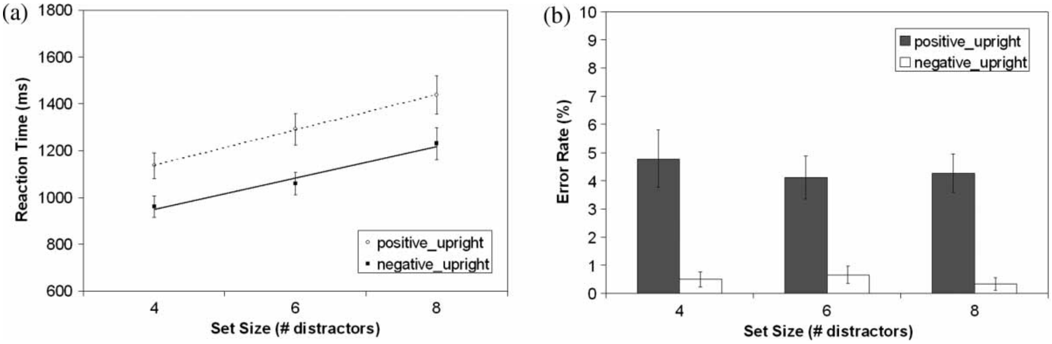

Figure 3. *(a) Average reaction time and (b) error rate for upright positive and negative target faces in upright neutral distractor faces, at display sizes of 4, 6 and 8 items. Error bars reflect standard error of the mean.*

advantage held at all three set sizes. As well, a main effect of accuracy was observed, with greater accuracy for the negative than positive faces at all three set sizes.

For the efficiency analyses, the difference in the means of the slopes was in the predicted direction, but was not significant.

EXPERIMENT 2

Introduction

The goal of Experiment 2 was to examine the effects of inversion on the pattern of results found in Experiment 1. Inversion disrupts facial processing and it has been argued that it should also disrupt the processing of the emotional expression of the face stimuli. Accordingly, any effects on search performance caused by emotional processing of the targets should disappear in the inverted condition. However, results from previous studies have been inconsistent.

Methods

Participants. Nineteen participants were recruited from staff of the TRI in accordance with Research Ethics Boards procedures. No one had participated in Experiment 1. Participants were blind to the purposes and hypotheses of the study until follow-up debrief. The sample contained 13 females and 6 males, with an average age of 27.57 years (range = 22–44, $SD = 5.39$).

Apparatus, stimuli and procedure. The stimuli, shown in panel (b) of Figure 1, were the same schematic emotional faces used in Experiment 1, but inverted. All other display and trial parameters were identical to Experiment 1.

Results

Reaction time results for Experiment 2 are shown in Figure 4a. Incorrect trials were not analysed (3.5%). Data were examined for outliers in the same manner as in Experiment 1, resulting in the removal of one data point each from two participants, and two data points from two additional participants, for a total of six data points (0.33%). A 2 (Valence) × 3 (Set Size) repeated-measures ANOVA yielded significant main effects of Valence, with inverted negative targets found significantly faster than inverted positive targets overall, $F(1, 18) = 32.40$, $p < .001$, $\eta_p^2 = .64$. A significant main effect of Set Size, $F(2, 36) = 60.09$, $p < .001$, $\eta_p^2 = .77$, was also observed, with reaction times increasing with number of distractors. The interaction between Valence and Set Size was not significant, $F(2, 36) = 1.32$, $p = .28$, *ns*. However, a *t*-test revealed a significantly shallower search function for the inverted negative targets ($S = 106.59$ ms/item)

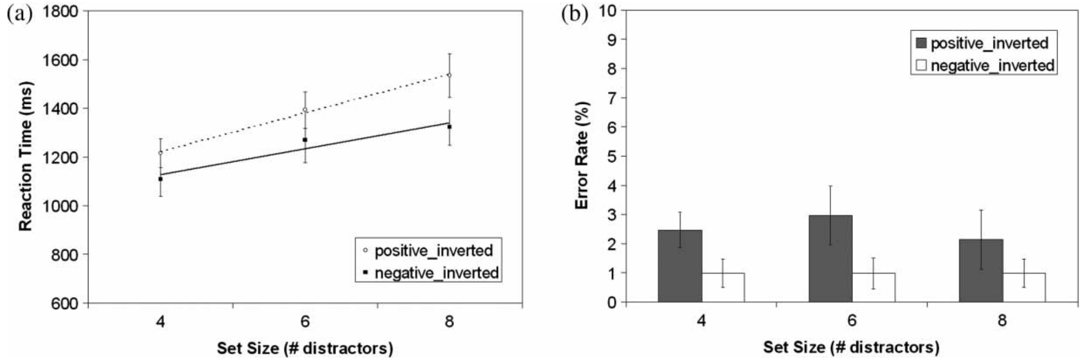

Figure 4. *(a) Average reaction time and (b) error rate for positive and negative inverted face targets embedded in distractor inverted neutral faces at display sizes of 4, 6 and 8 items. Error bars reflect standard error of the mean.*

than that for inverted positive targets ($S =$ 159.35 ms/item), $t(19) = 2.49$, $p = .02$. Faster reaction times for the inverted negative-face target were significant for set sizes of 4 items, $t(18) = 3.32$, $p = .004$, and 8 items, $t(18) = 6.87$, $p < .001$, and there was a trend towards significance for the set size of 6 items, $t(18) = 1.77$, $p = .09$.

To examine accuracy, the average number of incorrect trials was computed for each condition for each participant. These data are shown in Figure 4b. A 2 × 3 ANOVA revealed a significant main effect of Valence, $F(1, 18) = 13.09$, $p = .002$, $\eta_p^2 = .42$. Accuracy for the negative targets was significantly better than accuracy for the positive targets. The main effect of Set Size and the interaction were not significant, Set Size: $F(2, 36) = 0.25$, $p = .78$, *ns*; interaction: $F(2, 36) = 0.26$, $p = .78$, *ns*.

Discussion

Results showed both a speed and efficiency processing advantage for the negative faces, even when inverted. Thus, a perceptual explanation for these findings cannot be ruled out. As previous studies have not examined the feature of "closure" that is present in these and other schematic face stimuli with curved-line mouth features, Experiment 3 tested the hypothesis that closure could be contributing to the preservation of this advantage in the inverted condition.

EXPERIMENT 3

Introduction

In this final experiment, the schematic face stimuli were manipulated so that internal features no longer formed the proper featural relationships of a face or emotional expression. However, the placement of the upward or downward curved feature (previously the mouth) adjacent to the perimeter of the face was preserved in these scrambled stimuli, creating two different targets that differed as a function of the property of perceptual closure (Elder & Zucker, 1993). For comparative purposes, we will refer to these two targets as "scrambled-negative" and "scrambled-positive", though they no longer contain the emotional characteristics of previous targets. If effects on search performance were being driven by this perceptual property, speed and efficiency effects on reaction time and accuracy in favour of the scrambled-negative targets relative to the scrambled-positive targets would be found.

Methods

Participants. Nineteen people were recruited from staff of the TRI in accordance Research Ethics Boards procedures. No one had participated in Experiments 1 or 2. Participants were blind to the purposes and hypotheses of the study until follow-up debrief. The sample contained 8 females and 11 males, with an average age of 28.11 years (range = 21–37, *SD* = 4.36).

Apparatus, stimuli, and procedure. The stimuli were based on the same schematic emotional faces used in Experiment 1, but internal features were scrambled. Importantly, the spatial proximity between the internal curve feature ("mouth") and the circle representing the perimeter of the face was preserved in the scrambling procedure. Panel (c) of Figure 1 shows the three types of stimuli. The first stimulus (scrambled-negative) contains the appearance of a closed structure formed by the opposite curvatures of the internal curve and the outside circle of the stimulus, a critical feature shared with the negative target from Experiments 1 and 2. In the second stimulus (scrambled-positive) the internal curve and the perimeter of the face curve are in the same direction, and no closed structure is formed. The third stimulus (scrambled-neutral stimulus) does not possess an internal curve feature at all. None of the stimuli, therefore, possessed emotional significance, but the scrambled-negative target differed from the rest based on the presence of the perceptual closed structure. All other parameters were identical to Experiment 1, that is, there were two conditions, one in which scrambled-positive stimuli were embedded in scrambled-neutral ones, and one in which scrambled-negative stimuli were embedded in scrambled-neutral ones. As in the previous experiments, participants were asked to decide if the stimuli were all the same or if one was different.

Results

For consistency, the independent variable differentiating the two targets was still referred to as "valence". Reaction-time results are shown in Figure 5a. Incorrect trials were not analysed (3.4%). Data were examined for outliers in the same manner as in Experiment 1, resulting in the removal of one data point from one participant (0.05%).

Results showed a significant main effect of Valence, with scrambled-negative faces found faster overall than scrambled-positive faces, $F(1, 18) = 83.70$, $p < .001$, $\eta_p^2 = .82$, which held at each set size of 4 items, $t(18) = 6.20$, $p < .001$, 6 items, $t(18) = 6.79$, $p < .001$, and 8 items, $t(18) = 6.93$, $p < .001$, as well as a significant overall effect of Set Size, $F(2, 36) = 38.93$, $p < .001$, $\eta_p^2 = .80$. There was also a significant Valence by Set Size interaction, $F(2, 36) = 5.87$, $p = .006$, $\eta_p^2 = .33$. The mean slope of the scrambled-negative target search function ($S = 70.44$ ms/item) was also significantly shallower than the mean slope of the scrambled-positive target search function ($S = 123.27$ ms/item), $t(18) = 2.77$, $p = .013$.

The average number of incorrect trials was computed for each condition for each participant. These data are shown in Figure 5b. A 2 × 3 ANOVA revealed a significant main effect of

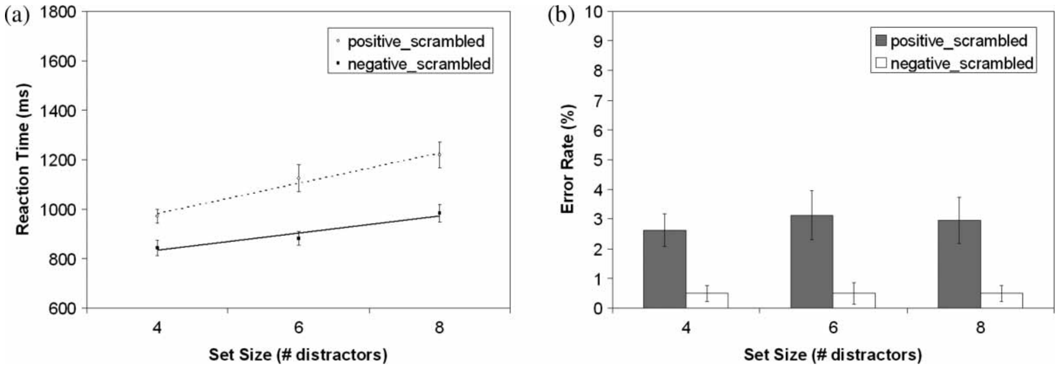

Figure 5. *(a) Average reaction time and (b) error rate for "positive" and "negative" scrambled face targets embedded in distractor scrambled "neutral" faces at display sizes of 4, 6 and 8 items. Error bars reflect standard error of the mean.*

Valence, $F(1, 18) = 26.93$, $p < .001$, $\eta_p^2 = .60$. The main effect of Set Size and the interaction were not significant, Set Size: $F(2, 36) = 0.13$, $p = .88$, *ns*; interaction: $F(2, 36) = 0.16$, $p = .85$, *ns*.

Comparative error analysis. A one-way ANOVA was carried out on the average error rate data for all participants for each experiment. This was undertaken to examine whether fundamental differences in response bias (which might be evidenced in differences in error rates) were detectable. This analysis revealed no significant difference in average error rate for the three experiments, $F(2, 54) = 1.05$, $p = .36$, *ns*.

Discussion

The results of the third experiment showed a marked effect of closure (previously caused by the "mouth" feature and outer circle of the negative face). In this experiment, similar speed advantages as observed in Experiments 1 and 2 were seen for the scrambled-negative stimuli, and the speed and efficiency advantages for scrambled-negative stimuli were consistent with those shown for negative schematic faces in previous studies by Öhman et al. (2001b), Fox et al. (2000), Eastwood et al. (2001), Tipples et al. (2002) and Horstmann (2006).

GENERAL DISCUSSION

In this series of experiments, we examined a paradigm that has been used in a number of studies to investigate the relationship between processing of emotional-face stimuli and the guidance of attention. In Experiment 1, we replicated a previous finding that schematic negative-face targets embedded in a search array of neutral face distractors are found more quickly and accurately than positive-face targets in neutral face distractors. This finding has previously been taken as evidence that negative emotional faces are capable of guiding the allocation of attention (Fox et al., 2000; Öhman et al., 2001b). In Experiment 2, we inverted the face stimuli, and found that the advantage in search speed and accuracy for the negative-face targets remained. Based on some previous studies of inversion effects on facial emotion perception (e.g., Calder & Jansen, 2005; McKelvie, 1995), many researchers have reasoned that this manipulation should have disrupted processing of emotional expression information, and consequently, a search advantage for negative-face stimuli. The absence of such a finding may be explained in one of two ways: (1) processing of emotion from the schematic faces is not sufficiently disrupted by inversion (Lipp et al., 2009; Öhman et al., 2001b); or (2) a perceptually salient feature of the negative-face targets confers a processing advantage. Previous studies have controlled for a number of possible perceptual confounds (e.g., Fox et al., 2000; Öhman et al., 2001b; Tipples et al., 2002), but not the feature of "closure", which is a basic perceptual feature capable of causing enhanced performance on visual search tasks (Elder & Zucker, 1993). In Experiment 3, in which we manipulated closure in the absence of emotional expression, the presence of closure in one of the search targets conferred both speed and efficiency advantages.

Importantly, closure is an inadvertent perceptual feature of the schematic negative faces used in this and past studies, the result of the curvature of the down-turned mouth in proximity to the curvature (in the opposite direction) of the perimeter of the face. In positive schematic faces, the convexities run in the same direction and thus do not create this perceptual feature. While it is possible that other emergent features also played a role, an explanation based on the closure present in these stimuli is consistent with established findings on the perceptual significance of closure (e.g., Elder & Zucker, 1993).

Another interpretation of our data is that perceptual closure, rather than being construed as an experimental confound, is a critical feature involved in the perception of emotion in faces. Although we find this interpretation unlikely, future research could test this hypothesis using real and schematic faces. We also do not know if the effects observed in this study would generalise to schematic emotional faces that contain the additional features of eyebrows (e.g., Öhman et al., 2001b), as this feature was not included in the stimuli for these experiments. In addition, a study by Tipples et al. (2002) showed that a detection advantage could extend to faces with V-shaped eyebrows both with and without a down-turned mouth ("angry", and "scheming" faces), which was replicated by Lipp et al. (2009). This finding stands in contrast to previous findings using similar "scheming"-face stimuli (Öhman et al., 2001b), but nonetheless indicates that perceptual closure may not confer a search advantage in all cases. However, it is reasonable to propose that any schematic emotional face that contains a curved-line mouth within a curved-face perimeter would produce the perceptual effect of closure. In short, these results provide a strong case that the visual search paradigm—when it involves schematic emotional faces that contain a curved-line mouth feature—is not optimal for evaluating the influence of pre-attentive processing on attentional allocation.

In Experiment 1, the search efficiency advantage for negative-face targets reported by Eastwood et al. (2001), as measured by shallower search slopes and a Valence by Set Size interaction, did not reach significance. Nonetheless, the search efficiency advantage did emerge as significant in the second experiment for the inverted negative faces, and in the third experiment for the scrambled-negative stimuli. These latter results demonstrate that targets with no emotional value, but a perceptual feature in common with previously used positive- and negative-face targets, demonstrated exactly the same pattern of results on search speed and accuracy as found in Experiments 1 and 2, and on search efficiency as found in Experiment 2 and past studies.

Importantly, the results do not refute the hypothesis that a relationship between emotional processing and attentional allocation exists, a hypothesis investigated in a growing body of literature using visual search with other stimuli (e.g., photographic faces) as well as many other paradigms. However, they do suggest that future studies employing the visual search paradigm with schematic faces should control for perceptual "closure" cues, and that caution should be exercised when adopting such paradigms for investigation of atypical emotional processing in clinical populations.

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