Perception & Psychophysics
2003, 65 (3), 352-358

Negative facial expression captures attention and disrupts performance

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In two experiments, participants counted features of schematic faces with positive, negative, or neutral emotional expressions. In Experiment 1 it was found that counting features took longer when they were embedded in negative as opposed to positive faces. Experiment 2 replicated the results of Experiment 1 and also demonstrated that more time was required to count features of negative relative to neutral faces. However, in both experiments, when the faces were inverted to reduce holistic face perception, no differences between neutral, positive, and negative faces were observed, even though the feature information in the inverted faces was the same as in the upright faces. We suggest that, relative to neutral and positive faces, negative faces are particularly effective at capturing attention to the global face level and thereby make it difficult to count the local features of faces.

Given the profound social significance of emotion, it is not surprising that the human visual system is highly efficient at perceiving facial expression. Indeed, infants demonstrate an early proficiency at discriminating face from nonface stimuli (e.g., Meltzoff & Moore, 1977; Öhman & Dimberg, 1978; Sackett, 1966) and at discriminating different emotional expressions (Younge-Browne, Rosenfeld, & Horowitz, 1977). It also appears that the perception of facial expression occurs automatically (e.g., Stenberg, Wilking, & Dahl, 1998) and without awareness (e.g., Morris, Öhman, & Dolan, 1998). Such efficient perception of facial expression is advantageous because of the important role faces play in communicating potential positive or negative outcomes.

Previously it has been demonstrated that negative faces attract attention to themselves more effectively than positive faces (Eastwood, Smilek, & Merikle, 2001; Fox et al., 2000; Hansen & Hansen, 1988; Öhman, Lundqvist, & Esteves, 2001). For example, in our previous experiments (Eastwood et al., 2001), participants searched displays of schematic faces for the location of a unique face expressing either a positive or a negative emotion. The unique face was embedded among 6, 10, 14, or 18 distractor faces expressing neutral emotion. We found that the slope of the search function for locating the negative face was shallower than the slope of the search function for locating the positive face. However, when the faces were inverted to reduce holistic face perception, the slopes of the search functions for locating the positive and negative faces did not differ. The guided search model suggests that whenever the distractors and the observers' expectations are the same across two conditions, the condition yielding the shallower search slope is the condition in which attention is more effectively guided to the target (see Smilek, Eastwood, & Merikle, 2000; Wolfe, 1994). Therefore, we concluded that faces expressing negative emotion guide attention more effectively than faces expressing positive emotion.

One question that arises is whether the differential attraction of attention by positive and negative faces we observed previously (Eastwood et al., 2001) is contingent on observers adopting the mental set of deliberately searching for an emotionally expressive face. In our previous experiments, the participants were given explicit instructions to search for the positive and negative faces. Therefore, on the basis of the results of these previous experiments, it is unclear whether negative faces "capture" attention better than positive faces even when emotionally expressive faces are "not explicitly related to the observer's perceptual goals or intention" (Yantis, 1996, p. 47). Given the social relevance of negative faces and the potential cost associated with failing to notice a threatening face, it is plausible that negative faces might capture attention more effectively than positive faces even when one is engaged in some other task. Such "capture of attention" by negative faces would be established by demonstrating that negative faces interfere more than positive faces with an observer's ability to perform an ongoing task. For this reason, in the present studies, we

This research was supported by a grant from the Natural Sciences and Engineering Research Council of Canada to P.M.M. We thank Heather Thompson for her assistance in data collection. Correspondence should be addressed to J. Eastwood, Department of Psychology, York University, 4700 Keele Street, Toronto, ON, M3J 1P3 Canada (e-mail: johneast@yorku.ca).

explored whether negative faces interfere with an ongoing task more than positive faces—even when emotional expression is irrelevant to the task demands.

The results of two previous studies suggest that negative facial expressions are capable of capturing attention and interfering with ongoing task performance (Vuilleumier, Armony, Driver, & Dolan, 2001; White, 1996). Vuilleumier et al. asked participants to judge whether two stimuli presented at a cued location were the same or different. On some trials, either a neutral or a negative (i.e., fearful) face appeared at an irrelevant, unattended location at the same time that the attended stimuli appeared at the cued location. Vuilleumier et al. found that the judgments of the attended stimuli were slower when negative as opposed to neutral faces appeared at unattended locations. Although these findings showed clearly that negative expressions in task-irrelevant faces can interfere with performance, it is not possible to determine the relative degree to which positive and negative faces interfere with performance because Vuilleumier et al. did not include positive faces in their experiments. Therefore, it is entirely possible that both positive and negative faces, relative to neutral faces, would interfere with performance. Similarly, in White's study there was no direct comparison of the relative effectiveness of task-irrelevant positive and negative faces in disrupting the performance of an ongoing task. Thus, even though there is some evidence that task-irrelevant negative faces can capture attention and disrupt performance of an ongoing task, there is no direct evidence regarding the relative effectiveness of task-irrelevant positive and negative faces in capturing attention.

The present experiments were based on previous findings showing that a global face gestalt can influence the detection of features, component parts, or targets embedded within the global face (e.g., Gyoba, Arimura, & Maruyama, 1980; Homa, Haver, & Schwartz, 1976; Mermelstein, Banks, & Prinzmetal, 1979; Suzuki & Cavanagh, 1995; van Santen & Jonides, 1978). For example, Mermelstein et al. found that the detection of a predetermined target (such as a specific nose or mouth) was easier when the target was part of a scrambled face than when the target was part of a coherent face. Findings such as these suggest that a face is processed holistically before the component parts are processed; therefore, the component parts of a face may become hidden within the whole so that additional cognitive resources are required to extract the individual parts from the whole. In terms of attention, the findings suggest that the global aspects of a face may initially capture attention before the component parts of the face are processed. Indeed, Mermelstein et al. proposed that attention might account for their findings; more specifically, they stated that it is possible that "the presence of an organized whole pattern forced [the participants'] attention temporarily to the whole, instead of to the individual features" (p. 479), whereas in the scrambled-face condition the participants' "attention is directed immediately to the individual units" (p. 479). On the basis of these previous findings, we examined whether the global aspect of a negative face captures attention more effectively than the global aspect of a positive face even when the global faces had not been part of the ongoing task demands.[1]

In the present experiments, participants were required to count the component parts or features (i.e., arcs, ovals, and circles) of emotionally expressive schematic faces. It was anticipated that a negative face would capture attention to the global face level more effectively than a positive face and therefore interfere more with the ongoing task of detecting facial features. If negative faces do capture attention more effectively than positive faces, then counting the component parts or features of faces should take longer when a face expresses a negative emotion than when a face expresses a positive emotion.

EXPERIMENT 1

To assess whether a negative facial expression captures attention more effectively than a positive facial expression, participants counted upward- or downward-curved arcs contained in displays presented on a computer screen. Each display consisted of four triplets of arcs arranged to form faces that varied in terms of both orientation (upright or inverted) and emotional expression (positive or negative) (Figure 1). Emotional expression was varied within participants whereas orientation was varied between participants. Face orientation was varied between participants because pilot studies indicated that observers perceive inverted faces differently depending on whether they are or are not preceded by a series of upright faces.

If negative faces capture attention to the global face level more effectively than positive faces, then counting the component parts of upright faces should take longer when faces expresses negative as opposed to positive emotion. To rule out the possibility that any observed differences between upright positive and negative faces are due to local feature differences rather than to the perception of emotional expression, the faces were inverted for half of the participants. Inverting the faces should disrupt the perception of emotional expression (Köhler, 1940; Parks, Coss, & Coss, 1985; Yin, 1969) while at the same time retaining the local feature differences between the negative and positive faces. Therefore, finding that more time is required to count the component parts of negative as opposed to positive faces when the faces are upright but not when the faces are inverted would constitute strong support for the conclusion that negative facial expression captures attention more effectively than positive facial expression.

Method

Participants. Fifty-two University of Waterloo undergraduate students participated in a 30-min experiment in exchange for $8.00. Each student had normal or corrected-to-normal vision. Half of the participants were assigned to the upright-face condition and half of the participants were assigned to the inverted-face condition.

Experimental displays. Examples of the four different types of stimulus displays are shown in Figure 1. All displays were composed of 12 individual arcs organized into four groups of 3 arcs (i.e., faces) on the basis of proximity.

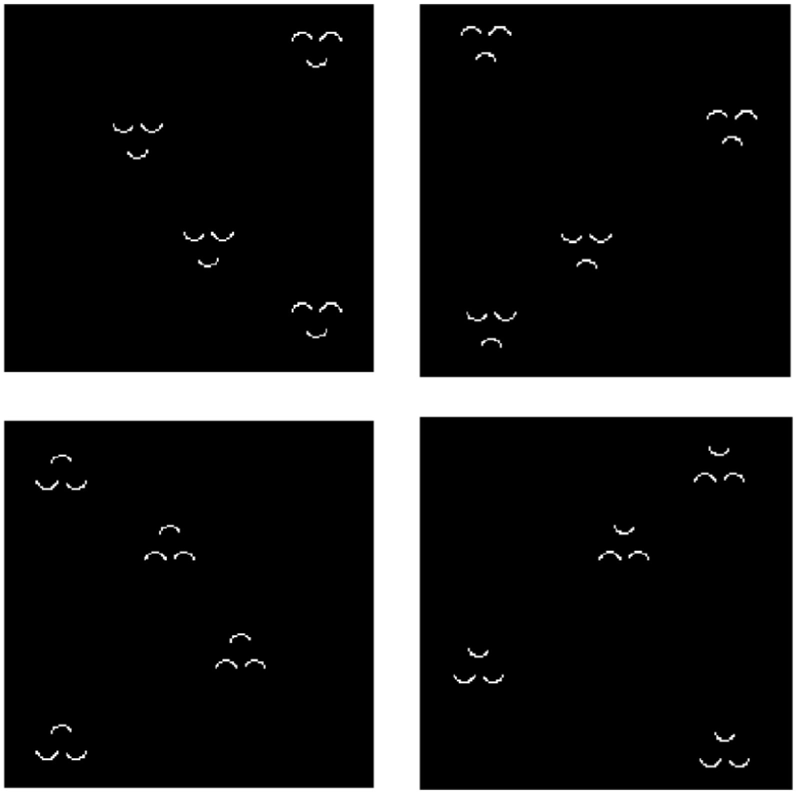

Figure 1. Examples of the stimulus displays used in Experiment 1.

Examples of the displays used in the upright-face condition are shown in the two top panels of Figure 1. Each upright face consisted of three arcs arranged so that they resembled the mouth and eyes of a face. Specifically, two arcs positioned side by side represented the eyes, and one arc centered below these two arcs represented a mouth. On half of the trials, the mouth arcs were curved upward, and on the other half of the trials the mouth arcs were curved downward. Depending on the orientation of the mouth arc, the four faces in each display were designed to resemble faces expressing either positive or negative emotion. In addition, for each face in each display, the arcs used to represent the eyes had the same curvature and varied in orientation independently of both the emotional expression, as indicated by the mouth, and the other faces in the display. The four faces (i.e., groups of three arcs) in each display occupied 4 of the 16 possible locations defined by an imaginary 4 × 4 matrix.

Examples of the displays used in the inverted-face condition are shown in the two bottom panels of Figure 1. The inverted displays were identical to the upright displays in all respects except they were rotated 180º so that the groups of arcs appeared as inverted schematic faces.

The displays were presented on an Iiyma Vision Master Pro 17 monitor controlled by a 200-mHz Pentium processor using Micro Experimental Laboratory software (Schneider, 1990). The imaginary matrix was 10-cm square and subtended a visual angle of approximately 9.5º at the prescribed viewing distance of 60 cm. Each individual arc was light gray on a dark background, 0.7 cm wide and 0.4 cm high, and subtended a visual angle of approximately 0.7º × 0.4º. Each group of three arcs, or each face, was 1.7 cm wide and 1.2 cm high and subtended a visual angle of approximately 1.6º wide and 1.1º high.

Procedure. The procedure was identical for participants in the upright- and inverted-face conditions. On each trial, the participants were required to count either upward- or downward-curved arcs in the display. They were told to count the arcs as quickly as possible while maintaining high accuracy. On half of the trials, the participants were required to count the downward-curved arcs, and on the other half of the trials participants were required to count the upward-curved arcs. At the beginning of each trial, a single arc was presented on the monitor to inform the participants which arc orientation, upward or downward, they were to count on that particular trial. This arc stayed on the screen for 1,000 msec before it was replaced by the display. The display stayed on the screen until the participants pressed the "b" key, indicating that they had finished counting the prescribed arcs. After the participants had pressed the "b" key, the display was terminated and replaced by a prompt for the participant to enter the number of arcs that had been counted. Feedback regarding accuracy was provided on each trial. For each trial, one of the two facial expressions (positive or negative facial expressions) was randomly selected with the constraint that each facial expression was tested 120 times across 240 experimental trials. For each emotional expression, participants counted upward-curved arcs on half of the trials and downward-curved arcs on the remaining trials.

Results and Discussion

Reaction time. Before the mean reaction times (RTs) for correct responses were analyzed, outliers in each cell were removed using a recursive procedure (Van Selst & Jolicœur, 1994). The highest and lowest RTs were removed, one at a time, and the mean and standard deviation of the remaining distribution were calculated following the removal of each extreme RT. If the RT that was removed was more than 4 *SD* from the mean of the new distribution, the RT was deemed to be an outlier and removed permanently. This procedure was repeated until no outliers remained. A total of 1.16% of the data was removed in this manner. The remaining RT and error rate data were then each evaluated by a 2 × 2 analysis of variance (ANOVA) to assess facial expression (positive vs. negative) and face orientation (upright vs. inverted).

Figure 2 shows the mean RTs to count arcs embedded in positive and negative upright and inverted faces. As suggested by the figure, arcs embedded in negative faces took longer to count than arcs embedded in positive faces [$F(1,50) = 36.18$, $MS_e = 10{,}474.15$, $p < .001$]. However, the main effect for facial expression was qualified by a significant interaction with face orientation [$F(1,50) = 11.69$, $MS_e = 10{,}474.15$, $p < .001$]; the difference in the time required to count the arcs embedded in positive and negative faces was larger when the faces were upright than when the faces were inverted. There was no significant difference in the times required to count the arcs embedded in inverted and upright faces [$F(1,50) = 1.76$, $MS_e = 535{,}910.04$]. Planned comparisons revealed that participants were faster at counting the individual arcs when they formed upright positive faces than when they formed upright negative faces [$t(25) = 7.30$, $p < .001$]; however, there was no significant difference between the time to count the arcs contained in inverted positive and negative faces [$t(25) = 1.70$]. Thus, the results support the conclusion that, over and above differences due to local features, faces expressing positive and negative emotion have a differential ability to capture attention and disrupt the task of counting upward and downward arcs.

Error data. The mean error rates for each condition are shown in Figure 2. An ANOVA revealed that the participants made significantly more errors when counting the features of negative faces than when counting the features of positive faces [$F(1,50) = 6.08$, $MS_e = 0.000593$, $p < .02$]. Neither the main effect of face orientation (upright vs. inverted) nor the interaction between emotional expression and orientation was significant (all Fs < 2.44, all ps $> .124$). The greater number of errors for negative than positive faces is completely consistent with the longer RTs for negative as opposed to positive faces and indicates that interpretation of the RT data was not compromised by a speed–accuracy tradeoff.

EXPERIMENT 2

The results of Experiment 1 demonstrate that more time is required to count the component parts of negative faces than positive faces. We suggest that these findings indicate that negative faces capture attention more effectively than positive faces, and thus more effectively distract attention away from the primary task of processing the orientation of the individual arcs. There is, however, an obvious alternative interpretation of the results of Experiment 1. It is entirely possible that the difference in the time required to count the component parts of negative and positive faces does not reflect attention capture by negative faces but rather is the result of a facilitation in the processing of the component parts of positive faces. To decide which explanation is more plausible, it is necessary to compare performance when counting the component parts of positive and negative faces with performance in an appropriate baseline condition. In Experiment 2, a neutral nonexpressive face was used as a baseline (Figure 3). If negative faces capture attention and disrupt the processing of local features, then counting the component parts of negative faces should be slower than counting the parts of neutral faces, whereas if positive faces facilitate the processing of local features, then counting the component parts of positive faces should be faster than counting the parts of neutral faces. As in the previous experiment, in order to ensure that any differences between the positive, negative, and neutral faces were not due to dif-

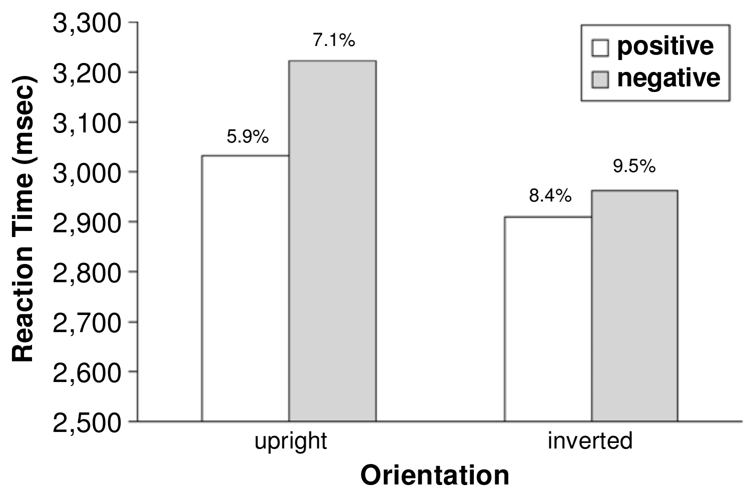

Figure 2. Mean reaction times and error rates (%) for counting arcs as a function of facial expression and orientation in Experiment 1.

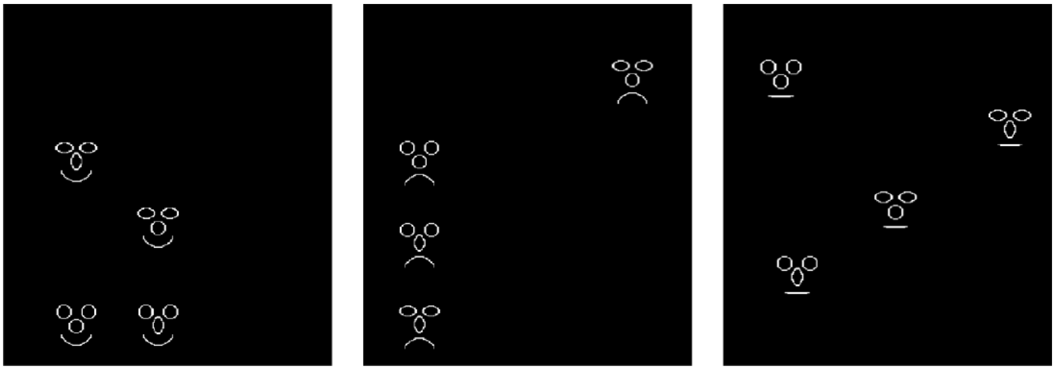

Figure 3. Examples of the displays used in Experiment 2 containing upright faces.

ferences in the local features of the faces, the faces were inverted for half of the participants.

Method

Participants. Twenty-eight University of Waterloo undergraduate students participated in the 30-min session in exchange for $8.00. Each student had normal or corrected-to-normal vision.

Experimental displays. Examples of the three different types of upright-face displays are shown in Figure 3. All displays contained four faces. The displays varied in terms of face orientation (upright or inverted) and emotional expression (positive, negative, or neutral). The faces were composed of two ovals or two circles positioned side-by-side representing eyes, with one oval or circle representing a nose, and a straight line, downward-curved arc, or upward-curved arc representing a mouth. On the basis of the mouth feature, the four faces in each display resembled faces expressing a neutral, positive, or negative emotion. For each face, the eyes (circles or ovals) varied independently of the nose feature, the mouth feature, and the other faces in the display. Each face occupied 1 of 36 possible locations defined by an imaginary 6 × 6 matrix.

The displays were presented on a ViewSonic 17PS monitor controlled by a 200-mHz Pentium processor using Micro Experimental Laboratory software (Schneider, 1990). The imaginary matrix was 12-cm square. At the prescribed viewing distance of 57 cm, 1 cm equaled approximately 1° of visual angle (i.e., 12-cm square equaled 12° square). Each face was 2 cm wide and 2 cm high, each oval was 0.9 cm wide and 0.5 cm wide, and each circle was 0.8 cm in diameter. The straight line, which composed the mouth of the neutral face, was 1.2 cm wide. The arc, which composed the mouth of the positive and negative face, was 1.5 cm high and 0.5 cm wide. All elements of the display were light gray on a dark background when presented on the monitor.

Procedure. On all trials, the participants were required to count either the ovals or the circles in the displays. They were told to count the ovals or circles as quickly as possible, while maintaining high accuracy. On half of the trials, the participants counted ovals, and on the other half of the trials, the participants counted circles. At the beginning of each trial, either the word *oval* or the word *circle* was presented on the monitor to inform participants which shape they were to count on that particular trial. Each prompt stayed on the screen for 1,000 msec before being replaced by an experimental display. The experimental displays stayed on the screen until participants pressed the space bar, indicating that they had finished counting the prescribed shapes. Once the space bar was pressed, the display was replaced by a prompt for the participant to enter the number of ovals or circles that had been counted. Feedback regarding accuracy was provided on each trial. Face orientation was varied between participants in order to avoid asymmetrical carry-over effects between the upright- and inverted-face conditions. For each trial, one of the three facial expressions (neutral, positive, or negative) was randomly selected with the constraint that each facial expression was tested 20 times across 60 experimental trials.

Results and Discussion

Reaction time. Before the mean RTs for correct responses were analyzed, outliers in each cell were removed using the same procedure as in Experiment 1. This resulted in the removal of a total of 1.6% of the data.

Figure 4 shows the mean RTs to count the ovals or circles embedded in positive, negative, and neutral upright and inverted faces. The data were evaluated initially by a 3 × 2 ANOVA to assess facial expression (positive, negative, and neutral) and face orientation (upright vs. inverted). As suggested by an inspection of Figure 4, the analysis revealed a significant effect of facial expression, indicating that the time required to count ovals and circles varied depending upon the facial expression in which they were embedded [$F(2,52) = 4.31$, $MS_e = 35{,}436.87$, $p < .02$]. The analysis also indicated that neither the main effect of orientation nor the interaction between facial expression and orientation was a significant source of variance (all Fs < 1.26, all ps $> .29$).

Before evaluating whether positive faces facilitate performance or negative faces interfere with performance, we analyzed the RT data to determine whether the results replicated the critical interaction between emotional expression (positive and negative only) and face orientation (upright and inverted) found in Experiment 1. The data were submitted to a 2 × 2 ANOVA to assess facial expression (positive vs. negative only) and face orientation (upright vs. inverted). The analysis revealed that it took significantly longer to count ovals and circles embedded in negative faces than to count ovals and circles embedded in positive faces [$F(1,26) = 10.91$, $MS_e = 24{,}239.02$, $p < .01$] and that the time required to count ovals and circles embedded in upright and inverted faces did not differ significantly [$F(1,26) = 0.944$, $MS_e = 889{,}854.32$]. Importantly, however, as in Experiment 1, the difference in the time required to count ovals and circles embedded in positive and negative faces was larger

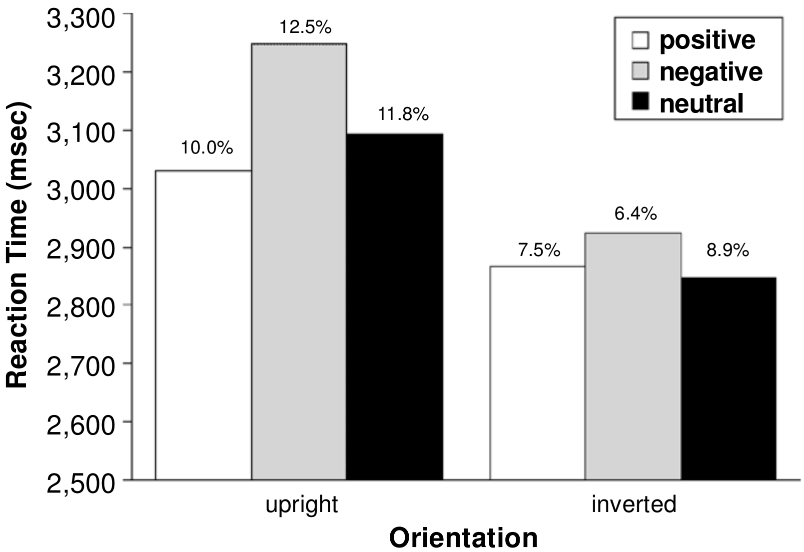

Figure 4. Mean reaction times and error rates (%) for counting ovals and circles as a function of facial expression and orientation in Experiment 2.

when the faces were upright than when the faces were inverted [$F(1,26) = 3.67$, $MS_e = 24{,}239.02$, $p = .066$].[2] Specifically, more time was required to count the component parts of upright negative than upright positive faces [$t(13) = 3.39$, $p = .005$], whereas there was no significant difference between the times required to count the component parts of inverted positive and inverted negative faces [$t(13) = 1.08$]. These findings fully replicate the results of Experiment 1 and once again suggest that negative facial expression captures attention more effectively than positive facial expression.

To assess whether the positive faces facilitated performance or whether the negative faces interfered with performance, the data were further analyzed using planned comparisons. Planned *t* tests revealed that the time required to count the component parts of the negative faces was greater than the time required to count the component parts of neutral faces [$t(13) = 3.35$, $p = .005$], whereas there was no significant difference between the times required to count the component parts of the positive relative to the neutral faces [$t(13) = 0.80$, $p = .44$]. Taken together, these findings suggest that the greater amount of time required to count the component parts of negative as opposed to positive faces reflects interference from the negative faces and not facilitation from the positive faces. Finally, no significant differences were found between the times required to count the component parts of inverted negative versus inverted neutral faces [$t(13) = 0.86$] or the times required to count the component parts of inverted positive versus inverted neutral faces [$t(13) = 0.22$]. The absence of any significant differences between the inverted-face conditions suggests that the significant differences found for the upright faces were due to the different emotional expressions and not due to local feature differences between the positive and negative faces.

Thus the results of Experiment 2 further support the conclusion that facial expression of negative emotion captures attention more effectively than facial expression of positive emotion. The results support this conclusion by (1) providing a replication of the critical interaction between emotional expression (positive and negative) and face orientation (upright and inverted) found in Experiment 1, and by (2) ruling out the possibility that the difference between positive and negative upright faces found in Experiments 1 and 2 was the result of facilitation by positive faces rather than interference by negative faces.

Error data. The mean error rates for each condition are shown in Figure 4. Paired-samples *t* tests, which corresponded to the analysis of RTs, revealed no significant differences in the error rates for upright and inverted positive, negative, and neutral faces (all ts < 1.34, all ps $>$ .19). Thus, interpretation of the RT data does not appear to have been compromised by speed–accuracy tradeoffs.

GENERAL DISCUSSION

In two experiments, participants counted the features of upright and inverted positive and negative schematic faces. The results of Experiment 1 revealed that counting features took longer when they were embedded in negative faces than when they were embedded in positive faces. In Experiment 2, it was found that more time was required to count the features of negative faces than to count the features of either positive or neutral faces. In both experiments, when the faces were inverted to reduce holistic face perception, no differences were observed in the times required to count the component parts of inverted faces even though the feature information in the inverted faces was the same as in the upright faces. Taken together, these findings strongly support the conclusion that negative faces are more effective at involuntarily attracting or capturing attention than are positive faces.

The conclusion that negative faces capture attention more effectively than positive faces extends earlier findings regarding the guidance of attention by emotionally expressive faces. Previously it has been demonstrated that when participants are *deliberately* searching for a unique face in a display of nonexpressive faces, attention is *guided* to a negative face more effectively than it is guided to the location of a positive face (e.g., Eastwood et al., 2001). The present results suggest that even when participants are *not deliberately* looking for faces, negative faces also *capture* attention more effectively than positive faces.

The present findings extend previous research regarding the capture of attention by global objects (e.g., Navon, 1977; Rauschenberger & Yantis, 2001; Suzuki & Cavanagh, 1995). For example, Rauschenberger and Yantis have shown that the global *visual form* of objects can capture attention away from the features of objects. Rauschenberger and Yantis suggested that global objects are particularly effective at capturing attention because it is adaptive for an animal to maintain sensitivity to important global levels of information relevant to the animal's survival. For instance, "an animal that continues to attend to the individual spots of a camouflaged cheetah even when they begin to cohere at a more global level would quickly regret this evolutionary error" (p. 1251). The present results extend these previous findings by showing that attention is captured not only by the global *visual form* of objects but also by the *meaning* of objects, such as the affective meaning of faces.

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NOTES

1. The present experiments examine what might be referred to as attention capture based on *within-object* shifts of attention (see Navon, 1977; Rauschenberger & Yantis, 2001) in contrast to *between-object* shifts of attention, which occur when emotionally expressive faces are presented at a different spatial location relative to an observer's ongoing task (Vuilleumier, Armony, Driver, & Dolan, 2001; White, 1996). It has been argued that within-object shifts of attention are mediated by different neurological mechanisms than between-object shifts of attention (e.g., Filoteo, Friedrich, & Stricker, 2001). In this respect, the present experiments extend the work of Vuilleumier et al. (2001) and White (1996).

2. This result is judged to be significant based on a one-tailed test ($p = .033$) because a specific pattern of results was predicted from the findings of Experiment 1.

(Manuscript received April 23, 2002;
revision accepted for publication October 6, 2002.)