Emotion
2011, Vol. 11, No. 3, 544–552

1528-3542/11/$12.00 DOI: 10.1037/a0022763

Task-Irrelevant Angry Faces Capture Attention in Visual Search While Modulated by Resources

Shwu-Lih Huang
National Chengchi University

Yu-Chieh Chang
National Chengchi University

Yu-Ju Chen
National Chengchi University

We investigated the attentional capture effect of emotional faces under sufficient or restricted attentional conditions. In a modified visual search paradigm, three kinds of schematic faces (angry, happy, and neutral) served as stimuli. Participants were instructed to search for a target face indicated by a dot and to respond to the dot's position. In this design, the emotional content of the face is task-irrelevant and does not need to be attended. The results of Experiment 1 demonstrate that having an angry face as the target face elicited a faster response than did the neutral target face, and when the angry face is used as a distractor, the response to the target was delayed compared to the response with no such distractor. Experiment 2 included inverted faces to decrease emotional content; results showed that inversion of the faces reduced the effect of angry faces on the search performance. When attention was cued to a specific area in Experiment 3, the effect of angry faces outside of the cued area became weaker. In conclusion, the results indicate that a task-irrelevant angry face can capture attention beyond top-down control, but this effect is modulated by the availability of attentional resources.

Keywords: angry face, attentional capture, top-down control, automaticity, attentional resources

From an evolutionary perspective, the automatic detection of threatening stimuli is highly valuable for survival. The early detection of threats permits a quick and appropriate response to potential danger. An evolved fear module or fear system has been proposed as the neural mechanism responsible for this function (Öhman & Mineka, 2001; Armony & LeDoux, 2000).

Previous studies have shown that threatening stimuli may capture the attention of an individual automatically. In visual search studies, threatening stimuli (such as snakes or spiders) are searched more efficiently than nonthreatening stimuli (such as flowers or mushrooms) (Öhman, Flykt, & Esteves, 2001). Also, searching for a threatening face among several neutral faces was found to be more efficient than searching for a nonthreatening happy face (Fox et al., 2000; Eastwood, Smilek, & Merikle, 2001). In the above studies, the participants' task was to search for a unique item (target) among distractors. This target was different from the distractors in perceptual features and emotional content. Therefore, the participants were able to perform the search task based solely on the emotional content of the search items. In this regard, the emotional or threat content was task-relevant in these studies. Hence, threatening stimuli may draw attention through top-down attentional control because their emotional content is task-relevant.

Other studies have employed tasks in which the emotional content of the stimulus is clearly task-irrelevant. In these studies, processing of the emotional content gives no useful information for doing tasks. The presence of angry faces was found to interfere in a counting task (Eastwood, Smilek, & Merikle, 2003). In spatial cuing studies, an angry face used as the invalid cue was found to delay responses more than a happy face in high anxious participants (Fox, Russo, Bowles, & Dutton, 2001). These results implied that task-irrelevant threatening stimuli can capture attention beyond top-down control. However, all supporting evidence mentioned above came from the interference effect of angry faces in which the task performance deteriorated. Using emotional faces as the cue in a spatial cuing task, Fox et al. (2001) could not find a facilitation effect (i.e., a faster response than for the control) of an angry face when it was the valid cue. In visual search, if the task-irrelevant angry face can capture attention, a target presented in the same location as the angry face should be detected more quickly. In other words, the angry face should have a facilitation effect in this condition. However, no study has employed a visual search task to test this predicted effect.

In the present study, the attentional capture effect of angry faces is tested through a task in which the emotional content of the faces is task-irrelevant. Therefore, whether an angry face may capture attention beyond top-down control can be tested. In addition, both the predicted effects of the angry face in different conditions to speed up responses (i.e., a facilitation effect) and to slow down responses (i.e., an interference effect) are tested using a new variation of the visual search task. In this task, the target is defined

This article was published Online First April 25, 2011.

Shwu-Lih Huang, Department of Psychology, Research Center for Mind, Brain, and Learning, National Chengchi University, Taiwan, R.O.C. Yu-Chieh Chang and Yu-Ju Chen, Department of Psychology, National Chengchi University, Taiwan, R.O.C.

Correspondence concerning this article should be addressed to Shwu-Lih Huang, No. 64, Sec. 2, NhiNan Road, Wenshan District, Taipei City 11605, Taiwan, R.O.C. E-mail: slh@nccu.edu.tw

by an attribute (a black dot) independent of emotional content. If an angry face can capture attention beyond top-down control, the search performance for the target should be affected. When the target is presented in a face that happens to express angry rather than neutral emotion, this target should be searched more efficiently and show a facilitation effect. Otherwise, when one of the distractors happens to express angry emotion, searching for the target should be hindered and thus show an interference effect. Two experiments were designed to test these predictions.

The issue of whether threatening stimuli can capture attention beyond top-down control is closely related to issues of automaticity. Based on the intentionality criterion of automaticity, automatic processes are under the control of stimulation rather than the participants' intentions (Neumann, 1984). In other words, an automatic process is not subject to top-down control. This claim is also consistent with Tzelgov (1997), in which an automatic process was thought to be running without monitoring. In this study, because the angry emotion was designed to be task-irrelevant, there was no need to attend to the angry face. If it still could not be ignored, its attentional capture effect is beyond top-down control and therefore satisfied the intentionality criterion of automaticity.

However, attentional capture that is beyond top-down control does not imply that it requires no attentional resources. For instance, when attention was allocated to a spatial location in advance, salient stimuli presented in other (i.e., unattended) locations did not capture attention, although they did in other conditions (Yantis & Jonides, 1990; Koshino, Warner, & Juola, 1992). It has been proposed that a salient stimulus can capture attention beyond top-down control if it is presented inside the attentional window, but not outside (Stigchel et al., 2009; Theeuwes, 2004). Also, evidence indicates that the detection and processing of emotional faces requires attention. When attentional resources were exhausted by a sufficiently demanding competing task, the responses to emotional and neutral faces did not differ significantly in event-related potential (ERP) and functional MRI (fMRI) studies (Eimer, Holmes, & McGlone, 2003; Holmes, Vuilleumier, & Eimer, 2003; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002). In addition, the interference effect of task-irrelevant emotional pictures can be disrupted if the search task is highly demanding (Okon-Singer, Tzelgov, & Henik, 2007). Therefore, whether threatening stimuli can capture attention in conditions of restricted resources also was investigated in the present study. A cuing procedure was adopted to guide attention to a small area so that the attention could be manipulated toward or away from angry faces. The attentional capture effects of attended and unattended angry faces were compared to reveal the effects of attentional resources. Experiment 3 was designed for this purpose.

In summary, the purpose of this study is to investigate whether a task-irrelevant angry face can capture attention beyond top-down control and how this attentional capture is modulated by attentional resources. To clarify these questions, the attentional capture effect of the angry face in visual search was observed under distributed and focused attention conditions. In Experiments 1 and 2, because the position of the target was randomized and could not be predicted, it is reasonable to assume that the participants allocated their attention broadly (i.e., in a distributed manner), even across the whole display, to improve their performance. Under this distributed attention condition, all stimuli presented in the display (including the angry face) may occupy some attentional resources. In Experiment 3, focused attention (i.e., when the attention is allocated in a small area) was induced using a cuing procedure in which the cue is fully predictive of the target's position. Thus, an angry face could be presented inside the attentional window and receive sufficient attentional resources or be presented outside with limited resources. It is predicted that an angry face may capture attention beyond top-down control under the distributed attention condition but not under the focused attention condition if the angry face is presented outside the attentional window.

Experiment 1

The predicted facilitation and interference effects of angry faces discussed above were tested using a modified visual search task in which the target was a black dot located with equal probability within one of eight simultaneously presented faces. Therefore, the emotional content of the faces is task-irrelevant. In addition, a happy face was also included as another kind of emotional stimulus for comparison.

Method

Participants. There were 23 participants, of which 12 were men and 11 were women, ranging in age from 18 to 27. All participants had normal or corrected-to-normal vision. All were college students and were either paid or received course credit.

Materials. Three kinds of schematic faces (angry, happy, and neutral) were included as the emotional stimuli (see Figure 1). In the stimulus display of each trial, eight faces were presented simultaneously in a circular layout around a central fixation cross to control eccentricity. One face with a black dot in it was defined as the target face. The black dot was located on either the left or right side of the target face with equal probability.

Experimental stimuli were generated by a computer program written in Visual Basic. Each face subtended $2.96° \times 3.24°$ of visual angle in width and height, respectively. The distance between the fixation point and the center of each face was 4.77° of visual angle. The viewing distance between the participants and the monitor was 60 cm.

Procedure. The procedure for each trial is summarized in Figure 2. First, an alert sound signaled the beginning of the trial. After 300 ms, a fixation cross was presented for 1000 ms. Participants were asked to fixate on the cross. The stimulus display of eight schematic faces was then presented. This display remained on the screen until the participant responded. The task for each participant was to search for the target face, which had a black dot in it, and to discriminate on which side of the target face the dot was located. All participants were instructed to press a left re-

Figure 1. Schematic faces used in Experiment 1. Angry, happy, and neutral faces are shown from left to right, respectively.

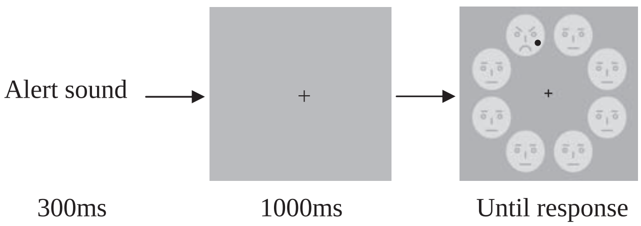

Figure 2. An example of a trial for the angry target condition of Experiment 1. An alert sound was presented first. After an interval of 300 ms, a fixation cross was presented for 1000 ms. The search display was then presented and remained on the screen until a response was made. To improve legibility, the black dot shown in the figure is larger than that actually presented during the experiment.

sponse key if the dot was located on the left side or a right response key for the right, as quickly as possible. The next trial began 1500 ms after the response. The reaction time (RT) of each trial was recorded as the dependent variable.

First, the participants gave informed consent and received instructions for the experiment. A practice block of five trials was used to familiarize participants with the procedure. Then, seven experimental blocks totaling 280 trials were completed by each participant.

Five variations of the visual search display were presented: (1) Neutral control condition: eight neutral faces were presented, one with a black dot. (2) Happy target condition: one happy face with a black dot and seven neutral faces were presented. (3) Happy distractor condition: one happy face and seven neutral faces were presented, and the dot was located in one of the neutral faces. (4) Angry target condition: one angry face with a black dot and seven neutral faces were presented. (5) Angry distractor condition: one angry face and seven neutral faces were presented, and the dot was located in one of the neutral faces. There were 56 trials for each of the five conditions. The 280 total trials were divided evenly into seven blocks. Each block included eight trials from every condition. The probabilities of the target appearing in each of the eight locations were equal, and the location of the angry or happy faces was controlled in the same manner. In addition, the dot's presentation on the left or right side of the target face was counterbalanced. All trials in each block were presented in random order.

Results and Discussion

The mean RT of the correct responses under each condition is shown in Figure 3. The error rates of all conditions were very low ($M = 0.854\%$), and the difference among them was not significant. In the RT data, one-way within-participants analysis of variance (ANOVA) showed a significant effect of condition, $F(4, 88) = 15.591$, $MSE = 1497.145$, $p < .001$, $\eta^2 = .415$. A Tukey's post hoc comparison indicated that the RT for the angry target condition ($M = 749.48$ ms) was significantly shorter than that for the neutral control condition ($M = 793.14$ ms), $p < .05$. The RT of the angry distractor condition ($M = 828.86$ ms) was significantly longer than that of the neutral control condition, $p < .05$. The happy target and happy distractor conditions did not differ significantly from the neutral control condition. These results are consistent with the predicted facilitation effect (i.e., that the target presented in the angry face should be searched faster) and with the interference effect (i.e., that the angry face as a distractor would slow down the search).

In this experiment, emotional content can be assumed to be task-irrelevant. Paying attention to the angry face cannot help improve the task performance. However, the angry face could not be ignored and still had effects on attention. When the angry face was the target face, search performance was facilitated compared to the neutral control condition. In contrast, when the angry face was a distractor, search performance was interfered with accordingly. Therefore, the data demonstrate that an angry face can capture attention beyond top-down control. However, no significant effect was observed for the happy faces although the data showed a similar trend. Thus, angry faces are more powerful stimuli for capturing attention than happy faces.

Experiment 2

In Experiment 1, the angry face was different at the perceptual level from all of the neutral faces presented simultaneously in the stimulus display. Therefore, attentional capture by angry faces may result from the singleton-like property of their physical shape. Happy faces did not have the same effect, which could be partial grounds to exclude this possibility, but this remains to be further verified. In this experiment, the faces were inverted to decrease the emotional content of the stimuli. Therefore, the contribution of angry emotions can be verified by comparing the effects of upright and inverted angry faces.

Method

Participants. Thirty participants, of which 10 were men and 20 were women, ranging in age from 18 to 23 and with normal or corrected-to-normal vision, completed Experiment 2. All participants were college students and were either paid or received course credit.

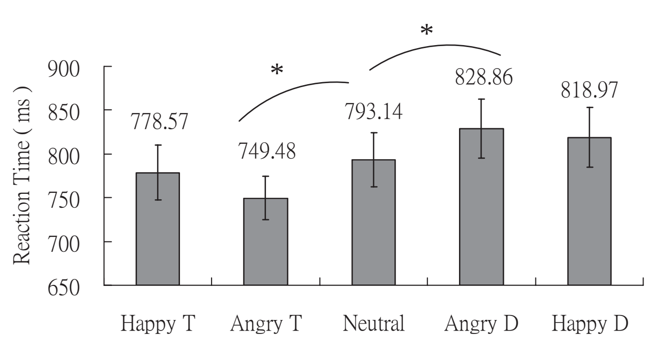

Figure 3. The mean reaction time (RT) in milliseconds (with error bar, *SEM*) as a function of the five conditions in Experiment 1. The numbers presented above the bars are the mean RTs for each condition. The happy target condition is denoted as "Happy T", and the happy distractor condition is denoted as "Happy D". The angry target/distractor conditions are denoted similarly. To compute the mean RT, trials with error reponses were discarded first. In addition, for each participant, RTs deviating more than 2 *SD*s from the mean RT under each condition were excluded (mean exclusion rate = 4.704%).

Materials and procedure. All experimental attributes except for two were the same as in Experiment 1: First, all eight faces were inverted in half of the trials. Second, only angry and neutral faces were included.

For each trial, the display sequence was the same as in the first experiment. One practice block with five trials and six experimental blocks totaling 336 trials were completed by each participant.

This experiment adopted a two-way within-participants design. The independent variables were orientation (inverted, upright) and display type (neutral control, angry target, angry distractor). Three conditions of display type were the same as described in Experiment 1, and RT was the dependent variable. There were 56 trials in each of the six conditions. The counterbalancing and randomization procedures were the same as those used in Experiment 1.

Results and Discussion

The mean RT of the correct responses under each condition is shown in Figure 4. The error rates of all conditions were very low ($M = 1.072\%$), and the difference among them was not significant. In the RT data (see Figure 4), a two-way within-participants ANOVA showed that the main effect of display type was significant, $F(2, 58) = 20.067$, $MSE = 13542.17$, $p < .001$, partial $\eta^2 = .409$. The interaction effect was also significant, $F(2, 58) = 4.629$, $MSE = 1597.344$, $p < .05$, partial $\eta^2 = .138$. The main effect of orientation was only marginally significant, $F(1, 29) = 3.941$, $MSE = 2567.123$, $p = .057$, partial $\eta^2 = .120$. For the main effect of display type, a post hoc Tukey's test indicated that the RT of the angry target condition ($M = 878.00$ ms) was significantly shorter than that of the neutral control condition ($M = 974.38$ ms), $p < .05$. The RT of the angry target condition was also significantly shorter than that of the angry distractor condition ($M = 1007.55$ ms), $p < .05$. For the interaction effect, further analysis showed that the simple main effect of orientation was only significant under the angry distractor condition ($F(1, 29) = 9.504$, $MSE = 2178.421$, $p < .05$, partial $\eta^2 = .247$), but not under the neutral control and angry target conditions.

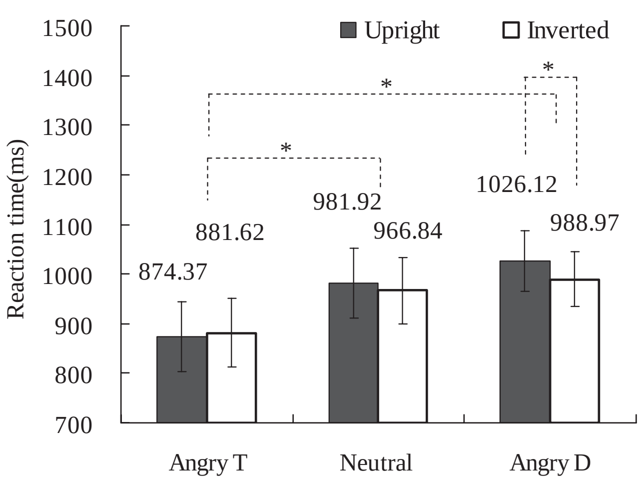

Figure 4. The mean reaction time (RT) in milliseconds (with error bar, *SEM*) as a function of orientation (inverted, upright) and display type (angry target, neutral control, and angry distractor) in Experiment 2. The numbers presented above the bars are the mean RTs for each condition. To compute the mean RT, trials with error responses were discarded first. In addition, for each participant, RTs deviating more than 2 *SD*s from the mean RT under each condition were excluded (mean exclusion rate = 4.593%).

As the difference between the inverted and upright neutral control conditions was not significant, the significant effect of orientation under the angry distractor condition indicated that the interference effect of inverted angry faces was decreased compared to the upright condition as predicted (see Figure 4). After decreasing the emotional content of an angry face by face inversion, its effect on attention was reduced accordingly. The facilitation effect of the inverted angry face also decreased (i.e., the mean RT of the angry target condition was shorter under the upright than the inverted condition) as predicted. However, this decrease did not reach the significant level. One possible reason for this result is that the effect of the task-relevant dot and the singleton-like property of the inverted angry face were powerful enough in combination to survive the detrimental effect of decreasing the emotional content. Further studies will be needed to clarify this possibility.

However, a further Scheffé test revealed that the mean RT difference between the angry distractor and angry target conditions of the inverted orientation was smaller than that of the upright orientation, $F(2, 58) = 9.258$, $MSE = 1597.344$, $p < .05$, $d = 1.15$. This result provides clear support evidence for the decreased facilitation and interference effects of the angry face in combination under the inverted condition. Therefore, to analyze the effect of face inversion in a more meaningful way, the indices of the facilitation and interference effects were calculated by subtracting the mean RT of the control condition from that of the angry target or angry distractor conditions, respectively (see Figure 5). A 2 (orientation: inverted, upright) $\times$ 2 (facilitation, interference) within-participants ANOVA showed that the main effect of facilitation/interference was significant, $F(1, 29) = 22.67$, $MSE = 22213.37$, $p < .001$, partial $\eta^2 = .440$. More importantly, the interaction effect was also significant, $F(1, 29) = 11.32$, $MSE = 1306.07$, $p < .01$, partial $\eta^2 = .280$. It can be seen from Figure 5 that the interaction effect came from the reduced facilitation effect and the interference effect in the inverted condition compared to the upright condition. Because both the facilitation and interference effects originate from attentional capture by the angry face, this result supports that face inversion attenuated the attentional capture by the angry face.

In general, the results show that after the emotional content was decreased by face inversion, the effect of angry faces on capturing attention decreased accordingly. This result implies that the emotional contents, not only the physical properties, of faces contribute to the effect.

Experiment 3

The results of Experiments 1 and 2 reveal that task-irrelevant angry facial emotion may capture attention beyond top-down control. However, it cannot be claimed that an angry face does not require attentional resources for the attentional capture to occur. In addition, the presentation time of the visual search displays was unlimited in these two experiments. As a result, attentional resources may be distributed broadly across the entire display to improve task performance. In other words, the angry face may

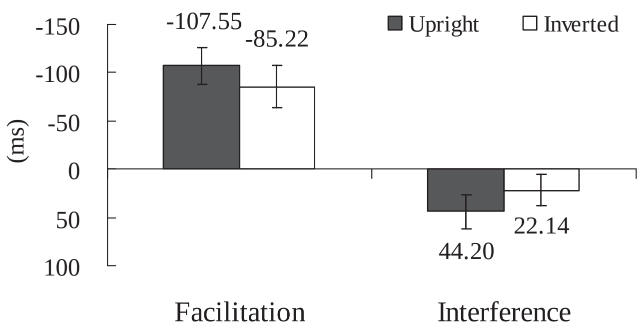

Figure 5. Facilitation/inhibition effects as a function of orientation (inverted, upright) in Experiment 2. The facilitation/inhibition effects shown in the figure are the mean RT differences (in ms) between the angry target/distractor and neutral control conditions, respectively. The numbers presented above or below the bars are the values of the facilitation/inhibition effects for each condition.

have received sufficient resources in the previous two experiments. Therefore, whether attentional capture by angry faces can occur under conditions of restricted attentional resources is not clear and needs to be investigated.

In this experiment, a cuing paradigm was adopted to manipulate the attentional status of an angry face. To induce focused attention on a small area, flashing high-luminance light in one quadrant of the display was used as the 100% valid cue to guide attention to this area (Schreij, Owens, & Theeuwes, 2008). Using this method, stimuli presented inside the attended area would receive sufficient resources, but those outside would not. In addition, the presentation time of the search display was limited to 300 ms to increase the task difficulty. Participants had to focus their attention on the cued area to perform the task well. The effects of angry faces inside and outside the attended area were observed and compared. If attentional capture by the angry face does not require any attentional resources, then an angry face presented inside or outside of the attended area should have the same effect. In contrast, if it does require attentional resources, then an angry face presented outside of attended area (which cannot have sufficient attentional resources) should have a smaller effect or possibly no effect at all.

Method

Participants. Twenty-three participants, ranging in age from 18 to 25 years, all had normal or corrected-to-normal vision. They were either paid or received course credit.

Materials and procedure. Angry and neutral faces were included as the stimuli in this experiment. The search task was similar to that in Experiment 1. To manipulate the attended area of the stimulus display, a high-luminance flash was used as an exogenous cue for attracting attention to the cued area. This cue was 100% valid, giving participants a high incentive to use it to enhance their performance. Because an abrupt onset of the search display would disrupt the attention allocation induced by the cue, a no-onset procedure was designed (see Figure 6) (Todd & Van Gelder, 1979). A pooled-face mask was prepared by overlapping the neutral, angry, and happy faces. Eight such camouflaging masks were presented beforehand in the locations where the faces would later appear. Hence, presentation of the search display involved removing only some parts of the camouflaging masks.

For each trial (see Figure 6), an alert sound was presented, followed by an interval of 300 ms. Then, the fixation cross and eight surrounding pooled-face masks were presented for 1000 ms.

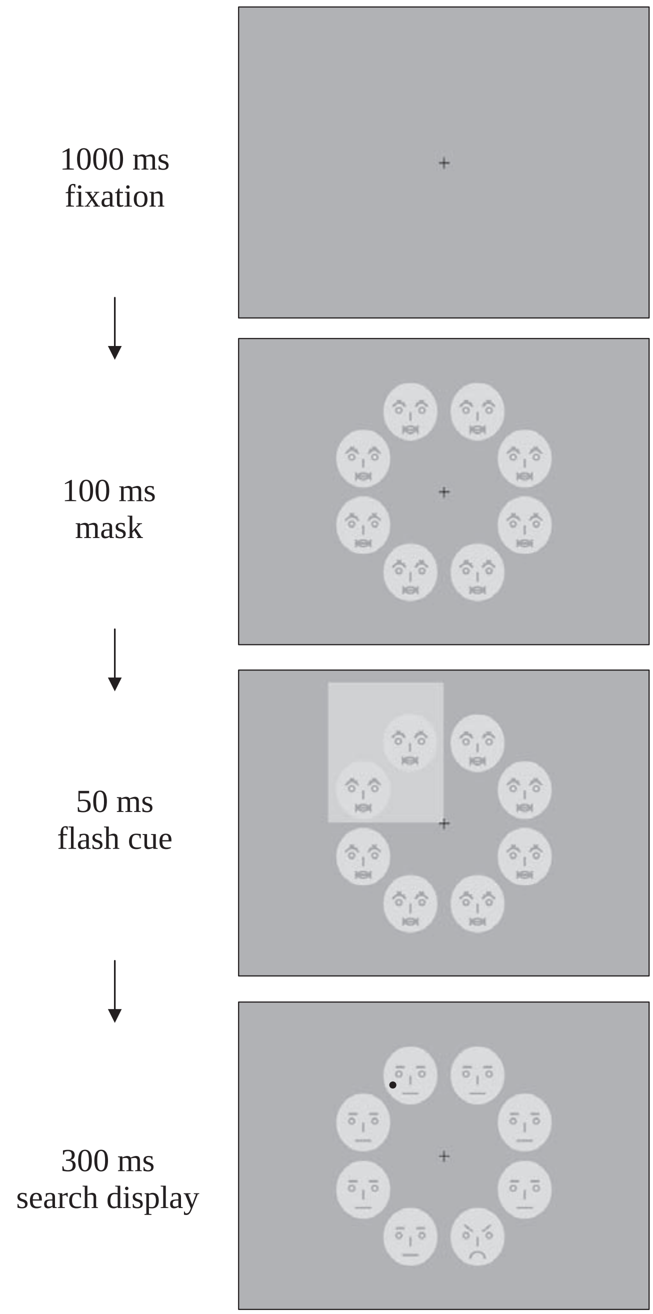

Figure 6. An example of a trial under the angry target outside condition of Experiment 3. First, a fixation cross was presented for 1000 ms. The pooled-face mask was then presented for 100 ms. After that, a high luminance flash was presented in one quadrant of the display as an exogenous cue. Finally, the search display was presented for 300 ms. To improve legibility, the black dot shown in the figure is larger than that actually presented during the experiment.

Next, a high-luminance flash cue was presented for 50 ms in one quadrant of the display. Finally, eight no-onset faces were disclosed from the pooled-face masks and presented for 300 ms. The target face was always presented in the cued area.

Four conditions of the visual search display were included: neutral control condition, angry target condition, angry distractor inside condition, and angry distractor outside condition. The definition of each condition was the same as in Experiment 1, except that the angry distractor condition was further divided into two conditions according to the location of the angry face: inside or outside of the attended area. RT was the dependent variable. There were 48 trials in each of the four conditions. All trials were randomly divided into four blocks with equal numbers of trials in each condition. The counterbalancing procedure was the same as before.

Results and Discussion

The mean RT of correct responses under each condition is shown in Figure 7. The error rates of all four conditions ranged from 5.253% to 5.887% ($M = 5.547\%$), and the difference among them was not significant. For the angry distractor outside condition, because the attention allocation may not be totally restricted within the cued area, only the data of the trials in which the angry distractor was presented in the quadrant opposite to the cued area was included for analysis. One-way within-participants ANOVA showed that the effect of condition was significant, $F(3, 66) = 2.953$, $MSE = 487.08$, $p < .05$, $\eta^2 = .118$. A post hoc Tukey's test indicated that the RT of the angry distractor outside condition ($M = 620.92$ ms) was significantly shorter than that of the angry distractor inside condition ($M = 638.22$ ms), $p < .05$. However, all of the other paired comparisons were not significant.

In Figure 7, it can be seen that the mean RT of the angry target condition was shorter than that of the neutral control condition, but the difference did not reach significance. Also, the mean RT of the angry distractor inside condition was longer than that of the neutral control condition, but the difference was not significant. Therefore, the facilitation and interference effects obtained in Experiment 1 could not totally be replicated in this experiment, although the trends were correct. One possible reason results from the ceiling effect due to the presentation of only two faces in the attended area. In addition, two faces presented inside of the attended area would receive highly sufficient resources. Thus, the predicted effects could not manifest in the two comparisons discussed above. Another possible reason results from the small sample size in this experiment. However, the predicted effects in the attended area were partially supported by the matched-sample *t* test between the angry target and angry distractor inside conditions, which was significant, $t(22) = -1.845$, $SEM = 6.047$, $p < .05$ (one-tailed).

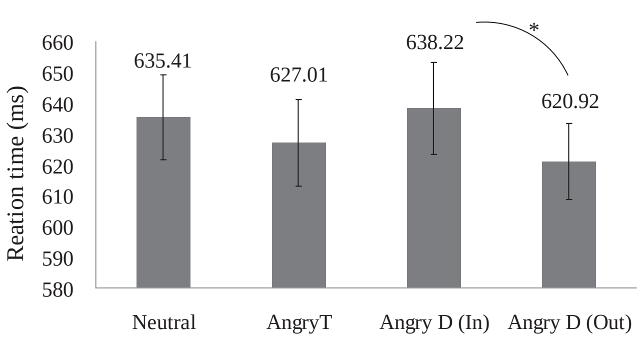

Figure 7. The mean reaction time (RT) in milliseconds (with error bar, *SEM*) as a function of the four conditions used in Experiment 3. The numbers presented above the bars are the mean RTs for each condition. The denotations in the abscissa are similar to those in Figure 3. Angry D (In) and Angry D (Out) denote the angry distractor inside and outside conditions, respectively. To compute the mean RT, trials with error responses were discarded first. In addition, for each participant, RTs deviating more than 2 *SD*s from the mean RT under each condition were excluded (mean exclusion rate = 4.121%).

Most importantly, the RT of the angry distractor outside condition was significantly shorter than that of the inside condition. This result implies that the interference effect of angry faces was reduced outside of the attended area. To explore this effect further, the effect of the angry distractor's position relative to the target's position and the attended area was analyzed. One example of the position assignment is shown in Figures 8A and 8B. For example, position 1 represents an angry distractor presented neighboring the target face but outside of the attended area (Figure 8B). The results are shown in Figure 8C, with the position effect obtained from Experiment 1 as a comparison. It can be seen that the position effects obtained in these two experiments differed greatly. In Experiment 1, the RT grew longer as the distance between the angry distractor and the target became larger, but in Experiment 3, the angry distractor outside of the attended area tended to have approximately the same RT regardless of its position. Further, the RT data of positions 1 to 4 from Experiments 1 and 3 were entered into a 4 (position: 1, 2, 3, 4) $\times$ 2 (experiment: Experiment 1, Experiment 3) two-way ANOVA with position as a within-participants factor and experiment as a between-participants factor. The results revealed that the position by experiment interaction was significant, $F(3, 132) = 7.14$, $MSE = 1290.71$, $p < .001$, partial $\eta^2 = .140$. A Tukey's post hoc comparison indicated that the differences between positions 1 and 2, 1 and 4, and 3 and 4 were significant in Experiment 1 (ps $< .05$). However, none of the paired comparisons in Experiment 3 were significant. Therefore, the different position effects observed in Experiments 1 and 3 are reliable.

Because a larger distance between an angry distractor and target would require more time for shifting attention if the angry distractor did capture attention, a position effect like that obtained in Experiment 1 can be used as an index to reveal the interference effect of an angry distractor. Therefore, the lack of a position effect in the angry distractor outside condition of this experiment implies reduced interference under that condition. Thus, the angry distractor must be presented in the possibly to-be-attended area for its interference effect to occur. In this experiment, attentional resources were allocated mostly within the cued area because of the high task demands. As a result, an angry face presented outside of the cued area could not have sufficient attentional resources such that its interference effect was reduced. Hence, the results of this experiment showed that attentional capture by the angry face was modulated by the availability of attentional resources.

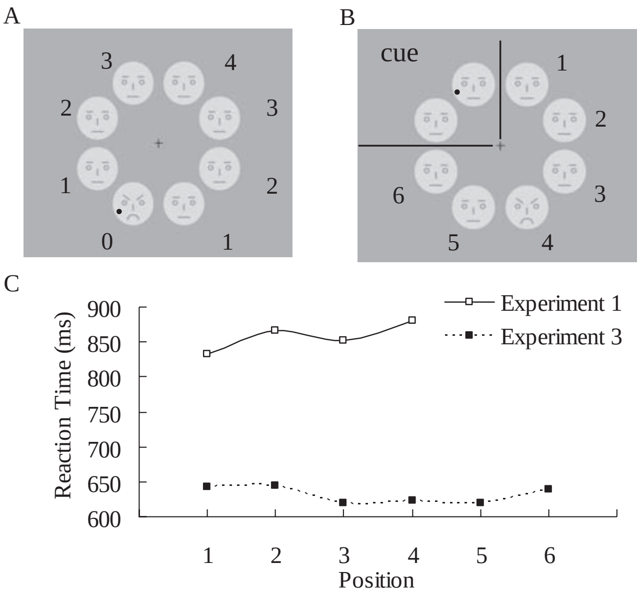

Figure 8. Examples of position assignments and the different position effects of the angry distractor in Experiment 3 compared to that in Experiment 1. (A) An example of position assignments in Experiment 1. The position number shows the distance between that position and the target face. (B) An example of position assignments in Experiment 3. The position number shows the distance between that position (outside of the cued area) and the target face in a clockwise or counterclockwise direction according to the target face position within the cued area. (C) Position effects for the angry target outside condition of Experiment 3 compared with Experiment 1. To improve legibility, the black dot shown in the figure is larger than that actually presented during the experiment.

General Discussion

The results obtained in this study reveal that task-irrelevant angry faces can have facilitation and interference effects under different conditions as predicted. In Experiment 1, search performance was improved when the angry face was the target face. In contrast, search performance was impaired when the angry face was a distractor. A relatively smaller effect was found when the happy face was the target face or distractor.

Because the angry emotion of the face is task-irrelevant in this study, the effects obtained cannot be the outcome of top-down attentional control. Although the attentional capture effect may partially result from the perceptual singleton-like property of the angry face due to the specific design of the search display in this study, the contribution of angry emotion was verified through the face inversion in Experiment 2. The relatively larger effect of angry than happy faces obtained in Experiment 1 also supports the contribution of angry emotion. Therefore, these results support the hypothesis that angry faces may capture attention beyond top-down control.

However, from the results of Experiment 3, it can be seen that an angry face may not capture attention if it is presented outside the attentional focus and consequently could not have sufficient attentional resources. These results are consistent with previous studies (e.g., Pessoa et al., 2002; Okon-Singer et al., 2007). Therefore, the data obtained in this study suggest that angry faces may capture attention beyond top-down control, but minimal attentional resources are required. Some implications of these results will now be discussed.

Drawing Versus Holding Attention

In previous cuing experiments, the hypothesis that threatening stimuli hold attention was supported by the interference effect obtained under the invalid condition. However, the facilitation effect of threatening stimuli under the valid condition predicted by the drawing attention hypothesis could not be found. Based on these results, it has been proposed that negative stimuli may hold, but not draw, attention (Fox, Russo, & Dutton, 2002; Fox et al., 2001). In these studies, the threatening stimuli or neutral stimuli presented as the cues appeared abruptly. Because abrupt-onset stimuli can capture attention efficiently (Yantis & Jonides, 1984), it is possible that the failure to find a facilitation effect of a threatening valid cue was caused by a ceiling effect under the valid condition. Some ERP studies have revealed that the P1 component is enhanced in response to threatening stimuli (angry or fearful faces) compared to that of neutral faces (Pourtois, Grandjean, Sander, & Vuileumier, 2004; Santesso et al., 2008). Task-irrelevant fearful faces were also found to elicit the N2pc component, an index of attentional capture in visual search (Eimer & Kiss, 2007). In addition, a recent fMRI study by Pourtois, Schwartz, Seghier, Lazeyras, and Vuilleumier (2006) found that fearful faces can activate neural responses similar to those activated by exogenous cues. All of these results are consistent with rapid spatial orienting toward threatening stimuli. Therefore, it is still possible that threatening stimuli could draw attention at an early stage.

In this study, the facilitation effect of a task-irrelevant angry face as the target face was observed. This facilitation effect can be regarded as preliminary evidence to support the attention-drawing effect of angry faces. Despite that, it is difficult to decompose the contributions of the engagement and disengagement components of attention in visual search tasks. Because there is no need to disengage from the angry face when it is the target face, it is reasonable to assume that easy engagement with the angry face (i.e., drawing attention) contributes to the facilitation effect. On the other hand, the interference effect of the angry face distractor demonstrates that an angry face can hold attention to a greater degree than a happy face. Hence, based on the results obtained in this study, it can be tentatively proposed that angry faces may both draw and hold attention.

Degree of Automaticity

Many studies using physiological measures have shown that threatening stimuli, such as angry faces, may be processed automatically and without conscious awareness. For instance, individuals can be conditioned to elicit higher levels of skin conductance responses (SCR) to masked angry faces that cannot be perceived consciously (Esteves, Dimberg, & Öhman, 1994; Parra, Esteves, Flykt, & Öhman, 1997). In addition, a masked conditioned angry face was found to elicit a larger positron emission tomography (PET) response in the right amygdala (Morris, Öhman, & Dolan, 1998). Relevant evidence also can be found in Öhman (2002) and Lundqvist & Öhman (2005). In contrast, the results of behavioral studies are inconsistent. Although there is some evidence that subliminal threatening stimuli may affect task performance (e.g., Mogg & Bradley, 1999), other studies have failed to replicate this effect (e.g., Koster, Verschuere, Burssens, Custers, & Crombez, 2007).

The notion that automatic processing must be able to operate on a nonconscious level is a strong version of automaticity (Pessoa, 2005). Some alternative definitions of automaticity differ from this view. For instance, Tzelgov (1997) proposed that automaticity is not equal to the absence of consciousness and must be differentiated. In the present study, a weaker version known as the intentionality criterion of automaticity in attention studies is discussed (Neumann, 1984). The critical question is whether the effect can be obtained beyond the intention of the person. In this vein, the results of the present study showed that a task-irrelevant angry face can influence attention beyond top-down intentional control. Therefore, the attentional capture effect of angry faces can satisfy the intentionality criterion of automaticity.

This result is consistent with other studies demonstrating that emotional stimuli can have an effect beyond top-down control. For example, emotional faces have been found to predominate in binocular rivalry, which is known to involve a low-level process that is difficult to control intentionally (Alpers & Gerdes, 2007). Another paradigm also involving binocular rivalry showed that fearful faces can overcome suppression and enter into awareness more easily (Yang, Zald, & Blake, 2007).

Attentional Resources Required

Some previous studies have shown that unattended emotional stimuli can elicit activation of the amygdala automatically and affect task performance (e.g., Vuilleumier, Armony, Driver, & Dolan, 2001; Anderson, Christoff, Panitz, de Rosa, & Gagrieli, 2003). However, other studies using competing tasks to exhaust attentional resources have revealed that the detection of emotional faces requires attention. Task-irrelevant emotional stimuli could not influence task performance under this restricted condition (e.g., Eimer et al., 2003; Pessoa et al., 2002). Furthermore, Okon-Singer et al. (2007) systematically manipulated the task difficulty of visual search to observe the interference effect of emotional pictures that were irrelevant to the task. Their results showed that the interference effect was observed under the easier conditions, but not under the most difficult condition because of its high demands. Similar results can also be found in the behavioral study of Erthal et al. (2005) and the fMRI study of Pessoa, Padmala, and Morland (2005) using a bar-orientation task.

In the present study, the focus of spatial attention was manipulated instead of the attentional load. It was found that the interference effect of the angry face was reduced when it was presented outside rather than inside an attended area. In other words, although an angry face can capture attention beyond top-down control in a distributed attention condition with sufficient resources (such as in Experiments 1 and 2), it may not capture attention if the attention is guided away from it under a focal attention condition such that the resources were restricted (Experiment 3). This result implies that some minimal attentional resources are needed for an angry face to be detected and to capture attention, and this result is consistent with previous findings, such as those of Okon-Singer et al. (2007).

In conclusion, a task-irrelevant angry face may capture attention beyond top-down control in visual search. However, some minimal attentional resources allocated to the angry face were required for this effect to occur. Further research will be needed to study how the attention allocation affects the processing and attentional capture effects of threatening stimuli.

References

Alpers, G. W., & Gerdes, A. B. M. (2007). Here is looking at you: Emotional faces predominate in binocular rivalry. *Emotion, 7(3),* 495–506. doi:10.1037/1528–3542.7.3.495

Anderson, A. K., Christoff, K., Panitz, D., De Rosa, E., & Gabrieli, J. D. E. (2003). Neural correlates of the automatic processing of threat facial signals. *Journal of Neuroscience, 23,* 5627–5633. Retrieved from http://www.jneurosci.org

Armony, J. L., & LeDoux, J. E. (2000). How danger is encoded: Toward a systems, cellular, and computational understanding of cognitive-emotional interactions in fear. In M. S. Gazzaniga (Ed.), *The New Cognitive Neurosciences* (pp. 1067–1079). Cambridge, MA: MIT Press.

Eastwood, J. D., Smilek, D., & Merikle, P. M. (2001). Differential attentional guidance by unattended faces expressing positive and negative emotion. *Perception & Psychophysics, 63*(6), 1004–1013. Retrieved from http://app.psychonomic-journals.org

Eastwood, J. D., Smilek, D., & Merikle, P. M. (2003). Negative facial expression captures attention and disrupt performance. *Perception & Psychophysics, 65(3),* 352–358. Retrieved from http://app.psychonomic-journals.org

Eimer, M., Holmes, A., & McGlone, F. P. (2003). The role of spatial attention in the processing of facial expression: An ERP study of rapid brain responses to six basic emotions. *Cognitive, Affective, & Behavioral Neuroscience, 3*(2), 97–110. doi:10.3758/CABN.3.2.97

Eimer, M., & Kiss, M. (2007). Attentional capture by task-irrelevant fearful faces is revealed by the N2pc component. *Biological Psychology, 74,* 108–112. doi:10.1016/j.biopsycho.2006.06.008

Erthal, F. S., de Oliveira, L., Mocaiber, I., Pereira, M. G., Machado-Pinheiro, W., Volchan, E., & Pessoa, L. (2005). Load-dependent modulation of affective picture processing. *Cognitive, Affective, & Behavioral Neuroscience, 5*(4), 388–395. doi:10.3758/CABN.5.4.388

Esteves, F., Dimberg, U., & Öhman, A. (1994). Automatically elicited fear: Conditioned skin conductance responses to masked facial expressions. *Cognition and Emotion, 8,* 393–413. doi:10.1080/02699939408408949

Fox, E., Lester, V., Russo, R., Bowles, R. J., Pichler, A., & Dutton, K. (2000). Facial expressions of emotion: Are angry faces detected more efficiently? *Cognition and Emotion, 14*(1), 61–92. doi:10.1080/026999300378996

Fox, E., Russo, R., Bowles, R., & Dutton, K. (2001). Do threatening stimuli draw or hold visual attention in subclinical anxiety? *Journal of Experimental Psychology: General, 130*(4), 681–700. doi:10.1037/0096–3445.130.4.681

Fox, E., Russo, R., & Dutton, K. (2002). Attentional bias for threat: Evidence for delayed disengagement from emotional faces. *Cognition and Emotion, 16,* 355–379. doi:10.1080/02699930143000527

Holmes, A., Vuileumier, P., & Eimer, M. (2003). The processing of emotional facial expression is gated by spatial attention: Evidence from event-related brain potentials. *Cognitive Brain Research, 16,* 174–184. doi:10.1016/S0926-6410(02)00268–9

Koshino, H., Warner, C. B., & Juola, J. F. (1992). Relative effectiveness of central, peripheral, and abrupt-onset cues in visual search. *Quarterly Journal of Experimental Psychology, 45*A, 609–631. doi:10.1080/14640749208401335

Koster, E. H. W., Verschuere, B., Burssens, B., Custers, R., & Crombez, G. (2007). Attention for emotional faces under restricted awareness revisited: Do emotional faces automatically attract attention? *Emotion, 7,* 285–295. doi:10.1037/1528–3542.7.2.285

Lundqvist, D., & Öhman, A. (2005). Caught by the evil eye. Nonconscious information processing, emotion, and attention to facial stimuli. In L. F. Barrett, P. M. Niedenthal, & P. Winkielman (Eds.), *Emotion and consciousness* (pp. 97–122). New York, NY: Guilford Press.

Mogg, K., & Bradley, B. P. (1999). Orienting of attention to threatening facial expressions presented under conditions of restricted awareness. *Cognition and Emotion, 13*(6), 713–740. doi:10.1080/026999399379050

Morris, J. S., Öhman, A., & Dolan, R. J. (1998). Conscious and unconscious emotional learning in the human amygdala. *Nature, 393,* 467–470.

Neumann, O. (1984). Automatic processing: A Review of recent findings and a plea for an old theory. In W. Prinz, & A. F. Sanders (Eds.), *Cognition and automatic processing* (pp. 255–293). Berlin: Springer-Verlag.

Öhman, A. (2002). Automaticity and the amygdala: Nonconscious responses to emotional faces. *Current Directions in Psychological Science, 11,* 62–66. doi:10.1111/1467–8721.00169

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General, 130*(3), 466–478. doi:10.1037/0096–3445.130.3.466

Öhman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review, 108*(3), 483–522. doi:10.1037/0033-295X.108.3.483

Okon-Singer, H., Tzelgov, J., & Henik, A. (2007). Distinguishing between automaticity and attention in the processing of emotionally significant stimuli. *Emotion, 7*(1), 147–157. doi:10.1037/1528–3542.7.1.147

Parra, C., Esteves, F., Flykt, A., & Öhman, A. (1997). Pavlovian conditioning to social stimuli: Backward masking and the dissociation of implicit and explicit cognitive processes. *European Psychologist, 2,* 106–117. doi:10.1037/1016–9040.2.2.106

Pessoa, L. (2005). To what extent are emotional visual stimuli processed without attention and awareness? *Current Opinion in Neurology, 15,* 188–196. doi:10.1016/j.conb.2005.03.002

Pessoa, L., McKenna, M., Gutierrez, E., & Ungerleider, L. G. (2002). Neutral processing of emotional faces requires attention. *Proceedings of the National Academy of Science of the United States of America, 99*(17), 11458–11463. doi:10.1073/pnas.172403899

Pessoa, L., Padmala, S., & Morland, T. (2005). Fate of unattended fearful faces in the amygdala is determined by both attentional resources and cognitive modulation. *NeuroImage 28*(1), 249–255. doi:10.1016/j.neuroimage.2005.05.048

Pourtois, G., Grandjean, D., Sander, D., & Vuilleumier, P. (2004). Electrophysiological correlates of rapid spatial orienting towards fearful faces. *Cerebral Cortex, 14,* 619–633. doi:10.1093/cercor/bhh023

Pourtois, G., Schwartz, G., Seghier, M. L., Lazeyras, F., & Vuilleumier, P. (2006). Neural systems for orienting attention to the location of threat signals: An event-related fMRI study. *NeuroImage, 31,* 920–933. doi:10.1016/j.neuroimage.2005.12.034

Santesso, D. L., Meuret, A. E., Hofmann, S. G., Mueller, E. M., Ratner, K. G., Roesch, E. B., & Pizzagalli, D. A. (2008). Electrophysiological correlates of spatial orienting towards angry faces: A source localization study. *Neuropsychologia, 46,* 1338–1348. doi:10.1016/j.neuropsychologia.2007.12.013

Schreij, D., Owens, C., & Theeuwes, J. (2008). Abrupt onsets capture attention independent of top-down control settings. *Perception and Psychophysics, 70*(2), 208–218. doi:10.3758/PP.70.2.208

Stigchel, S. V. D., Belopolsky, A. V., Peters, J. C., Wijnen, J. G., Meeter, M., & Theeuwes, J. (2009). The limits of top-down control of visual attention. *Acta Psychologica, 132*(3), 201–212. doi:10.1016/j.actpsy.2009.07.001

Theeuwes, J. (2004). Top-down search strategies cannot override attentional capture. *Psychonomic Bulletin & Review, 11,* 65–70. Retrieved from http://pbr.psychonomic-journals.org

Todd, J. T., & van Gelder, P. (1979). Implications of a transient-sustained dichotomy for the measurement of human performance. *Journal of Experimental Psychology: Human Perception and Performance, 5,* 625–638. doi:10.1037/0096–1523.5.4.625

Tzelgov, J. (1997). Specifying the relations between automaticity and consciousness: A theoretical note. *Consciousness and Cognition, 6,* 441–451. doi:10.1006/ccog.1997.0303

Vuilleumier, P., Armony, J. L., Driver, J., & Dolan, R. J. (2001). Effects of attention and emotion on face processing in the human brain: An event-related fMRI study. *Neuron, 30*(3), 829–841. doi:10.1016/S0896-6273(01)00328–2

Yang, E., Zald, D. H., & Blake, R. (2007). Fearful expressions gain preferential access to awareness during continuous flash suppression. *Emotion, 7*(4), 882–886. doi:10.1037/1528–3542.7.4.882

Yantis, S., & Jonides, J. (1984). Abrupt visual onsets and selective attention: Evidence from visual search. *Journal of Experimental Psychology: Human Perception and Performance, 10,* 601–621. doi:10.1037/0096–1523.10.5.601

Yantis, S., & Jonides, J. (1990). Abrupt visual onsets and selective attention: Voluntary versus automatic allocation. *Journal of Experimental Psychology: Human Perception and Performance, 16,* 121–134. doi:10.1037/0096–1523.16.1.121

Received December 15, 2009
Revision received July 28, 2010
Accepted August 12, 2010 ■