Research Report

Attentional Inhibition Has Social-Emotional Consequences for Unfamiliar Faces

Mark J. Fenske,[1] Jane E. Raymond,[2] Klaus Kessler,[3] Nikki Westoby,[2] and Steven P. Tipper[2]

[1]Harvard Medical School; [2]University of Wales Bangor, Bangor, Wales, United Kingdom; and [3]Heinrich Heine University Düsseldorf, Düsseldorf, Germany

ABSTRACT—*Visual attention studies often rely on response time measures to show the impact of attentional facilitation and inhibition. Here we extend the investigation of the effects of attention on behavior and show that prior attentional states associated with unfamiliar faces can influence subsequent social-emotional judgments about those faces. Participants were shown pairs of face images and were asked to withhold a response if a transparent stop-signal cue appeared over one of the faces. This served to associate the cued face with an inhibitory state. Later, when asked to make social-emotional choices about these face pairs, participants chose uncued faces more often than cued faces as "more trustworthy" and chose cued faces more often than uncued faces as "less trustworthy." For perceptual choices, there was no effect of how the question was framed (which face is "on a lighter background" vs. "on a darker background"). These results suggest that attentional inhibition can be associated with socially relevant stimuli, such as faces, and can have specific, deleterious effects on social-emotional judgments.*

A number of visual attention studies have demonstrated that the time needed to identify a stimulus (or discriminate its location, color, etc.) can depend on the task relevance of prior events. Some events, such as the presentation of a cue indicating a forthcoming target's location, speed responding (Posner, 1980). Other events slow responding. For example, when attention is drawn to the location of an uninformative cue (and then withdrawn), responses to subsequent stimuli are slower if they appear at that location than if they appear elsewhere (Posner & Cohen, 1984). Neural mechanisms that speed or otherwise enhance processing of task-relevant information and those that suppress processing of task-irrelevant information (for review, see Kastner & Ungerleider, 2000) are thought to subserve attentional facilitation and inhibition processes, respectively.

Although contributing greatly to the empirical basis for the construct of attention, response time (RT) effects are relatively small (often measured in tens of milliseconds). They seem unlikely to be the only, or even the main, behavioral consequence of a system that involves a large parallel network of brain areas (e.g., Posner & Petersen, 1990). Indeed, other work has shown that attention can alter visual sensitivity (Raymond, O'Donnell, & Tipper, 1998), spatial resolution (Yeshurun & Carrasco, 1998), and even memory for visual events (Kessler & Tipper, 2004). Here we expand the search for the effects of attention by exploring whether attention can also modify emotional response; specifically, we report a study in which we investigated whether attentional inhibition activated at one point in time can influence social-emotional appraisal of faces seen later on.

There are two reasons why we thought this influence might occur. First, neuroanatomical and neuroimaging evidence suggests that the brain systems subserving emotion and attention are connected and can be activated in common (Amaral & Price, 1984; Armony & Dolan, 2002; Bush, Luu, & Posner, 2000; Vuilleumier, Armony, Driver, & Dolan, 2001; Yamasaki, LaBar, & McCarthy, 2002). These links provide biological plausibility for our expectation that attention can influence later emotional behavior. Second, two previous studies have shown that prior attention can modulate subjective emotional appraisal of abstract stimuli (Fenske, Raymond, & Kunar, 2004; Raymond, Fenske, & Tavassoli, 2003). In the study by Raymond et al., for

Address correspondence to Mark J. Fenske, MGH Martinos Center for Biomedical Imaging, Harvard Medical School, 149 Thirteenth St., Room 2301, Charlestown, MA 02129; e-mail: fenske@nmr.mgh.harvard.edu.

example, participants evaluated the cheerfulness or dreariness of colorful abstract images they had just viewed in a simple visual search task. The interesting result was that images seen as distractors in the search task were rated more negatively than novel images or images seen as targets. Ratings of previous targets were no different from ratings of novel stimuli. This pattern of results specifically suggests that inhibitory, though perhaps not facilitatory, attentional processes are able to exert a persistent influence on affective responses. Using a more complex visual search paradigm, Fenske et al. obtained additional evidence that attentional inhibition influences emotional appraisal of abstract stimuli.

Central to the inhibitory explanation for the effect of attention on emotion is the idea that an attentional state, such as inhibition, can be associated with a stimulus, stored in memory, and then later reinstated in a subsequent encounter (Treisman & DeSchepper, 1996). Recently, Tipper, Grison, and Kessler (2003) provided evidence that an inhibitory attentional state produced through suppression of a response to an irrelevant sudden-onset cue can be stored in memory for a relatively long period of time. In their task, novel faces were first associated with a stop-action cue, then followed by a filler task. Later (up to 13 min), when participants were required to detect simple targets, responses were slower to targets superimposed on previously cued faces than to targets appearing on previously viewed but uncued faces. In the present study, we asked if retention of an inhibitory state, like that evidenced by Tipper et al., could have consequences for social-emotional appraisal of associated faces.

Our study is based closely on that of Tipper et al. (2003), but instead of measuring RT for targets superimposed on previously seen faces, we assessed emotional appraisal of the perceived attributes of the faces, specifically, their apparent trustworthiness. We contrasted participants' social-emotional judgments with their perceptual judgments to assess whether the hypothetical inhibition elicited by an abrupt-onset no-go signal has a selective impact on emotional response. Participants were asked, on different trials, which of two previously seen faces was more trustworthy, which was less trustworthy, which was on a lighter background, and which was on a darker background. We predicted that evaluative choices involving face pairs seen previously with a no-go cue over one of the faces would specifically reflect the negative emotional impact of prior inhibition. If the hypothetical inhibition induced by a no-go cue affects emotional response per se, then judgments of which face is more trustworthy and judgments of which face is less trustworthy should show opposite effects; uncued (noninhibited) faces should be chosen more often than cued (inhibited) faces as being more trustworthy, and cued faces should be chosen more often than uncued faces as being less trustworthy. Moreover, if inhibition specifically affects emotional response, then judgments of which background is lighter and judgments of which background is darker should not show such opposite effects.

METHOD

Participants

Twenty-four University of Wales Bangor students (18 females; mean age = 24.3 years) with normal or corrected-to-normal vision participated in exchange for course credit or money. Informed consent was obtained.

Apparatus

A Pentium-4 computer, running E-Prime-1.0 (Schneider, Eschman, & Zuccolotto, 2002), recorded data and presented stimuli on a 55.9-cm monitor (100 Hz, 1024 × 768 resolution). The viewing distance was 70 cm.

Stimuli

Stimuli were digital color photographs (Art-Explosion 250,000, 1995). Face images (height: 7.5°) were frontal views, with neutral or smiling expressions and visible hair, neck, and eyes. Half were female and half were male. Pairs of face images, matched for sex, race, expression, age, gaze direction, and hair length and color, appeared on a black field (see Fig. 1). Filler stimuli were neutral scenes of interiors and exteriors measuring 19.8° × 14.6°.

Two types of cues were used: a transparent red or green oval for experimental trials and a single letter (*O* or *X*) for filler trials. An oval cue (height: 5.0°) was superimposed on one face of each pair; these cues were sufficiently transparent to allow the underlying face images to be seen clearly. Letter cues (height: 0.4°) were positioned 6.0° above or below the center of the display. The specific oval color used for each type of signal was counterbalanced across participants: Half saw red as a no-go signal and green as a go signal; the remaining participants saw green as a no-go signal and red as a go signal. The oval was presented over the left face in half of the displays and over the right face in the remaining displays. For filler-scene displays, the letter *X* was the no-go signal, and the letter *O* was the go signal.

Design and Procedure

The experiment, approximately 45 min long, included 12 practice and 96 experimental trials with unique face-pair displays, interleaved with displays from filler trials with unique scenes. Each trial consisted of a cue sequence of events and a subsequent evaluation sequence of events. Experimental and filler trials partially overlapped such that each experimental-trial cue sequence was immediately followed by a filler-trial cue sequence, then an experimental-trial evaluation sequence, and finally a filler-trial evaluation sequence (see Fig. 1). To begin a trial, the participant pressed a "start" key, and a 500-ms fixation cross appeared, followed by a face pair (experimental trials) or a scene (filler trials) for 1,000 ms. A 200-ms cue (an oval for faces, a letter for scenes) was then superimposed on the display. The

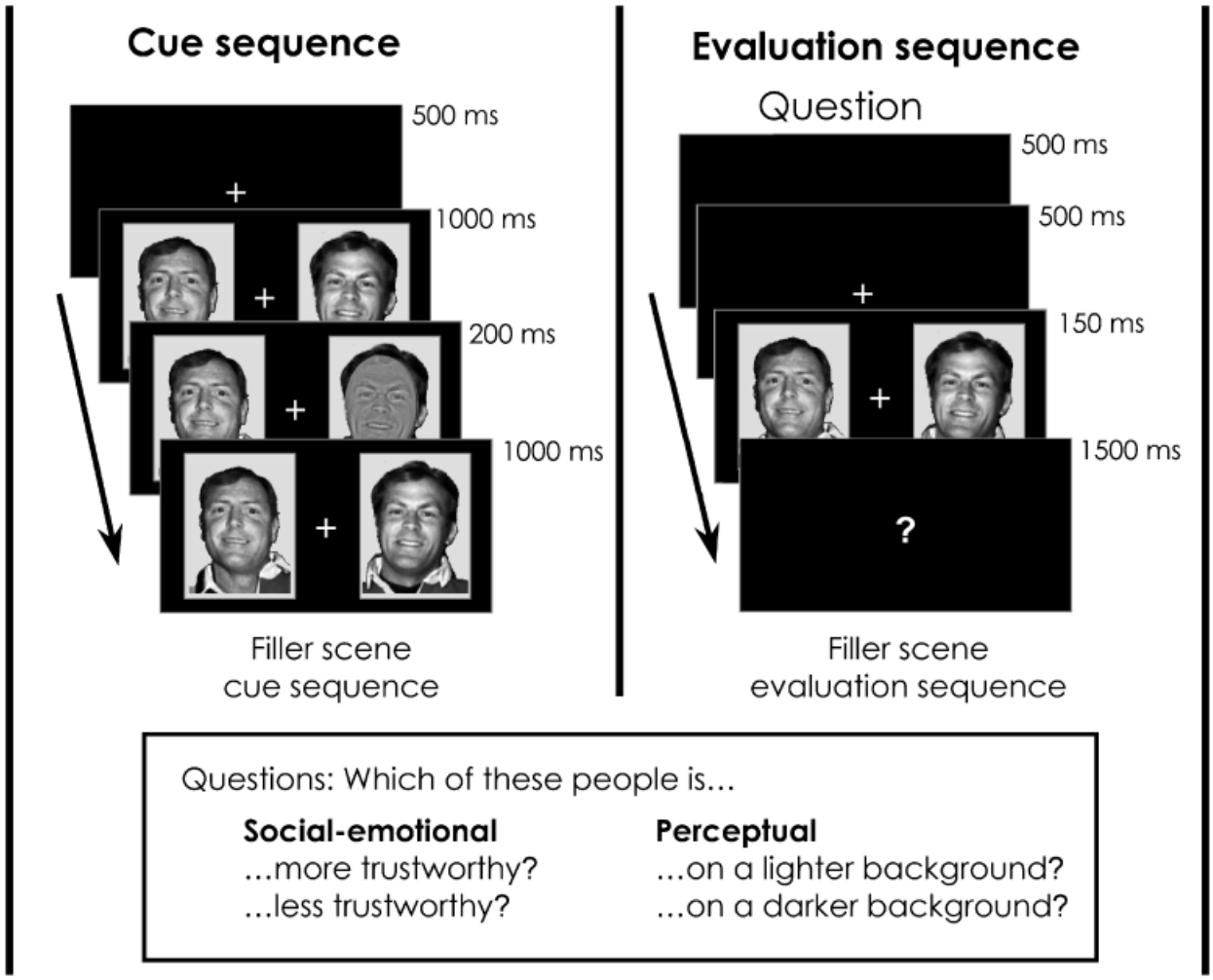

Fig. 1. Examples of stimulus displays and the order of events in the cue and evaluation sequences of experimental trials. All stimuli were presented in full color in the experiment. Each experimental-trial cue sequence was followed by a filler-trial cue sequence, the corresponding experimental-trial evaluation sequence, and finally a filler-trial evaluation sequence. During experimental-trial cue sequences, a red or green oval cue (depicted here in gray) appeared over one face in the pair; this cue was sufficiently transparent to allow the underlying face image to be seen clearly. The question asked in each experimental-trial evaluation sequence was selected from the set of questions shown at the bottom of the figure.

original display remained visible for an additional 1,000 ms, followed by a 500-ms blank interval.

When the cue was a no-go signal, participants were required to refrain from pressing any key. For a go signal, participants were required to quickly press a number-pad key with the index finger of each hand ("4" and "6" for experimental trials, "8" and "2" for filler trials). Auditory feedback was provided for correct and incorrect responses. Two thirds of trials were no-go trials, and one third were go trials. Each cue type appeared equally often on the left and right face in experimental trials and above and below fixation on filler trials. For each face pair, cue location and subsequent evaluation question were randomly determined for each participant.

Evaluation sequences for experimental trials began with a display of one of four different questions, asking which person was "more trustworthy," "less trustworthy," "on a lighter background," and "on a darker background." Evaluation sequences for filler trials used four different questions, asking whether the following scene was beautiful, was indoors, might be local, or was bright. Pressing a "ready" key initiated a 500-ms blank interval and 500-ms fixation cross, followed by a 150-ms presentation of the same face pair (experimental-trial evaluation) or scene (filler-trial evaluation) just viewed in the corresponding cue sequence (approximately 9 s earlier). A central "?" prompt then appeared for 1,500 ms. For experimental-trial evaluations, choices were made during this time by pressing the "4" ("left face") or "6" ("right face") key. For filler-trial evaluations, participants indicated their response using the "8" ("yes") or "2" ("no") key. If no response was made within 1,650 ms, visual feedback was given.

Data Analysis

Data from filler-trial evaluations were excluded from subsequent analysis. Experimental-trial evaluations were excluded from

analysis if the participant had responded incorrectly during the corresponding cue sequence or if the evaluation response was not made within the response interval. These criteria excluded only 2% of trials.

Choice scores were calculated from the evaluation data by subtracting the proportion of chosen faces previously superimposed with a cue from the proportion not associated with a cue. Positive scores on this index indicate a tendency to select the cued face; negative scores indicate a tendency to select the other, uncued, face. A separate choice score was calculated for each participant and each question following no-go trials and following go trials. Averaged choice scores were submitted to one-group t tests. Differences among choice scores for social-emotional and perceptual questions were assessed using one-way repeated measures analyses of variance.

RESULTS

The novel and important finding of our experiment is that on no-go trials, the tendency to select a previously uncued face, rather than a cued face, depended significantly on the type of question asked, $F(3, 69) = 4.32$, $p < .01$, $\eta^2 = .158$. As can be seen in Figure 2, following a no-go cue sequence, there was an overall bias against choosing the previously cued face for three of the questions, $t(23) = -3.71$, $p < .01$. This suggests that the presentation of a no-go cue on a task-irrelevant object generally produces avoidance of that object, a result that nicely mirrors the slowed RTs Tipper et al. (2003) reported for detection of targets presented on faces previously associated with a no-go cue. In contrast, the average choice score for go trials did not differ from 0, $t(23) = 0.551$, $p > .1$, and was not affected by the question asked, $F(3, 69) < 1$, $\eta^2 = .022$, indicating no effect of go cues on choice. These results suggest that it was not the presentation of a cue per se that produced the bias against cued faces on no-go trials.

A remarkable feature of our results is that on no-go trials, the effect of question valence was different for perceptual versus social-emotional questions. Figure 2 shows that the two perceptual questions ("which background is lighter?" "which background is darker?") produced the same marginal bias, $t(23) = -2.03$, $p < .06$, toward the uncued face. This appears to be a general response bias, because a consideration of the two questions' meanings shows that there is no evidence of a "true" perceptual bias. That is, the percentage of uncued faces that were chosen as having a lighter background (53%) was the same as the percentage of uncued faces (53%) that were chosen as having the darker background, suggesting that the no-go cues produced no systematic effect on the perception of lightness in the face pictures, but did produce a modest response bias (away from the cued image).

This pattern is in stark contrast to that observed for the oppositely phrased emotional questions. When participants were asked to choose the more trustworthy face, the uncued face was chosen 57% of the time. This effect marginally exceeded the response bias estimated from the choice-score data for the two perceptual questions combined, $F(1, 23) = 3.30$, $p < .09$, $\eta^2 = .126$. In contrast, when asked to choose the less trustworthy face, participants chose the cued face 55% of the time, clearly overcoming any general response-related avoidance of the cued face. The qualitative difference in the choice scores for the two emotional questions, in combination with the significance of this difference, $F(1, 23) = 12.06$, $p < .01$, $\eta^2 = .344$, clearly shows that the no-go cues produced a social-emotional avoidance of the previously cued face. This avoidance cannot be attributed to simple color preferences or to learned associations between the overlay color and an affective response (e.g., red = "avoid" or "do not trust"), because the different colors of no-go cues were counterbalanced across participants. A mixed-factors analysis of variance confirmed that cue color (red vs. green no-go cues) had no reliable effects on the tendency to choose cued or uncued faces in response to any question (all Fs < 1).

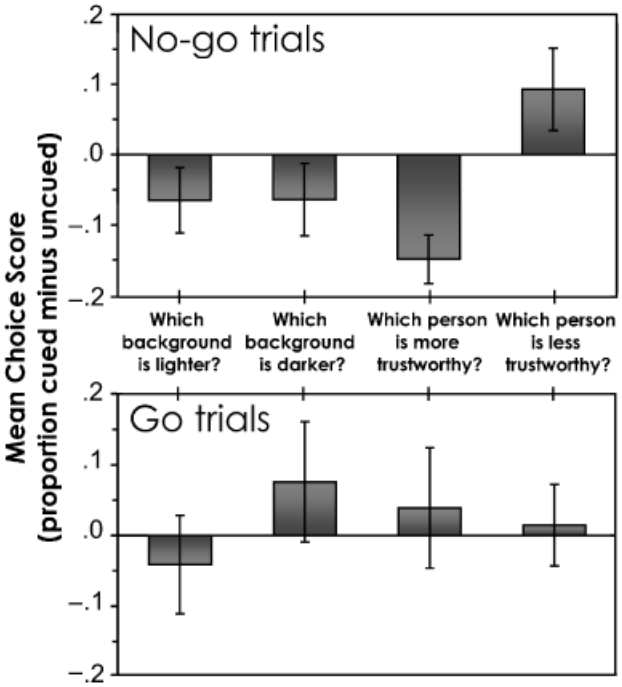

Fig. 2. Mean choice scores (the proportion of cued faces chosen minus the proportion of uncued faces chosen) for each question in the experimental trials. Scores above zero indicate a tendency to select the cued face; scores below zero indicate a tendency to select the uncued face. Results for no-go trials are shown in the top panel, and results for go trials are shown in the bottom panel. Error bars represent standard errors of the means.

DISCUSSION

The principal finding of this study is that the inhibition of a simple action evoked by a sudden-onset cue can later influence an evaluative judgment concerning an irrelevant stimulus that

was present at the same time and place as the cue. We found that no-go cues produce a modest response bias to choose an alternative to the cue-associated stimulus, a result that is consistent with findings of slowed RTs to targets associated with no-go cues (Tipper et al., 2003). Kessler and Tipper (2004) observed a similar bias in their study of memory effects of prior inhibition; participants were more likely to report that a no-go cue had been presented over the face that had, in fact, not been cued than to report that a no-go cue had been presented over the face that had been cued. However, the particularly remarkable finding in the present study is that no-go cues have a substantial negative impact on social-emotional evaluation. They have no impact on perceptual appraisal.

These findings are important because they show that attentional mechanisms can actively influence emotional response mechanisms. Our results converge with previous demonstrations of attentional modulation of emotional appraisal of abstract patterns (Fenske et al., 2004; Raymond et al., 2003) and show that attention has important consequences for human behavior beyond the speeding or slowing of responses. Extending the demonstration of the relation between attention and emotion to situations involving the social-emotional appraisal of human faces is particularly important. Although there is substantial evidence that emotionally salient stimuli (e.g., angry faces) can attract (e.g., Eastwood, Smilek, & Merikle, 2001; Vuilleumier & Schwartz, 2001), constrict (Fenske & Eastwood, 2003), and hold (e.g., Fox, Russo, Bowles, & Dutton, 2001) the focus of attention, evidence for the reciprocal influence of attention on emotion has been lacking. Yet, given the shared responsibility of the emotion and attention systems for prioritizing response to stimuli, especially social responses to other humans, a truly reciprocal relation should exist between these two systems. The present data, in combination with the results of previous studies, evidence this clearly.

The bodily state of tensed inaction associated with an inhibited response may also contribute to the negative affect attributed to faces on which a no-go cue is superimposed, just as arm extension during stimulus presentation promotes negative evaluative responses (e.g., Cacioppo, Priester, & Berntson, 1993; Chen & Bargh, 1999). Our findings suggest that such influences can affect social-emotional response to an unfamiliar face even after a brief initial experience with it. Although future research is needed to examine the specific social ramifications of prior attentional states on human interaction, our findings suggest that such states can be associated with socially relevant stimuli and have specific, persistent effects on social-emotional judgments.

Acknowledgments—This work was supported by the Economic and Social Research Council (ROPA-R022250212 to J.E.R.) and the Biotechnology and Biological Sciences Research Council (5/S1355 to S.P.T.).

REFERENCES

Amaral, D.G., & Price, J.L. (1984). Amygdalo-cortical projections in the monkey (*Macaca fascicularis*). *Journal of Comparative Neurology*, *230*, 465–496.

Armony, J.L., & Dolan, R.J. (2002). Modulation of spatial attention by fear-conditioned stimuli: An event-related fMRI study. *Neuropsychologia*, *40*, 817–826.

Art-Explosion 250,000 [CD-ROM]. (1995). Calabasas, CA: Nova Development Corp.

Bush, G., Luu, P., & Posner, M.I. (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends in Cognitive Sciences*, *4*, 215–222.

Cacioppo, J.T., Priester, J.R., & Berntson, G.G. (1993). Rudimentary determinants of attitudes II: Arm flexion and extension have differential effects on attitudes. *Journal of Personality and Social Psychology*, *65*, 5–17.

Chen, M., & Bargh, J.A. (1999). Consequences of automatic evaluations: Immediate behavioral predispositions to approach or avoid the stimulus. *Personality and Social Psychology Bulletin*, *25*, 215–224.

Eastwood, J.D., Smilek, D., & Merikle, P.M. (2001). Differential attentional guidance by unattended faces expressing positive and negative emotion. *Perception & Psychophysics*, *63*, 1004–1013.

Fenske, M.J., & Eastwood, J.D. (2003). Modulation of focused attention by faces expressing emotion: Evidence from flanker tasks. *Emotion*, *3*, 327–343.

Fenske, M.J., Raymond, J.E., & Kunar, M.A. (2004). The affective consequences of visual attention in preview search. *Psychonomic Bulletin & Review*, *11*, 1034–1040.

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*, 681–700.

Kastner, S., & Ungerleider, L.G. (2000). Mechanisms of visual attention in the human cortex. *Annual Review of Neuroscience*, *23*, 315–341.

Kessler, K., & Tipper, S.P. (2004). Retrieval of implicit inhibitory processes: The impact of visual field, object-identity and memory dynamics. *Visual Cognition*, *11*, 965–995.

Posner, M.I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, *32*, 3–25.

Posner, M.I., & Cohen, Y. (1984). Components of visual orienting. In H. Bouma & D. Bouwhuis (Eds.), *Attention and performance X: Control of language processes* (pp. 531–556). Hillsdale, NJ: Erlbaum.

Posner, M.I., & Petersen, S.E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, *13*, 25–42.

Raymond, J.E., Fenske, M.J., & Tavassoli, N.T. (2003). Selective attention determines emotional responses to novel visual stimuli. *Psychological Science*, *14*, 537–542.

Raymond, J.E., O'Donnell, H.L., & Tipper, S.P. (1998). Priming reveals attentional modulation of human motion sensitivity. *Vision Research*, *38*, 2863–2867.

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime user's guide*. Pittsburgh, PA: Psychology Software Tools.

Tipper, S.P., Grison, S., & Kessler, K. (2003). Long-term inhibition of return of attention. *Psychological Science*, *14*, 19–25.

Treisman, A., & DeSchepper, B. (1996). Object tokens, attention, and visual memory. In T. Inui & J. McClelland (Eds.), *Attention and performance XVI: Information integration in perception and communication* (pp. 15–46). Cambridge, MA: MIT Press.

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*, 829–841.

Vuilleumier, P., & Schwartz, S. (2001). Emotional facial expressions capture attention. *Neurology*, *56*, 153–158.

Yamasaki, H., LaBar, K.S., & McCarthy, G. (2002). Dissociable prefrontal brain systems for attention and emotion. *Proceedings of the National Academy of Sciences, USA*, *99*, 11447–11451.

Yeshurun, Y., & Carrasco, M. (1998). Attention improves or impairs visual performance by enhancing spatial resolution. *Nature*, *396*, 72–75.

(RECEIVED 4/5/04; REVISION ACCEPTED 3/17/05;
FINAL MATERIALS RECEIVED 3/24/05)