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The Impact of Task-Irrelevant Emotional Stimuli on Attention in Three Domains

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Whether task-irrelevant emotional stimuli facilitate or disrupt attention performance may depend on a range of factors, such as emotion type, task difficulty, and stimulus duration. Few studies, however, have systematically examined the influence of these factors on attention performance. Sixty-three adults, scoring within a normative range for mood and anxiety symptoms, completed either an easy or difficult version of an attention task measuring three aspects of attention performance: alerting, orienting, and executive attention. Results showed that in the easy task only, threatening versus nonthreatening task-irrelevant emotional faces facilitated orienting regardless of stimulus duration. These effects were no longer significant during the difficult condition. When the easy and difficult conditions were examined together, duration effects emerged such that stimuli of longer durations lead to greater interference, although effects were nonlinear. Findings illustrate that threat-relevant emotional stimuli facilitate attention during tasks with low cognitive load, but underscore the importance of considering a range of task parameters. Results are discussed in the context of adaptive and maladaptive emotion-attention interactions.

Keywords: attention, emotions, task difficulty

Attention is biased toward the detection of emotional stimuli, in particular stimuli that are unpleasant or threat-relevant, such as fearful or angry faces (Bannerman, Milders, & Sahraie, 2010; Lipp, Price, & Tellegen, 2009; Mogg, Garner, & Bradley, 2007; Pinkham, Gribbin, Baron, Sasson, & Gur, 2010). This enhancement of attention occurs at extremely early stages of visual processing (Phelps, Ling, & Carrasco, 2006) and does not require conscious awareness (Marcos & Redondo, 2005). Such biasing of attention toward threat is thought to promote evolutionarily adaptive behavior that increases the likelihood of survival (LoBue, 2010). For example, this bias could enhance the ability to attend to and respond quickly and effectively to threat.

Experimental evidence supports this idea—the detection of targets is faster when the target appears in the location of threatening versus nonthreatening stimuli (Bradley, Mogg, Falla, & Hamilton, 1998; Koster, Crombez, Verschuere, & De Houwer, 2006; MacLeod, Mathews, & Tata, 1986; Mogg & Bradley, 1998), and the presence of threat stimuli (i.e., target angry faces) improves the ability to ignore task-irrelevant distracters (Fenske & Eastwood, 2003). However, other research has suggested that multiple domains of attention are disrupted by threat, perhaps because processing is hindered for all stimuli other than the threat itself. For example, relatively controlled and top-down executive attention performance is disrupted by the presence of unpleasant emotional stimuli (Schimmack & Derryberry, 2005). Disruptions also occur at the level of relatively automatic and bottom-up attention performance, such as reduced alerting efficiency following task-irrelevant fearful versus neutral faces (Dennis, Chen, & McCandliss, 2008). The goal of the current study was to examine the boundary conditions under which emotional stimuli (faces) facilitate or disrupt attention performance in multiple domains, varying from relatively automatic alerting to relatively controlled executive attention.

One important factor that could influence whether threat facilitates or disrupts attention performance is whether the stimulus is task relevant or task-irrelevant. In cases when emotional stimuli are task relevant, a bias toward processing threat could lead to emotional processing being prioritized over attention performance when there is competition between the two stimuli (Easterbrook, 1959; Hanoch & Vitouch, 2004; Meinhardt & Pekrun, 2003)—thus threat would disrupt attention. However, if stimuli are task irrelevant and presented prior to the target task, direct competition would be lessened, and thus interference may be reduced. Further-

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more, emotional stimuli with significant "motivational intensity"—like threat stimuli—heighten attentional focusing (Gable & Harmon-Jones, 2008, 2010a, 2010b) and thus might actually facilitate subsequent attention performance. This ideas is consistent with the dual competition framework (Pessoa, 2009), which posits that mildly threatening emotional stimuli (e.g., task-irrelevant angry faces) should bolster subsequent attention performance because such stimuli are ambiguous, and thus trigger a vigilant "information gathering" mode. This possibility has important theoretical and practical implications. In real-life situations, threat is often perceived as being external and irrelevant to a current task or activity. For example, while working on your computer, you stop to glance out the window and see an emergency vehicle racing down the street with sirens blaring. The empirical literature is inconclusive about whether this threat-relevant information, that is independent of your current task, would facilitate or disrupt your ability to subsequently attend to your computer work.

Indeed, research findings are mixed as to whether task-irrelevant emotional stimuli facilitate or interfere with attention performance. For example, in several studies, researchers have used a modified version of the Attention Network Test (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002) to examine whether task-irrelevant emotional stimuli (i.e., faces) influence the efficiency of three aspects of attention: alerting (achieving and maintaining a state of awareness that facilitates readiness for action), orienting (the ability to engage, disengage, and shift attention from one spatial location to another), and executive attention (the ability to resolve conflict among competing response options; Fan, McCandliss, Fosella, Flombaum, & Posner, 2005; Fan et al., 2002). In each study, researchers presented emotional faces very briefly (50 ms) before each trial of the ANT. In one study, Dennis et al. (2008) found that executive attention was disrupted following fearful versus neutral faces but only for people showing low levels of state anxiety; alerting and orienting were unaffected. However, in other studies, it was found that orienting and executive attention were enhanced following fearful and sad compared to neutral faces (Dennis & Chen, 2007a), and that executive attention was enhanced following sad compared to fearful and happy faces (Dennis & Chen, 2007b). A study from another lab found that executive attention performance improved following presentation of fear-evoking stimuli—but only for those with relatively high state anxiety (Finucane & Power, 2010). Thus, these studies documented both interference and facilitation of attention by task-irrelevant emotional stimuli.

Methodological differences among the studies, however, make comparisons difficult. For example, each of these studies compared distinct types of emotional faces and stimuli, and primarily presented stimuli for very brief durations (50 ms). In addition, only one of the studies used a block design in which one face type was presented per block (Dennis & Chen, 2007b); other studies presented multiple types of faces within a given block of trials, perhaps leading to contamination of emotion effects across trials (e.g., Dennis et al., 2008). Also, participants in these studies showed significant variability in state anxiety, which could have influenced the impact of emotional faces on attention (Egloff & Hock, 2001). To our knowledge, no studies have systematically compared how threat, nonthreat, and neutral task-irrelevant faces of different durations influence attention performance in multiple domains of attention in a sample of adults not showing elevated state or trait anxiety. That was the goal of the current study.

To systematically examine the impact of task-irrelevant emotional stimuli on attention, the duration of the stimulus must be considered. Stimuli that are presented for longer durations may be processed more and be perceived as more motivationally significant (Hajcak, Dunning, & Foti, 2009), and thus tax attentional resources (and compromise attention performance) more than briefly presented stimuli. However, one study (Bradley et al., 1998) using a dot probe task found that when threat compared to happy faces were presented as cues prior to the target probe, performance differences between high and low trait anxiety participants only emerged at the shorter cue duration (500 ms vs. 1,250 ms). Thus, although we expect that longer durations would lead to greater interference, the effects of duration may not be linear.

Another factor that might influence the effects of task-irrelevant emotional stimuli on attention is task difficulty. For example, several studies have documented enhanced amygdala responses to task-irrelevant fearful compared to happy and neutral faces, but that such biased processing of threat is diminished when concurrent task difficulty increases (Pessoa, McKenna, Gutierrez, & Ungerleider, 2002; Pessoa, Padmala, & Morland, 2005). Taken together, these studies suggest that attentional resources may be preferentially allocated to threat-relevant distracters during an easy task, but redistributed to focus on the task when difficulty is increased, thus reducing attention interference. Thus, although in the current study, emotional stimuli were not distracters (that is, they were not presented simultaneously with the target task), these findings suggest that there may be reduced interference effects in the difficult versus easy task condition.

To address an important gap in our current understanding of how task-irrelevant emotional stimuli, in particular threat-relevant faces, influence attention performance in multiple domains, the current study included a normative sample of adults, screened for elevated symptoms of anxiety or depression, to examine how five different types of faces (four emotional faces and neutral faces) varying in duration influenced attention performance in three domains: alerting, orienting, and executive attention. Threat (angry and fearful), negative nonthreat (sad), positive nonthreat (happy), and neutral faces were presented for five durations ranging from brief (50 ms) to prolonged (1,000 ms). In addition, to examine whether task difficulty reduced the effects of task-irrelevant emotional stimuli on attention, we included both an easy and difficult task condition.

Although previous research has suggested that threat stimuli may have a particularly robust influence on attention, findings are inconclusive in terms of whether threat-relevant faces facilitate or disrupt attention and whether effects differ across domains of attention. Thus, the first exploratory hypothesis was that, in this normative sample of adults, angry and fearful faces will facilitate attention compared to neutral and happy faces. We explore whether these effects are most robust for orienting and executive attention, give previous findings (e.g., Dennis & Chen, 2007a; Finucane & Power, 2010). The second hypothesis was that the effect of task-irrelevant emotional stimuli on attention performance will be increased when stimuli are presented for a longer duration. The third hypothesis was that the effects of these stimuli on attention will be absent when task difficulty is high.

Method

Participants

Participants were 102 nondisordered adults recruited through the psychology participant research pool at Hunter College in New York City. To achieve a normative sample, five participants were excluded from analyses due to elevated scores (greater than or equal to 29) on the Beck Depression Inventory (BDI; Beck, Steer, & Brown, 1996) or a score greater than three standard deviations of the college norm on the State–Trait Anxiety Inventory (STAI; Spielberger, 1983). Each combination of parameters in the attention task appeared four times; 22 participants were excluded for having one or less of each trial type due to errors and outliers. Twelve participants refused to complete the experiment due to fatigue and an additional five participants were lost due to computer malfunction. The final sample consisted of 63 participants (46 women), with ages ranging from 18 to 46 years ($M = 21.14$, $SD = 5.19$). The mean BDI score was 11.79 ($SD = 7.26$) and the mean trait STAI score was 42.76 ($SD = 10.13$). Self-reported race/ethnicity was as follows: 14 White, 10 Hispanic, 31 Asian or Pacific Islander, 5 African American, and 3 of other races/ethnicities.

Procedure and Measures

Participants spent approximately two hours in the laboratory. Prior to beginning the attention task, participants completed questionnaires to screen for mood disruptions: The STAI is a 40-item questionnaire that measures participants' perceptions of their current state and general level of nervousness, anxiety, and shyness (Spielberger, 1983); the BDI is a 21-item questionnaire that asks participants to assess their experience of depressive symptoms over the past 2 weeks (Beck et al., 1996). State anxiety and current positive and negative affect (PANAS; Watson, Clark, & Tellegen, 1988) were also assessed before starting the attention task and following each block of the task.

Emotional ANT (E–ANT). Stimuli were presented via E-Prime software Version 1.1 (Schneider, Eschman, & Zuccolotto, 2002) on a 17" monitor. Responses were collected via the left and right buttons on the mouse. The ANT (Fan et al., 2002) is a combination of a cued reaction time (RT) and a flanker task that requires the subject to determine whether a central arrow points to the left or right. First, one of four cue conditions are presented: no cue, double cue (appearing above and below fixation), center cue (superimposed on fixation), and spatial cue (appearing either above or below fixation. The cues signal the impending presentation (alerting) or location (orienting) of the flanker task. Participants respond to the direction (either right or left) of a central arrow that is flanked by either four arrows facing the same direction as the central arrow (congruent flankers) or four arrows facing the opposite direction as the central arrow (incongruent flankers). Comparison of RTs to the two flanker types provides a measure of conflict interference (executive attention).

The ANT generates attention efficiency scores for alerting, orienting, and executive attention (conflict interference) by assessing how RTs are affected by cues (alerting and orienting) and flankers (executive attention; Fan et al., 2002). Alerting scores compare the response to all types of flankers based on whether a cue indicating the upcoming flanker was presented or not (RT no cues—RT double cues). The double cue is used to maintain diffuse spatial attention across the two potential target locations. Higher scores indicate greater alerting efficiency due to the presentation of the double cue (faster RT when cue is given). Therefore, if a cue is present and the participant can use the cue to respond more quickly, then this provides evidence for the maintenance of an alert and vigilant state. Orienting scores compare the response to all types of flankers based on whether a cue indicating the location of the upcoming flanker was presented or not (RT center cues—RT spatial cues). Because the spatial cue necessarily involves alerting participants to the impending stimulus, the center cue was used as the comparison to similarly alert participants while maintaining fixation at the center of the screen. Higher scores indicate greater orienting efficiency due to the presentation of the spatially relevant cue (faster RT when location is indicated). Therefore, if the participant is responding more quickly to flankers that are in the location of the spatial cue, then this provides evidence for efficient shifts in spatial attention. Executive attention scores compare the response to flankers with and without interference across all cue conditions (RT incongruent flankers—RT congruent flankers). Higher scores indicate reduced executive attention efficiency or greater conflict interference. Therefore, if the participant is showing a clear RT distinction between conflict and no conflict conditions, then this provides evidence for the recruitment of executive attention.

The modified version of the ANT, the E-ANT (Dennis et al., 2008), used in the current study differs from the original ANT in that a task-irrelevant emotional face is presented prior to the beginning of each trial. Figure 1 shows components of the task: face types presented before each trial of the task (1a), cue conditions (1b), flanker conditions (1c), and the sequence of events for a single trial (1d). Each trial lasts 4,000 ms plus the duration of the emotional face. Faces were presented for 50, 100, 250, 500, or 1,000 ms. The first variable delay (D1) occurs for 600 to 1,300 ms. Cues are presented for 100 ms followed by a fixation period for 400 ms. Trials ended with a variable fixation period (based on RT and D1).

The current study used a between-subjects design in examining task difficulty (easy and difficult). For the easy task, the flanker remained on the screen until participants responded, but no longer than 1,700 ms. For the difficult task, the flanker was removed after 100 ms but participants had the remaining 1,600 ms (a fixation cross was presented) to respond. There were no other differences between the tasks.

Both the easy and difficult versions of the experiment consisted of six blocks. The first block contained 24 practice trials with feedback (percentage accuracy). Participants were told that an 80% accuracy rate was required to proceed to the experimental trials. The five remaining blocks contained 240 experimental trials each (with no feedback) and contained only one emotional face type (angry, fearful, sad, happy, or neutral). Block order was counterbalanced across participants. For a given block, the emotional face was presented randomly for all five durations (50, 100, 250, 500, 1,000 ms). Given the five stimulus durations, four cue types, and three flanker types, 240 trials per block correspond to four trials for each duration/cue/flanker combination.

Emotional face stimuli. This study included 80 black-and-white photographs of angry, fear, happy, sad, and neutral faces

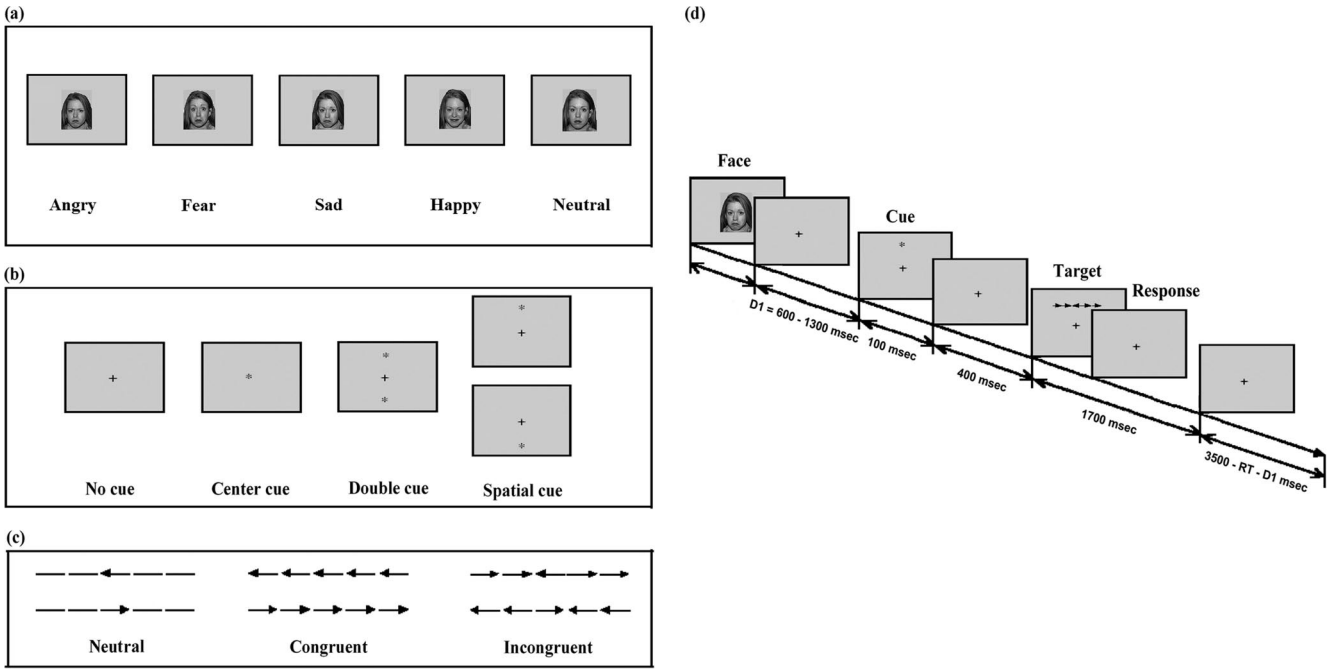

Figure 1. Sequence of events in the Emotional Attention Network Test (E-ANT). RT = reaction time; D1 = first variable delay. Faces were taken from the NimStim set (Tottenham et al., 2009). The face in the figure is not one used in the task. Please see the footnote for the list of actors used in the current study.

from 16 actors (Tottenham et al., 2009). Eight male actors and eight female actors were used, half of which were Black and the other half were White.[1] Faces were presented at the beginning of each trial in the E-ANT, and each actor's face was presented 15 times per block.

Statistical analyses were conducted using PASW General Linear Model software Verson 17 (SPSS Inc., 2009). Greenhouse–Geisser corrections were used when the sphericity assumption was violated.

Results

Descriptive Statistics

Table 1 presents the mean RTs for each cue and flanker type averaged across the two task-irrelevant emotional stimulus parameters (emotion, duration). Table 2 presents the mean and standard deviation for the three attention scores for each emotional block from the easy task. Table 3 presents the mean and standard deviation for the three attention scores for each emotional block from the difficult task.

Table 1
Means and Standard Deviations for Reaction Times

	Easy task	Difficult task
Stimulus condition	*M* (*SD*)	*M* (*SD*)
No cue	566.73 (55.13)	575.50 (55.84)
Center cue	543.98 (61.85)	542.74 (60.54)
Double cue	536.61 (57.05)	533.53 (60.64)
Spatial cue	510.38 (63.82)	493.95 (61.62)
Neutral flanker	501.94 (50.36)	504.67 (54.60)
Congruent flanker	513.59 (54.95)	511.64 (58.96)
Incongruent flanker	602.74 (73.65)	593.08 (64.47)

Note. Given in ms.

The ANT: Effects of Cue and Flanker Type

To confirm that the presence of the emotional stimuli did not alter the basic properties of the ANT, a 4 (cue: no, center, double, spatial) × 3 (flanker: neutral, congruent, incongruent) repeated-measures analysis of variance (ANOVA) was conducted on RTs, separately for the easy and difficult tasks.

For the easy task, the significant main effects of cue, $F(1.89, 54.70) = 93.98$, $p = .001$, $\varepsilon = .63$, $\eta_p^2 = .76$, and flanker, $F(1.09, 31.73) = 252.66$, $p = .001$, $\varepsilon = .55$, $\eta_p^2 = .90$, were subsumed under the significant two-way interaction between the two, $F(6, 174) = 7.37$, $p = .001$, $\eta_p^2 = .20$, all follow-up comparisons $p < .01$. Consistent with the unmodified ANT (Fan et al., 2002), RTs to all three flanker types were fastest following the spatial cue versus all other cue types and slowest following no cue versus all other cue types. Furthermore, RTs were slowest to incongruent flankers versus neutral and congruent flankers following all cue types. This pattern of RTs was the same for the difficult task, Cue × Flanker, $F(3.92, 125.45) = 10.94$, $p = .001$, $\varepsilon = .65$, $\eta_p^2 = .26$. These results confirm that the addition of task-irrelevant emotional stimuli did not fundamentally alter the task.

[1] Actor numbers: 05F, 07F, 08F, 10F, 11F, 12F, 13F, 14F, 20M, 21M, 23M, 33M, 38M, 39M, 41M, 43M.

Table 2
Means and Standard Deviations for Attention Scores From the Easy Task

Emotional face type	Alerting	Orienting	Executive attention
	M (*SD*)	*M* (*SD*)	*M* (*SD*)
Angry			
50	27.55 (41.57)	54.24 (41.19)	94.98 (56.40)
100	30.45 (43.43)	33.32 (51.51)	77.79 (48.20)
250	33.30 (52.54)	27.47 (45.82)	79.49 (40.80)
500	31.66 (48.03)	33.45 (36.52)	86.66 (51.52)
1,000	31.57 (46.01)	38.49 (49.35)	101.81 (71.93)
Fear			
50	32.30 (48.30)	35.16 (47.95)	90.28 (56.77)
100	37.93 (42.63)	39.54 (46.87)	86.38 (53.23)
250	25.15 (37.37)	37.71 (48.09)	81.40 (39.72)
500	20.06 (39.21)	45.81 (37.67)	84.71 (35.88)
1,000	21.48 (61.68)	43.76 (40.63)	99.22 (48.22)
Sad			
50	17.83 (44.61)	33.30 (38.16)	84.59 (48.72)
100	39.83 (53.40)	43.30 (46.79)	90.75 (67.74)
250	30.48 (44.36)	41.82 (47.88)	81.13 (56.45)
500	23.31 (44.35)	21.64 (43.77)	82.62 (63.98)
1,000	47.01 (50.10)	25.12 (49.39)	107.32 (51.62)
Happy			
50	16.81 (47.30)	23.43 (58.32)	96.50 (44.92)
100	31.41 (50.87)	34.91 (57.68)	99.49 (42.01)
250	32.46 (42.49)	25.58 (37.67)	89.82 (44.94)
500	27.91 (50.57)	19.59 (50.12)	81.74 (52.17)
1,000	41.84 (37.46)	28.25 (52.02)	87.96 (44.21)
Neutral			
50	21.64 (50.01)	34.33 (64.61)	82.83 (46.30)
100	31.39 (36.81)	26.64 (44.13)	96.39 (57.53)
250	22.05 (57.29)	31.51 (49.69)	89.62 (49.30)
500	47.52 (35.25)	25.94 (44.71)	88.20 (48.32)
1,000	30.09 (40.44)	29.75 (51.86)	87.08 (64.22)

Note. Given in ms.

Effects of Type and Duration of Task-Irrelevant Emotional Stimuli on Attention: Easy Task

To test predictions concerning the effects of emotion type (first hypothesis) and duration (second hypothesis) of task-irrelevant stimuli on attention we first analyzed the three attention efficiency scores for participants from the easy task only ($n = 30$), when attention would not be further taxed by the difficult task. A 5 (emotion: angry, fear, sad, happy, neutral) × 5 (duration: 50, 100, 250, 500, 1,000) repeated-measures ANOVA was conducted separately for each of the attention efficiency scores (e.g., three different repeated-measures ANOVAs for alerting, orienting, and executive attention).

Alerting. There were no significant main effects or interactions for alerting efficiency.

Orienting. The main effect of emotion on orienting was significant, $F(4, 116) = 2.60$, $p = .04$, $\eta_p^2 = .08$. Orienting efficiency was greatest following angry, $t(29) = 2.10$, $p = .04$, and fearful faces, $t(29) = 2.45$, $p = .02$, compared to happy faces (see Figure 2). There was no main effect of duration.

Executive attention. There were no significant main effects or interactions for executive attention efficiency.

In summary, findings supported predictions that attention would be facilitated for threat- versus nonthreat faces (for orienting only). However, counter to predictions no effects of duration emerged.

Effects of Task Difficulty on Attention

Next we tested whether the influence of emotional face type persisted when the task was more difficult (third hypothesis). Unlike the previous analysis, difficulty (easy and difficult) was included as a between-subjects variable in a 5 (emotion: angry, fear, sad, happy, neutral) × 5 (duration: 50, 100, 250, 500, 1,000) × 2 (difficulty: easy, difficult) repeated-measures ANOVA. We again conducted three separate repeated-measures ANOVAs for each of the attention scores: alerting, orienting, and executive attention.

Alerting. Participants in the difficult versus easy task had greater alerting efficiency, $F(1, 61) = 8.16$, $p = .006$, $\eta_p^2 = .12$ (see Figure 3). No other significant effects emerged.

Orienting. Participants in the difficult versus easy task had greater orienting efficiency $F(1, 61) = 5.13$, $p = .03$, $\eta_p^2 = .09$ (see Figure 3). No other significant effects emerged.

Executive attention. Executive attention did not differ between the two task difficulties. However, the main effect of duration was significant, $F(4, 244) = 3.98$, $p = .004$, $\eta_p^2 = .06$. Conflict interference was greatest following task-irrelevant emotional faces presented for 1,000 ms versus 50, $t(62) = -2.08$, $p = .04$; 250, $t(62) = -3.94$, $p = .001$; and versus 500 ms, $t(62) = -2.84$, $p = .006$. Conflict interference was also greater following faces presented for 100 ms versus 250 ms, $t(62) = 2.17$, $p = .03$.

Table 3
Means and Standard Deviations for Attention Scores From the Difficult Task

Emotional face type	Alerting	Orienting	Executive attention
	M (*SD*)	*M* (*SD*)	*M* (*SD*)
Angry			
50	39.41 (49.96)	52.79 (57.43)	68.11 (45.63)
100	35.79 (43.30)	39.52 (55.11)	68.16 (41.66)
250	37.30 (54.63)	60.38 (53.76)	65.11 (55.79)
500	46.55 (49.77)	32.78 (41.95)	81.41 (40.87)
1,000	51.13 (43.49)	47.77 (58.91)	85.00 (47.49)
Fear			
50	32.04 (47.97)	50.20 (59.70)	75.09 (52.04)
100	29.13 (44.57)	42.28 (39.69)	78.47 (51.51)
250	38.29 (49.78)	57.27 (55.24)	76.89 (53.69)
500	30.79 (55.99)	29.87 (49.55)	90.58 (45.67)
1,000	41.59 (44.16)	46.86 (53.36)	91.89 (47.78)
Sad			
50	44.82 (53.81)	42.08 (67.04)	85.38 (45.18)
100	33.94 (66.76)	59.29 (65.06)	101.43 (56.08)
250	41.34 (51.27)	51.21 (55.35)	69.57 (45.47)
500	54.36 (56.35)	48.34 (56.13)	66.49 (56.13)
1,000	50.57 (48.66)	60.16 (45.85)	88.92 (54.94)
Happy			
50	44.29 (58.42)	53.99 (46.24)	84.65 (46.92)
100	27.27 (66.42)	67.65 (55.14)	78.63 (52.63)
250	45.84 (48.55)	43.76 (62.38)	79.36 (49.91)
500	39.07 (50.05)	52.17 (48.75)	88.59 (51.20)
1,000	48.81 (50.98)	39.94 (43.25)	93.74 (43.66)
Neutral			
50	51.23 (55.85)	45.90 (49.86)	79.66 (46.35)
100	40.53 (44.81)	58.79 (61.46)	96.27 (54.60)
250	50.07 (50.87)	40.04 (54.78)	80.17 (45.32)
500	47.89 (46.01)	47.10 (37.08)	84.06 (52.71)
1,000	47.06 (33.87)	48.23 (49.75)	77.92 (54.22)

Note. Given in ms.

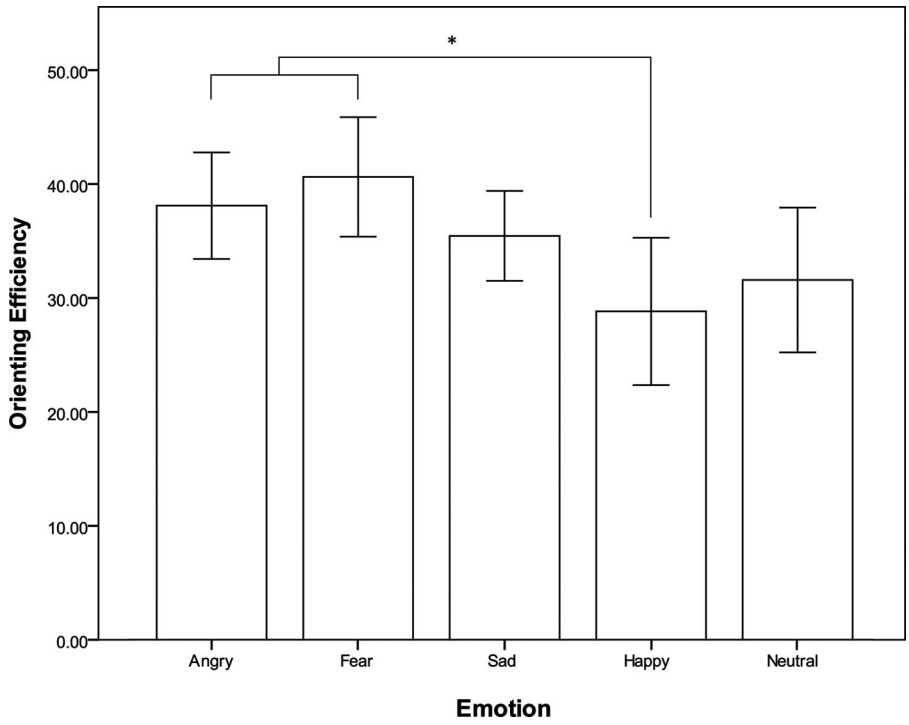

Figure 2. Orienting efficiency was facilitated following threatening faces (angry, fearful) versus happy faces for participants in the easy task. Bars represent means of orienting efficiency scores (RT center cues—RT spatial cues) and error bars represent 95% confidence intervals. RT = reaction time. $^{*}p < .05$.

In summary, findings support that hypothesis that effects of task-irrelevant emotional stimuli on attention performance are reduced when task difficulty is high. There was only mixed support for the exploratory hypothesis that stimuli of longer durations would disrupt attention.

Mood Changes

To assess potential mood induction effects of the emotional faces, difference scores were calculated between baseline (before starting the E-ANT) and after each block of trials (one block per face type) for the following: state anxiety, current positive affect, and current negative affect. A 5 (block: angry, fear, sad, happy, neutral) × 2 (difficulty: easy, difficult) repeated-measures ANOVA was conducted for each measure of change in mood. No significant effects emerged; suggesting that participants' self-report of mood did not change as a result of viewing task-irrelevant emotional faces.

Discussion

The goal of the current study was to determine whether threat-relevant and nonthreat relevant faces facilitate or disrupt different domains of attention. To be specific, we predicted that (1) threat-relevant faces would facilitate attention relative to nonthreat relevant faces, (2) that these effects would be increased when faces are presented for a longer duration, and (3) that these effects will be absent when task difficulty is high. Consistent with predictions, we found that for the easy task, threatening (fearful and angry) relative to happy faces facilitated orienting, whereas in the difficult task, effects of distinct emotional face types did not emerge. In addition, although stimuli of longer duration interfered more with attention, effects were nonlinear.

The effects of task-irrelevant emotional stimulus type and task difficulty are consistent with our hypotheses and some previous studies (Pessoa et al., 2002; Pessoa et al., 2005), but they are only partially consistent with other frameworks, such as attentional load theory (Lavie, Hirst, de Fockert, & Viding, 2004). This theory posits that distracter interference is reduced under conditions of high perceptual load, but is increased under conditions of high cognitive load. By varying task difficulty, the current study may have simultaneously varied perceptual and cognitive load, thus making it difficult to distinguish their impact on attention. Moreover, findings of the current study may have been inconsistent with attentional load theory because task-irrelevant stimuli were not distracters (i.e., emotional faces were not presented simultaneously with the target task)—attentional load theory may be most applicable when stimuli are distracters. Future research should carefully tease apart the role of perceptual and cognitive load as well as directly compare effects for task-irrelevant and distracting emotional stimuli when examining task difficulty effects on attention.

These findings also are consistent with previous research documenting that in nonclinical groups, stimuli that have relatively high motivational intensity (or associations with stronger impetus to act, such as threat-relevant stimuli) narrow the scope of attention (Gable & Harmon-Jones, 2008, 2010a, 2010b), and thus may actually facilitate attention relative to nonthreatening faces (Den-

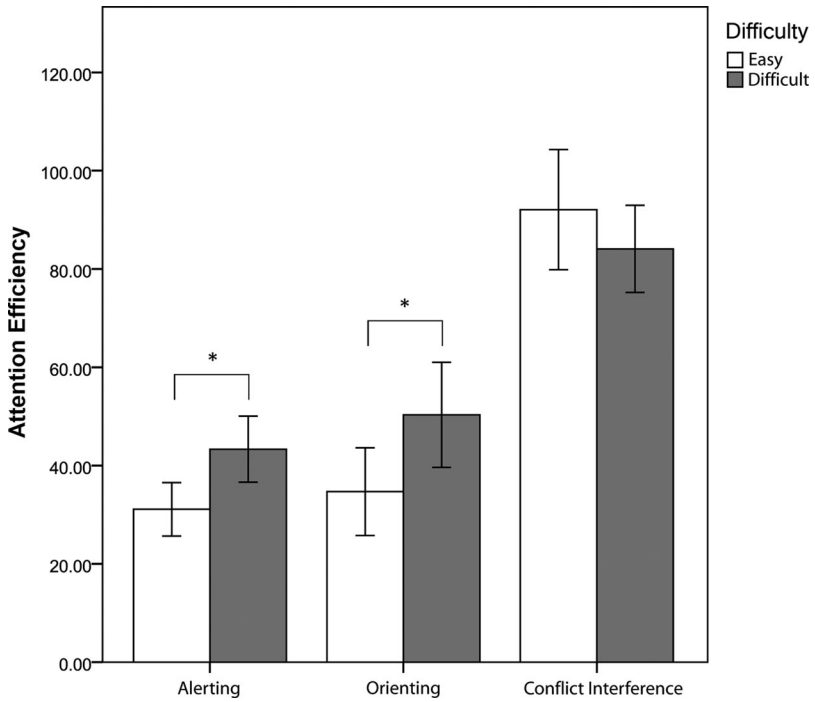

Figure 3. Alerting and orienting were more efficient during the difficult versus easy task. Bars represent means of alerting efficiency scores (RT no cues—RT double cues), orienting efficiency scores (RT center cues—RT spatial cues), and conflict interference (RT incongruent flankers—RT congruent flankers). Higher conflict interference indicates less efficient executive attention. Error bars represent 95% confidence intervals. RT = reaction time. * $p < .05$.

nis & Chen, 2007a). Although we found that this effect was specific to orienting, other studies have shown that executive conflict interference also was sensitive to complex fear images and in relation to state anxiety (Finucane & Power, 2010). In the current study, face stimuli were of relatively low intensity compared to complex emotional pictures, and thus a range of other stimuli should be explored. Facilitative effects of threat stimuli may emerge across other attentional networks besides orienting when more complex stimuli are used as task-irrelevant stimuli. However, as suggested by dual competition framework (Pessoa, 2009), it may be those mildly threatening emotional stimuli (e.g., task-irrelevant angry faces) that are most likely to stimulate attentional focus and thus bolster performance. Future research should systematically examine the impact of emotional stimuli of varying affective complexity and intensity in relation to attention performance in multiple domains. Taken together, results suggest that threat-relevant emotional faces can facilitate attention when task demands are low and the stimuli are task-irrelevant. This emotional facilitation disappears, however, when task difficulty is high.

Stimulus duration also influenced attention, but only executive attention efficiency. Conflict interference was generally greater (less efficient executive attention) following task-irrelevant stimuli presented for the longest duration as compared to the shorter durations regardless of emotional face type. More important, this effect emerged only when the difficult condition was included in analyses (although between-condition effects did not reach significance). This suggests that although in general, longer stimulus durations may cause more attentional interference, such effects may not be robust. Moreover, effects of stimulus duration may be nonlinear: Executive attention was more disrupted following task-irrelevant emotional stimuli lasting 100 versus 250 ms. This latter finding is difficult to interpret. One possibility is that, although the 50 ms faces were difficult to identify, and the 250 ms faces were relatively easy to identify, the ambiguity of the 100 ms faces added a level of cognitive load that might have compromised performance. Although this is highly speculative, it points to the need for future research examining how the duration of task-irrelevant emotional stimuli influences attention in linear and nonlinear ways.

Task difficulty alone also influenced attention, and this effect was not limited to one specific domain of attention. Participants in the difficult versus easy task were more alert and more adept at orienting. Improved efficiency may be linked to the fact that in the difficult task participants had only 100 ms to view the flankers and thus needed to remain vigilant for their appearance. The difficulty of the task is corroborated by the number of participants in the difficult task who were excluded from analyses due to excessive errors ($f = 19$) compared to the number from the easy task ($f = 3$). Another possibility is that the difficult task monopolized attentional resources such that emotional faces had less of an influence on attention as compared to the easy task (Pessoa et al., 2002, 2005). That is, if the easy task resulted in enhanced processing of threat-relevant faces this could have reduced overall performance efficiency for domains of attention like alerting and orienting that

are relatively sensitive to bottom-up, exogenous attentional processes.

Limitations of the current study include a variable interstimulus interval (ISI) between presentation of the task-irrelevant emotional stimuli and the task, thus making it difficult to assess the impact of this interval on attention performance. Research using the attentional blink paradigm suggests that the influence of emotional stimuli is greatest when the target task occurs within 500 ms (Chun & Potter, 1995; Raymond, Shapiro, & Arnell, 1992). The randomly generated ISI in the current study was based on previous studies using the ANT and E-ANT (e.g., Dennis & Chen, 2007b, 2009; Fan et al., 2002). This interval, however, is fairly long (600 to 1,300 ms); decreasing this time may lead to greater facilitation from threatening information or more disruption from stimuli presented for extended durations. In addition, due to the combination of three factors within each experimental block (duration, cue type, flanker type) there were only four trials in each cell of the experimental design. It is important to note that analyses were not conducted at the level of a single cell; for alerting and orienting RTs are collapsed across flanker type for each cue (eight trials) and for executive attention RTs are collapsed across cue type (16 trials). Furthermore, the main effects presented pool across the different durations or emotions, thus increasing the number of trials that go into the variable of interest. Though this may still have led to noisy measures of attention, we were concerned that increasing the number of trials would be too burdensome to participants and would lead to reduced task focus. Future research can use the results of the current study to reduce the number of levels of each variable and thus increase the amount of trials per cell without creating a long, taxing experiment that would fatigue participants and compromise the quality of measurement.

Future directions include the use of event-related potentials (ERPs), which can be used to track changes in emotional or task processing in relation to task-irrelevant emotional stimuli. A previous study using the E-ANT showed that greater processing of negative faces (as measured by ERPs) was associated with greater alerting and orienting (Dennis & Chen, 2007a). Such effects should be reduced when task difficulty is increased, as suggested by the current results showing no influence of the specific emotion of faces on attention performance. Including task difficulty as a within- rather than between-subjects factor would further improve our ability to assess this question. Examining the effects of task-irrelevant emotional faces on attention in clinical samples is also an important future direction. For example, anxious individuals show a threat bias in which attention is disrupted in the presence of threat stimuli (Fox, Russo, & Dutton, 2002; Mogg, Philippot, & Bradley, 2004), but effects may vary for state and trait anxiety (Dennis & Chen, 2007a; Pacheco-Unguetti, Acosta, Callejas, & Lupiáñez, 2010). The current study targeted participants falling within the normative range for anxiety and depression. Future studies will recruit high trait anxious participants and include mood inductions to examine the effect of trait and state mood on emotion-attention interactions, particularly in relation to threat-relevant stimuli.

In conclusion, the current study systematically evaluated the interplay between task-irrelevant emotional stimuli and attention in a nonclinical group of adults. After varying emotional face type, duration of distracters, and concurrent task difficulty, results suggests that threat-relevant faces are assigned particular attentional significance, which under easy task conditions serves to facilitate attention. High task difficulty, however, reduced the impact of emotion on attention. Future research should examine the effect of negative mood states on emotion-attention interactions to further understand how emotional information influences multiple domains of attention in both adaptive and maladaptive ways.

References

Bannerman, R. L., Milders, M., & Sahraie, A. (2010). Attentional bias to brief threat-related faces revealed by saccadic eye movements. *Emotion, 10,* 733–738.

Beck, A. T., Steer, R. A., & Brown, G. K. (1996). *Manual for Beck Depression Inventory II (BDI–II)*. San Antonio, TX: Psychology Corporation.

Bradley, B. P., Mogg, K., Falla, S. J., & Hamilton, L. R. (1998). Attentional bias for threatening facial expressions in anxiety: Manipulation of stimulus duration. *Cognition and Emotion, 12,* 737–753.

Chun, M. M., & Potter, M. C. (1995). A two-stage model for multiple target detection in rapid serial visual presentation. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 109–127.

Dennis, T. A., & Chen, C. (2007a). Emotional face processing and attention performance in three domains: Neurophysiological mechanisms and moderating effects of trait anxiety. *International Journal of Psychophysiology, 65,* 10–19.

Dennis, T. A., & Chen, C. (2007b). Neurophysiological mechanisms in the emotional modulation of attention: The interplay between threat sensitivity and attentional control. *Biological Psychology, 76,* 1–10.

Dennis, T. A., & Chen, C. (2009). Trait anxiety and conflict monitoring following threat: An ERP study. *Psychophysiology, 46,* 122–131.

Dennis, T. A., Chen, C., & McCandliss, B. D. (2008). Threat-related attentional biases: An analysis of three attention networks. *Depression and Anxiety, 25,* E1–E10.

Easterbrook, J. A. (1959). The effect of emotion on cue utilization and the organization of behavior. *Psychological Review, 66*(3), 183–201.

Egloff, B., & Hock, M. (2001). Interactive effects of state anxiety and trait anxiety on emotional Stroop interference. *Personality and Individual Differences, 31,* 875–882.

Fan, J., McCandliss, B. D., Fosella, J., Flombaum, J. I., & Posner, M. I. (2005). The activation of attentional networks. *NeuroImage, 26,* 471–479.

Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience, 14,* 340–347.

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

Finucane, A. M., & Power, M. J. (2010). The effect of fear on attentional processing in a sample of healthy females. *Journal of Anxiety Disorders, 24,* 42–48.

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

Gable, P., & Harmon-Jones, E. (2008). Approach-motivated positive affect reduces breadth of attention. *Psychological Science, 19,* 476–482.

Gable, P., & Harmon-Jones, E. (2010a). The blues broaden, but the nasty narrows: Attentional consequences of negative affects low and high in motivational intensity. *Psychological Review, 21,* 211–215.

Gable, P., & Harmon-Jones, E. (2010b). The motivational dimensional model of affect: Implications for breadth of attention, memory, and cognitive categorisation. *Cognition and Emotion, 24,* 322–337.

Hajcak, G., Dunning, J. P., & Foti, D. (2009). Motivated and controlled attention to emotion: Time-course of the late positive potential. *Clinical Neurophysiology, 120,* 505–510.

Hanoch, Y., & Vitouch, O. (2004). When less is more: Information, emotional arousal and the ecological reframing of the Yerkes-Dodson law. *Theory & Psychology, 14,* 427–452.

Koster, E. H. W., Crombez, G., Verschuere, B., & De Houwer, J. (2006). Attention to threat in anxiety-prone individuals: Mechanisms underlying attentional bias. *Cognitive Therapy and Research, 30,* 635–643.

Lavie, N., Hirst, A., de Fockert, J. W., & Viding, E. (2004). Load theory of selective attention on cognitive control. *Journal of Experimental Psychology: General, 133,* 339–354.

Lipp, O., Price, S. M., & Tellegen, C. L. (2009). Emotional faces in neutral crowds: Detecting displays of anger, happiness, and sadness on schematic and photographic images of faces. *Motivation and Emotion, 33,* 249–260.

LoBue, V. (2010). What's so scary about needles and knives? Examining the role of experience in threat detection. *Cognition and Emotion, 24,* 180–187.

MacLeod, C., Mathews, A., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology, 95,* 15–20.

Marcos, J., & Redondo, J. (2005). Facilitation and interference of the automatic information processing on a reaction time task to threat-relevant stimuli. *Psicothema, 17,* 332–337.

Meinhardt, J., & Pekrun, R. (2003). Attentional resource allocation to emotional events: An ERP study. *Cognition and Emotion, 17,* 477–500.

Mogg, K., & Bradley, B. P. (1998). A cognitive-motivational analysis of anxiety. *Behaviour Research and Therapy, 36,* 809–848.

Mogg, K., Garner, M., & Bradley, B. P. (2007). Anxiety and orienting of gaze to angry and fearful faces. *Biological Psychology, 76,* 163–169.

Mogg, K., Philippot, P., & Bradley, B. P. (2004). Selective attention to angry faces in clinical social phobia. *Journal of Abnormal Psychology, 113,* 160–165.

Pacheco-Unguetti, A. P., Acosta, A., Callejas, A., & Lupiáñez, J. (2010). Attention and anxiety: Different attentional functioning under state and trait anxiety. *Psychological Science, 21,* 298–304.

Pessoa, L. (2009). How do emotion and motivation direct executive control? *Trends in Cognitive Sciences, 13,* 160–166.

Pessoa, L., McKenna, M., Gutierrez, E., & Ungerleider, L. G. (2002). Neural processing of emotional faces requires attention. *Proceedings of the National Academy of Sciences, USA, 99,* 11458–11463.

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,* 249–255.

Phelps, E. A., Ling, S., & Carrasco, M. (2006). Emotion facilitates perception and potentiates the perceptual benefits of attention. *Psychological Science, 17,* 292–299.

Pinkham, A. E., Gribbin, M., Baron, R., Sasson, N. J., & Gur, R. C. (2010). The face in the crowd effect: Anger superiority when using real faces and multiple identities. *Emotion, 10,* 141–146.

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance, 18,* 849–860.

Schimmack, U., & Derryberry, D. (2005). Attentional interference effects of emotional pictures: Threat, negativity, or arousal? *Emotion, 5,* 55–56.

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

Spielberger, C. D. (1983). *State–Trait Anxiety Inventory manual.* Redwood City, CA: Mind Garden.

SPSS Inc. (2009). PASW STATISTICS 17.0. SPSS Inc., Chicago.

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., . . . Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research, 168,* 242–249.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scale. *Journal of Personality and Social Psychology, 54,* 1063–1070.

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