Emotion

Fear and Happiness, but Not Sadness, Motivate Attentional Flexibility: A Case for Emotion Influencing the Ability to Split Foci of Attention

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One prominent and consistent effect is that negative emotions with high motivational intensity, such as fear, narrow attention. However, recent data concerning how fear influences vision may suggest that fear could make attention flexible. Thus, the goal of the present study was to examine whether fear, like happiness, enhances attentional flexibility when multiple targets are present in noncontiguous locations. Fear, happiness, or sadness was induced followed by participants completing an attentional task that required splitting foci of attention to noncontiguous regions of space in the presence (Exp. 1) or absence (Exp. 2) of distractors or both (Exp. 3). Fear and happiness enhanced the reporting of targets in unattended locations demonstrating greater attentional flexibility. Sadness facilitated the splitting of attention through the suppression of irrelevant locations. The effects were replicated in a third experiment using a within-subjects design of distractor presence and an inclusion of a neutral condition. Taken together, results suggest fear and happiness increase attentional flexibility by impairing the suppression of irrelevant locations, which may allow for faster reallocation of attention facilitating detection of potential threats/rewards in one's environment.

Keywords: emotion, attention, flexibility, fear, happiness

Data and theory have long held that negative, motivationally intense emotions, such as fear, narrow attention (Easterbrook, 1959; Eysenck, Derakshan, Santos, & Calvo, 2007; Gable & Harmon-Jones, 2008; Wells & Matthews, 1996). However, fear may increase attentional flexibility given the recent results finding that fear increased the extent of the visual field and facilitated saccade speed and detection of entities in the periphery (Susskind et al., 2008; see also Bocanegra, Huijding, & Zeelenberg, 2012, and Phelps, Ling, & Carrasco, 2006). Given this evidence, we sought to explore whether an induced fear state, compared to happiness and sadness, can increase attentional flexibility, particularly when multiple, neutral targets are presented in noncontiguous regions of space.

A plethora of research has examined how induced affective states influence the breadth of attention (Ashby, Isen, & Turken, 1999; Clore & Huntsinger, 2007; Fredrickson, 2001; Gable & Harmon-Jones, 2008; Rowe, Hirsh, & Anderson, 2007). The most common paradigms (e.g., Eriksen flanker, Navon figures, and Kimchi/Palmer global/local tasks—Eriksen, 1995; Kimchi & Palmer, 1982; Navon, 1977)—used to assess these effects are often interpreted within a spotlight model of attention emphasizing spatial attention, the breadth of which is determined by the extent of the proverbial spotlight (Eriksen, 1995; Eriksen & St James, 1986; Müller, Malinowski, Gruber, & Hillyard, 2003). In this model, positive affect is associated with increased attentional breadth, which enhances global, flexible, and creative processes (Ashby et al., 1999; Clore & Huntsinger, 2007; Fredrickson, 2001; Gable & Harmon-Jones, 2008), but also enhances interference as distractors are more likely to compete for attention (Phaf, 2015; Rowe et al., 2007). Conversely, negative affect narrows attentional breadth, thereby minimizing interference effects (Finucane, 2011; Rowe et al., 2007) and promoting local rather than global processing (Clore & Huntsinger, 2007; Gable & Harmon-Jones, 2010); however, fear has been studied less within this paradigm (Derakshan & Eysenck, 2010). Alternatively, newer research has found evidence that motivationally intense emotions (e.g., desire, fear), regardless of the affective value, narrow attention, whereas less motivationally intense emotions (e.g., happiness, sadness) broaden attention (see Gable & Harmon-Jones, 2008, 2010). Regardless of the theory, fear is consistently associated with narrowing attention.

Splitting of Attention

While the spotlight model provides a parsimonious framework for attention, it is limited in explaining the full complexity of the attentional system. Specifically, foci of attention can be split

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across multiple, noncontiguous locations in space by suppressing or inhibiting irrelevant locations/entities (Awh & Pashler, 2000; Frey et al., 2014; Morawetz, Holz, Baudewig, Treue, & Dechent, 2007). In other words, the attentional system can deploy multiple, independent spotlights across noncontiguous regions of space. For instance, Awh and Pashler (2000) using a partial report procedure asked participants to attend to two cued-locations surrounded by distractors, including locations between the two cues (see Figure 1 for a pictorial display). For a majority of trials, targets were presented in these cued locations and reporting of targets was extremely accurate. Critically, to test the spotlight model, occasionally (20% of trials) the two targets were presented in noncued locations with one target being presented in between the two cued locations and the other target presented opposite the cued locations. Contrary to the spotlight model of attention, participants were less likely to report targets presented at the noncued locations, including the target presented between the two cued-locations (i.e., the noncued target was located within the *proverbial* attentional spotlight). Thus, they concluded that the attentional system is quite flexible in that the foci of attention can be split across multiple locations/entities across noncontiguous regions of space. Subsequent research has supported these findings (Frey et al., 2014; Jefferies, Enns, & Di Lollo, 2014).

Given the spotlight model of attention has informed much of the research examining effects of emotional states on attention, a comprehensive understanding of how emotion influences attention is lacking. Namely, if emotions are not simply making the proverbial spotlight larger (i.e., broaden) or smaller (i.e., narrow), then how are emotions affecting attention? Newer models of attention suggest attention consist of both spatial and temporal properties that often work together to influence attention. Spatial attention implies the ability to split attention described above (i.e., high flexibility to deploy multiple spotlights). Temporal attention is associated with shifting of attention or attentional flexibility (Heerebout & Phaf, 2010; Phaf, 2015). Specifically, low temporal attentional flexibility is associated with increased suppression of nonrelevant locations/entities and decreased susceptibility to distraction (i.e., maintaining attentional focus); conversely, high temporal attentional flexibility is associated with decreased suppression of nonrelevant locations/entities and increased susceptibility to distraction (i.e., shifting of attentional focus). Happiness may increase temporal attentional flexibility as happiness, compared to sadness, enhances task switching performance and susceptibility to distraction (Phaf, 2015). What about fear? Fear narrows attention within paradigms associated with spatial attention (e.g., Easterbrook, 1959; Eysenck et al., 2007; Finucane, 2011; Harmon-Jones, Gable, & Price, 2013); however, it remains unclear how fear influences attention beyond the constraints of an attentional spotlight paradigm. Recent evidence (Susskind et al., 2008) suggests that fear enhances visual extent, rapid saccade shifts, and detection of targets in the periphery, all of which are supportive perceptual mechanisms for rapid shifting to and detection of entities in extended space.

Design and Predictions

Three experiments were designed to examine how emotion influences splitting of attention. The first study examined if emotion influenced splitting of attention, and the second study tested whether suppressing noncued locations was a possible mechanism.
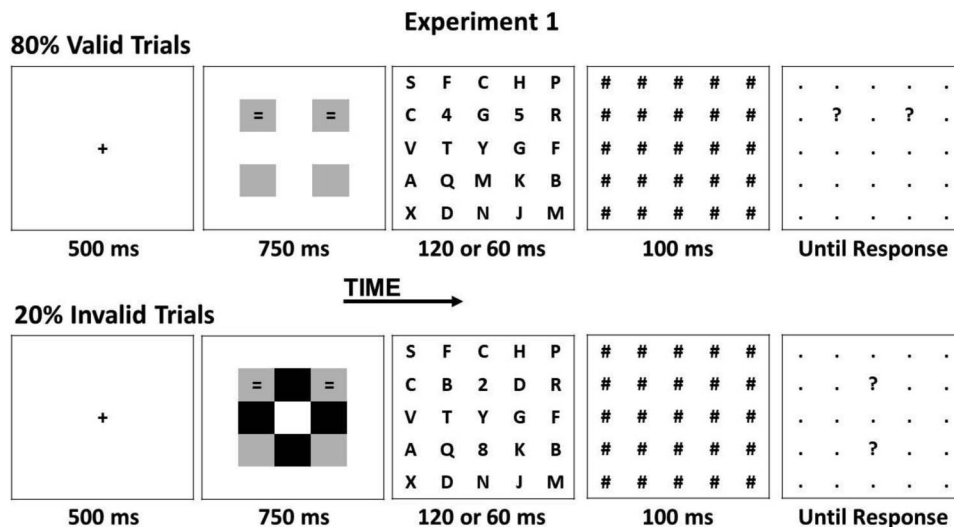
Figure 1. The procedure for the attentional task is presented with the top row representing the procedure for valid trials and the bottom row representing the procedure for invalid trials. Within the second box, for the valid (top) trials the gray shaded boxes yield possible cued locations; for the invalid (bottom) trials the gray shaded boxes yield possible cued locations and the black boxes yield possible target locations. Do note that the gray and black boxes were never shown to the participants as they saw a white background. The third box (both top and bottom) have a time of either 120 ms or 60 ms; 120 ms was used when distractors were present (Exp. 1 and 3) and 60 ms was used when distractors were absent (Exp. 2 and 3). When distractors were absent (Exp. 2 and 3), the only stimuli presented in boxes 3 and 4 (both top and bottom) were only the two numbers (box 3) and '#' signs (box 4) located where the numbers were presented, the remaining area was blank.

The third experiment replicated and extended the findings of the first two experiments. The design of the study followed Experiments 1 and 4 in Awh and Pashler (2000). As described earlier, a partial report procedure was used in which two cued locations are followed by a single target presented in each cued-location (valid = 80%) or in each noncued location (invalid = 20%). The noncued locations are systematic such that one location falls in between the two cues (invalid middle), whereas the other location is far away from the cued locations (invalid far). This arrangement allows for the testing of the spotlight model, such that support for the model would show high-level reporting for invalid middle targets because the target would be within the proverbial spotlight of attention, whereas reporting for invalid far targets would be impaired. However, if attention can be flexible (i.e., splitting foci of attention), then the most optimal way to accurately report targets would be to allocate all attentional resources to the two cued positions and ignore noncued locations, particularly when distractors are present. This optimal strategy on valid trials would result in extremely high report rates for targets. However, for invalid trials (targets located in noncued locations), the report rates for targets would be greatly reduced because attention has suppressed the processing of targets at noncued locations, including the noncued target located between the two cued locations. People who are better at inhibiting noncued locations (i.e., low attentional flexibility) would report fewer targets at noncued locations compared to those with less strong inhibitory tendencies (i.e., high attentional flexibility). Thus, performance on invalid trials, compared to valid trials, provides the greatest insight for how attention is being allocated and which attention model is most appropriate.

We induced three emotional states of happiness, sadness, and fear (and a control condition in Exp. 3) to examine how valence (positive vs. negative) and negative emotions with different motivational intensity (sad vs. fear) influenced attentional breadth and/or flexibility (Ashby et al., 1999; Clore & Huntsinger, 2007; Fredrickson, 2001; Phaf, 2015). Our predictions were specific to the reporting of noncued (invalid) targets given that prior research failed to find that emotion influenced reporting of targets to cued locations (see Finucane, Whiteman, & Power, 2010). We expected that happiness, compared to sadness, would increase attentional flexibility because happiness is associated with increased broadening of attention (Ashby et al., 1999; Clore & Huntsinger, 2007; Fredrickson, 2001) and increased distractibility within a task switching context (Dreisbach, 2006; Dreisbach & Goschke, 2004) or a modified flanker task (Phaf, 2015). We expected fear to increase attentional flexibility, similar to that of a happiness state, because fear is associated with increased target detection, saccade speed, and detection of targets in the periphery (Susskind et al., 2008). The motivational intensity model, however, would predict similar reporting of noncued targets between happiness and sadness (both are low in motivational intensity), but would predict fewer reported noncued targets for fear states as high motivationally intense emotions narrow attention (Gable & Harmon-Jones, 2008). In the first experiment, we predicted that happiness and fear, compared to sadness, would impair splitting of attention (i.e., increased attentional flexibility) evidenced by higher report rates for invalid targets (i.e., targets presented in noncued locations). In the second experiment, we predicted that emotional states would not differ on their reporting of invalid targets because the removal of distractors decreases the need to suppress irrelevant locations/

distractors. A null finding would be consistent with the findings from Awh and Pashler (2000) supporting suppression as the underlying mechanism for splitting of attention. Finally, we anticipate that the effects observed in Experiments 1 and 2 to be replicated in Experiment 3 when the distractor presence was manipulated within-subjects.

Experiment 1

Method

Participants. Eighty-three participants (51 females, 32 males; M_{age} = 21.36, SD = 6.15) from Queens College participated for course credit and provided informed consent. The Queens College institutional review board approved the study. Sample size was determined based on Awh and Pashler (2000) and previous research examining emotion and cognitive phenomena, which resulted in a target number of 25 subjects per cell. Data collection stopped at the end of the week for which at least 75 subjects were collected resulting in a total sample of 83.

Emotion induction. Thirty-one images were selected for each emotion (happy, sad, fear), and all images were selected from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 1999). For each emotion, images (e.g., people, animals, scenes) were selected to be emotionally similar (e.g., fear/threatening), while limiting contamination of other emotions (e.g., disgust, sadness, etc.; categorical ratings were obtained from: Barke, Stahl, & Kröner-Herwig, 2012; Libkuman, Otani, Kern, Viger, & Novak, 2007). Participants were instructed to view each image carefully and consider how they would feel and think if they were in the scene presented. See Table 1 (note) for the image numbers corresponding to the IAPS picture selected for each emotional category.

Attentional task. The goal of the attentional task was to report the two numbers presented within an array of distractor letters. The stimulus array consisted of 23 uppercase letters and 2 target digits. The letters were randomly selected from all 26 letters of the alphabet, and the digits were randomly selected from 1 to 9. All stimuli appeared as black objects on a white background. The stimuli appeared in a 5 × 5 array of evenly spaced positions (extent of square matrix was 10 × 10 cm as displayed on the monitor with participants sitting 55 cm away). The targets were restricted to a 3 × 3 array centered within the larger 5 × 5 array. There were four possible cue arrangements within the 3 × 3 matrix: top horizontal (upper left and upper right corners), bottom horizontal (lower left and lower right corners), left vertical (upper left and bottom left corners), and right vertical (upper right and bottom right corners; see the gray shaded locations in Figure 1—top panel). There were two trial types: valid and invalid. For valid trials, two digits appeared where the cues were previously presented and the remaining object locations were filled with the distractor letters. For invalid trials, the locations of targets (see the possible locations in Black in Figure 1—bottom panel) were based on the cue arrangement (see the possible locations in gray in Figure 1—bottom panel) and was consistent across each type of arrangement, such that one target (invalid middle) was always presented in between the two cued locations, and the other target (invalid far) was always presented opposite the invalid middle location (e.g., top horizontal cue arrangement: within the 3 × 3 interior grid, the invalid middle location was between upper left

Table 1
Emotion Manipulation Check and Attention Task Descriptive Statistics

Variables	Emotion conditions			
	Happy	Sad	Fear	Neutral
Experiment 1				
Happy	4.59 (1.05)[a]	2.10 (.82)	2.30 (.91)	
Sad	1.41 (.93)[a]	4.76 (1.09)	3.33 (1.64)[b]	
Fear	1.56 (1.19)[a]	3.03 (1.40)[b]	4.07 (1.21)	
Anger	1.15 (.46)[a]	3.14 (1.43)	3.11 (1.47)	
Disgust	1.15 (.46)[a]	3.34 (1.56)	3.56 (1.53)	
Arousal	3.22 (1.50)	3.62 (1.18)	3.26 (.98)	
Valid horizontal	.977 (.023)	.966 (.050)	.970 (.042)	
Valid vertical	.960 (.049)	.942 (.069)	.951 (.064)	
Invalid middle horizontal	.815 (.188)	.716 (.331)	.827 (.167)	
Invalid middle vertical	.778 (.179)	.652 (.328)	.855 (.171)	
Invalid far horizontal	.528 (.233)	.353 (.223)	.602 (.206)	
Invalid far vertical	.608 (.252)	.463 (.279)	.657 (.246)	
Experiment 2				
Happy	4.42 (1.41)[a]	2.10 (.70)	2.10 (.84)	
Sad	1.52 (1.18)[a]	4.54 (1.06)	3.30 (1.90)[b]	
Fear	1.35 (.88)[a]	3.03 (1.43)[b]	4.13 (1.59)	
Anger	1.29 (.97)[a]	3.03 (1.35)	2.80 (1.45)	
Disgust	1.19 (.54)[a]	3.00 (1.51)	2.70 (1.45)	
Arousal	3.48 (1.59)	3.65 (1.45)	3.57 (1.55)	
Valid horizontal	.985 (.04)	.990 (.02)	.994 (.01)	
Valid vertical	.982 (.06)	.988 (.02)	.990 (.02)	
Invalid middle horizontal	.960 (.10)	.976 (.04)	.981 (.04)	
Invalid middle vertical	.967 (.08)	.976 (.05)	.978 (.05)	
Invalid far horizontal	.948 (.09)	.965 (.06)	.958 (.06)	
Invalid far vertical	.953 (.09)	.954 (.07)	.964 (.06)	
Experiment 3				
Happy	4.51 (1.19)	2.27 (.80)[a]	2.00 (.86)[a]	3.22 (.72)
Sad	1.54 (1.24)	4.38 (1.06)	3.58 (1.20)	2.72 (1.21)
Fear	1.30 (1.05)	3.35 (1.44)	4.20 (1.19)	2.39 (1.42)
Anger	1.22 (.63)	3.00 (1.49)[ab]	3.39 (1.66)[a]	2.47 (1.32)[b]
Disgust	1.19 (.52)	3.03 (1.30)[ab]	3.44 (1.52)[a]	2.50 (1.30)[b]
Arousal	3.05 (1.70)[a]	3.00 (1.25)[ab]	3.58 (1.42)[ab]	2.33 (1.24)[ab]

Note. Emotional ratings for happy, sad, fear, anger, disgust, and arousal. Tukey post-hoc analyses were conducted and conditions with a superscript letter were not different from the other condition, $p > .050$. Accuracy rates for performance on the attentional task are also reported for Experiment 2. Standard deviations are in parentheses. Slide numbers separated by emotion category: happy: 1,440, 1,460, 1,590, 1,600, 1,610, 1,630, 1,750, 1,810, 2,040, 2,050, 2,057, 2,070, 2,091, 2,156, 2,165, 2,311, 2,341, 2,352, 2,395, 2,398, 2,550, 2,660, 4,601, 4,610, 5,480, 5,621, 5,829, 7,325, 7,492, 8,180, 8,370. Sad: 2,095, 2,276, 2,278, 2,301, 2,456, 2,490, 2,520, 2,703, 2,799, 9,000, 9,001, 9,002, 9,005, 9,050, 9,250, 9,254, 9,415, 9,430, 9,470, 9,491, 9,520, 9,530, 9,611, 9,900, 9,901, 9,903, 9,904, 9,910, 9,911, 9,920, 9,926. Fear: 1,050, 1,112, 1,120, 1,300, 1,302, 1,304, 1,525, 1,726, 1,930, 2,120, 2,811, 3,530, 5,961, 5,970, 5,971, 6,190, 6,211, 6,230, 6,231, 6,250, 6,260, 6,263, 6,300, 6,370, 6,510, 6,555, 6,571, 6,825, 9,620, 9,908, 9,930.

and upper right corners and invalid far location was between lower left and lower right corners).

Manipulation check. The emotion manipulation check asked participants to indicate how they felt while viewing the pictures, assessing six different emotions (Rottenberg, Ray, & Gross, 2007). The set of anchors ranged from (1)—not at all X— to (6)—very X— assessing the various emotions (X): happy, sad, angry, fearful, disgusted, and emotionally aroused.

Procedure. All participants received an overview of the study and a consent form. After providing consent, participants were randomly assigned to one of the three emotion inductions (happy, sad, or fear). Next, participants completed personality and demographic questionnaires, then received instructions for and subse-

quently completed 20 practice trials of the task. Practice trials were identical to the experimental trials, even maintaining the ratio of cue locations and valid and invalid trials. Each trial followed the same sequence of events (see Figure 1 for a graphical presentation of the attention task). First, participants were presented with a fixation cue presented in the center of the screen for 500 ms. Then, two cues (the symbol "=" served as the cue) were presented for 750 ms. The targets and distractors were presented for 120 ms, then each location was masked by the symbol "#" for 100 ms. The masks were then replaced with dots, with the exception of the two locations where the digits were presented. For these two locations, the symbol "?" was presented, prompting participants to manually type the number presented for each location signaled with the "?".

Participants were given unlimited time to report the digits with the next trial only beginning after both responses were recorded. Immediately following practice trials, the emotion induction began and consisted of 31 pictures presented for 5 s each. Participants were then provided a brief instructional reminder for the experimental attention task, and then completed 120 trials (~5 min in duration). Each of the four possible cue arrangements were presented for 30 trials (24 valid and 6 invalid), and all trial types were presented in a random order. Participants then completed the emotion manipulation check and were debriefed.

Results

Emotion check. The manipulation check confirmed the emotion manipulation was effective at inducing the intended emotional states (see Table 1 for Tukey post hoc effects). A multivariate analysis of variance (ANOVA) indicated that the six independent emotion check items and the overall effect were significant, $F(12, 152) = 14.80$, $p < .001$, $\eta_p^2 = 0.539$. For each individual item, there was a significant effect of emotion (happiness, $F(2, 80) = 60.23$, $p < .001$, $\eta_p^2 = 0.610$; sadness, $F(2, 80) = 50.13$, $p < .001$, $\eta_p^2 = 0.556$; fear, $F(2, 80) = 26.73$, $p < .001$, $\eta_p^2 = 0.401$; anger, $F(2, 80) = 23.83$, $p < .001$, $\eta_p^2 = 0.373$; disgust, $F(2, 80) = 28.77$, $p < .001$, $\eta_p^2 = 0.418$) with the exception of arousal, $F(2, 80) = 0.894$, $p = .413$, $\eta_p^2 = 0.022$. In addition, planned t tests were used to identify whether the self-reported emotion (e.g., happiness) within the induced emotional condition (e.g., happiness) was rated higher than any other self-reported emotion (e.g., sadness, fear, disgust, anger). The happy condition resulted in the highest level of happiness compared to the other self-reported emotion items, p values < 0.001. The sad condition resulted in the highest level of sadness compared to the other emotion items, p values < 0.001. The fear condition resulted in the highest level of fear compared to the other emotion items, p values < 0.001 (disgust; $p = .039$).

Attention task. Following the procedures of Awh and Pashler (2000), we averaged together the accuracy of the two valid locations into a single valid score, as there was no difference in the reporting of the two valid targets by emotion, $F(2, 80) = 0.510$, $p = .603$, $\eta_p^2 = 0.013$. We ran a 3 (Cue validity: valid, invalid-middle, invalid-far) × 2 (Position: horizontal, vertical) × 3 (Emotion: happy, sad, fear) repeated measures ANOVA with cue validity and position as within-subjects factors and emotion as the between-subjects factor with the outcome variable being the accuracy of reported targets. Of particular interest was the cue validity by emotion interaction, which was found to be significant, $F(4, 160) = 3.86$, $p = .005$, $\eta_p^2 = 0.090$. To breakdown the interaction, we assessed how emotion influenced the reporting of targets independently for valid, invalid middle, and invalid far locations. For valid locations, as predicted, emotion failed to influence reporting of targets, $F(2, 80) = 0.669$, $p = .515$, $\eta_p^2 = 0.016$. For the invalid middle position, emotion influenced the reporting of targets, $F(2, 80) = 3.494$, $p = .035$, $\eta_p^2 = 0.080$. Consistent with our predictions, the sad condition accurately reported fewer targets compared to the fear condition, $p = .013$, and the fear and happy conditions had similar means, $p = .477$. However, contrary to our prediction, the sad and happy conditions had similar reporting of targets, $p = .066$. As predicted, emotion influenced the reporting of targets in the invalid far position, $F(2, 80) = 8.542$, $p < .001$, $\eta_p^2 = 0.176$. The sad condition reported

fewer targets compared to both the fear, $p < .001$, and happy, $p = .005$, conditions, whereas the fear and happy conditions had similar means, $p = .278$. (See Table 1 for descriptive statistics for target reporting.)

As for the remaining effects, the main effect of cue validity was significant, $F(2, 160) = 163.64$, $p < .001$, $\eta_p^2 = 0.672$; the three types of cue validity were all significantly different from each other, p values < 0.001, with reporting of valid targets being associated with the highest accuracy, invalid middle targets being associated with the next highest accuracy level, and invalid far being associated with the lowest accuracy level. The position main effect was not significant, $F(1, 80) = 1.21$, $p = .274$, $\eta_p^2 = 0.015$. The main effect of emotion was significant, $F(2, 80) = 7.22$, $p = .001$, $\eta_p^2 = 0.153$, the sad condition reported the least number of targets accurately compared to the happy, $p = .008$, and fear, $p < .001$, conditions, and the happy and fear conditions had similar means, $p = .362$. The cue validity and position interaction, $F(2, 160) = 11.61$, $p < .001$, $\eta_p^2 = 0.127$, was also significant (see below for further analyses for the interaction). The position by emotion interaction, $F(2, 80) = 0.154$, $p = .858$, $\eta_p^2 = 0.004$, and three-way interaction of Cue Validity × Position × Emotion, $F(4, 160) = 1.49$, $p = .209$, $\eta_p^2 = 0.036$, were both nonsignificant.

We investigated the cue validity by position interaction. For the valid locations, the horizontal positions were more accurately reported than vertical positions, $F(1, 82) = 17.98$, $p < .001$, $\eta_p^2 = 0.180$. For the invalid middle positions, there was no difference in target reporting between the vertical or horizontal positions, $F(1, 82) = 2.362$, $p = .128$, $\eta_p^2 = 0.028$. For the invalid far positions, cues that were presented vertically (meaning the invalid targets were positioned horizontally) were more accurately reported than cues that were presented horizontally, $F(1, 82) = 9.50$, $p = .003$, $\eta_p^2 = 0.104$. This interaction replicates the findings of Awh and Pashler (2000), as attention is enhanced in the horizontal, compared to the vertical, plane.

Discussion

The happy and fear conditions reported more invalid far targets compared to the sad condition, and the fear condition also reported more invalid middle targets compared to the sad condition. Interestingly, the happy and sad condition had similar report rates for targets at invalid middle positions. Overall, these findings suggest that fear and happiness increased attentional flexibility facilitating the redeployment of attention to unattended targets, and fear may induce a more flexible attentional system than happiness. The spotlight model of attention cannot account for the present findings due to the reduced report rates for invalid middle targets. Moreover, the findings, particularly for fear, were inconsistent with the motivation intensity hypothesis (e.g., Gable & Harmon-Jones, 2008) and other theories suggesting that fear narrows attention (Easterbrook, 1959; Eysenck et al., 2007; Wells & Matthews, 1996), because narrowing of attention would have resulted in less, not greater, reporting of invalid far targets.

Experiment 2

Suppression of noncued locations is only required when distracting information is present; thus, removal of distracting stimuli

should eliminate the need to suppress noncued or task irrelevant locations. If sadness decreased report rates for invalid targets due to suppression of task irrelevant locations, then report rates for invalid targets should be similar across the three emotion conditions.

Method

Participants.   Ninety-two participants (62 females, 30 males; $M_{age} = 21.52$, $SD = 5.70$) from Queens College participated for course credit and provided informed consent. Using G*Power 3.1, we aimed for 30 participants per cell to ensure sufficient power (0.80) to adequately detect a significant emotion by cue validity interaction given the effect size obtained from Experiment 1 (0.33; Faul, Erdfelder, Lang, & Buchner, 2007). Assessment of power after completion of the study confirmed there was sufficient power (0.96) to observe a significant main effect of emotion in reporting invalid cues. Participant collection was stopped at the end of the week for which at least 90 participants were collected.

Emotion induction and manipulation check.   The emotion induction and manipulation check were the same as in Experiment 1.

Attentional task.   The attentional task was the same as in Experiment 1, however distracting letters were omitted from the attentional task and only the two digits were presented.

Procedure.   The procedures were identical to those in Experiment 1, with the exception of the reduced presentation duration of the targets (digits) from 120 ms to 60 ms following the procedure of Awh and Pashler (2000). This reduction in time was to ensure that individuals did not have time to scan the display.

Results

Emotion check.   The emotion check analysis was identical to the one conducted in Experiment 1. The multivariate effect of emotion was significant, $F(12, 170) = 11.91$, $p < .001$, $\eta_p^2 = 0.46$; and each individual emotion item also revealed a significant effect (happiness, $F(2, 89) = 51.89$, $p < .001$, $\eta_p^2 = 0.54$; sadness, $F(2, 89) = 35.65$, $p < .001$, $\eta_p^2 = 0.45$; fear, $F(2, 89) = 33.81$, $p < .001$, $\eta_p^2 = 0.43$; anger, $F(2, 89) = 17.07$, $p < .001$, $\eta_p^2 = 0.28$; disgust, $F(2, 89) = 16.41$, $p < .001$, $\eta_p^2 = 0.270$) with the exception of arousal, $F(2, 89) = 0.086$, $p = .917$, $\eta_p^2 = 0.002$. In general, the emotion manipulation was successful at inducing the intended emotional state (see Table 1 for Tukey post hoc effects). Again, planned t tests were used to identify whether the emotion of the induced emotional state was rated higher than any other emotion. Within each emotion condition, the induced emotion was experienced to a greater degree than any other emotions, p values < 0.05.

Attention task.   The same 3 (Cue validity) × 2 (Position) × 3 (Emotion) repeated measures ANOVA was run as in Experiment 1. The only effect that emerged was a main effect for cue validity, $F(2, 178) = 25.51$, $p < .001$, $\eta_p^2 = 0.22$. Specifically, targets presented in valid locations were more accurately reported than targets presented at the invalid middle, $p = .001$, and the invalid far, $p < .001$, locations. The invalid middle locations were associated with higher report rates compared to invalid far locations, $p = .001$. These findings conceptually replicate the findings in Experiment 4 of Awh and Pashler (2000). All other effects failed to reach significance including, position main effect, $F(1, 89) =$

0.021, $p = .892$, $\eta_p^2 < 0.001$, emotion main effect, $F(2, 89) = 0.67$, $p = .521$, $\eta_p^2 = 0.023$, cue validity by emotion interaction, $F(4, 178) = 0.16$, $p = .964$, $\eta_p^2 < 0.001$, position by emotion interaction, $F(2, 89) = 0.31$, $p = .737$, $\eta_p^2 < 0.001$, cue validity by location interaction, $F(2, 178) = 0.14$, $p = .869$, $\eta_p^2 < 0.001$, and the Cue Validity × Location × Emotion interaction, $F(4, 178) = 0.28$, $p = .891$, $\eta_p^2 < 0.001$. (See Table 1 for descriptive statistics for target reporting.)

Interim Summary

All emotion conditions performed similarly when reporting valid and invalid targets when distractors were not present. These findings suggest that when the need to suppress distractors was removed, suppression of noncued locations was greatly reduced allowing for a more flexible temporal attentional system for all emotional states. Together, Experiments 1 and 2 suggest that fear and happiness, compared with sadness, enhanced temporal attentional flexibility, and this was caused by reduced suppression/inhibition to nonrelevant locations/entities.

Experiment 3

The first two experiments provided support that fear and happiness increased attentional flexibility (Exp. 1) by decreasing the suppression of distractors (Exp. 2). However, there were two issues with the above experiments. First, the identified mechanism, suppression of attention to task nonrelevant locations, was dependent on a null effect in a sample different from that in Exp. 1. Second, the lack of control (neutral) condition precluded the ability to draw definitive conclusions about the influence emotion has on attentional flexibility. Thus, Experiment 3 was conducted to conceptually replicate the results and to address the identified concerns by manipulating distractor presence as a within-subjects variable and include a neutral condition.

Method

Participants.   One hundred fifty-two participants (99 females, 53 males; $M_{age} = 20.92$, $SD = 5.22$) from Queens College participated for course credit and provided informed consent. As discussed below, several participants were removed for overall performance that was beyond 3 standard deviations, and the final sample included in the analyses consisted of 146 participants (95 females, 51 males; $M_{age} = 20.64$, $SD = 4.30$). The Queens College institutional review board approved the study. Sample size of 35 per cell (140 total) was determined based on the findings of Exp. 1 (emotion by cue validity interaction—effect size f = 0.12) to ensure sufficient power (0.80) to detect critical interactions taking into account the additional factor (i.e., distractors vs. no distractors) and condition (i.e., addition of neutral; calculations were conducted using G*Power 3.1.9.2). The experiment ran till the end of the week for which at least 140 participants were collected.

Emotion induction.   The happy, sad, and fear conditions were induced using the same images described in Experiment 1. Thirty-one images were selected from the International Affective Picture System (IAPS; Lang et al., 1999) to induce a neutral state. The images selected were based on previous studies (see Storbeck,

2012; Storbeck, Davidson, Dahl, Blass, & Yung, 2015), and the goal was to identify images that fell between the sad and happy images with respect to valence ratings. The neutral images also had lower arousal ratings than the emotional images based on the IAPS arousal norms.

Attentional task. The stimuli were identical to those used in Experiments 1 and 2.

Manipulation check. The manipulation check matched that of Experiment 1.

Procedure. The procedures were the same as in Experiments 1 and 2. Half of the trials replicated the stimuli and timing procedures of Experiment 1, and the other half of the trials replicated the stimuli and timing procedures of Experiment 2 for both practice and experimental trials.

Results

Emotion check. The manipulation check revealed a significant effect of emotion condition on intended emotional state. A multivariate ANOVA was significant, $F(18, 417) = 10.397$, $p < .001$, $\eta_p^2 = 0.310$, and for each individual item, there was a significant effect of emotion (happiness, $F(3, 142) = 56.686$, $p < .001$, $\eta_p^2 = 0.545$; sadness, $F(3, 142) = 39.160$, $p < .001$, $\eta_p^2 = 0.453$; fear, $F(3, 142) = 34.514$, $p < .001$, $\eta_p^2 = 0.422$; anger, $F(3, 142) = 18.549$, $p < .001$, $\eta_p^2 = 0.282$; disgust, $F(3, 142) = 23.784$, $p < .001$, $\eta_p^2 = 0.334$; arousal, $F(3, 142) = 4.682$, $p = .004$, $\eta_p^2 = 0.090$). The emotion manipulation was successful at inducing the intended emotional state (see Table 1 for Tukey post hoc effects). In addition, the repeated t tests conducted within each emotional condition found that for the happy, sad, and fear conditions the respective induced emotions were experienced more intensely than any other emotion, p values < 0.005. The neutral condition reported higher feelings of happiness compared to fear ($p = .01$), anger ($p = .018$), and disgust ($p = .013$); all other effects for neutral were nonsignificant.

Attention task. To parse through the effect of emotion condition on target detection, a 2 (Distractors: distractors, no distractors) $\times$ 3 (Cue Validity: valid, invalid-middle, invalid-far) $\times$ 2 (Position: horizontal, vertical) $\times$ 4 (Emotion: happy, sad, fear, neutral) repeated measures ANOVA with distractors, cue validity, and position as within-subjects factors and emotion as the between-subjects factor was run with the outcome variable being the accurate reporting of targets. Position was a nonessential factor for the theoretical goals, and because it did not interact with the emotion condition (there was a significant position by cue validity by distractor presence, $p < .001$), we reran the repeated-measures ANOVA without position. Critically, the distractor presence by cue validity by emotion interaction, $F(6, 284) = 3.409$, $p = .003$, $\eta_p^2 = 0.067$, was found to be significant, and therefore, to better understand this three-way interaction, we ran another set of repeated-measures ANOVAs separating the ANOVAs based on distractor presence (See Figure 2 for a graphical presentation of the reporting of targets for both distractor presence and absence).

In replicating Exp. 1, we examined performance with the presence of distractors by running a repeated-measures ANOVA (Cue Validity $\times$ Emotion). As predicted and consistent with the findings in Exp. 1, we observed the cue validity by emotion interaction, $F(6, 284) = 3.958$, $p = .001$, $\eta_p^2 = 0.077$. For the reporting of valid cues, there were no effects due to emotion condition, $F(3, 142) =$
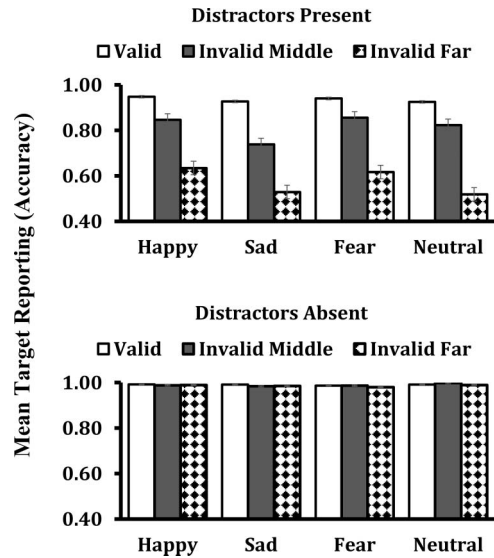

Figure 2. The mean accuracy for recalling the targets presented in the valid and invalid positions for Experiment 3. Error bars represent one standard error of the mean.

0.694, $p = .557$, $\eta_p^2 = 0.014$. When reporting invalid middle targets, a main effect for emotion was observed, $F(3, 142) = 5.179$, $p = .002$, $\eta_p^2 = 0.099$, with the sad condition reporting fewer invalid middle targets than all conditions, p values < 0.007. The other three conditions reported similar number of targets (happy/fear, $p = .468$; happy/neutral, $p = .854$; fear/neutral, $p = .367$). As for the invalid far targets, again, emotion influenced target reporting, $F(3, 142) = 4.296$, $p = .006$, $\eta_p^2 = 0.083$, and the sad and neutral conditions reported fewer targets than the happy, $p = .007$ and $p = .009$, respectively, and fear, $p = .018$ and $p = .023$, respectively, conditions, but the sad and neutral conditions reported a similar number of targets, $p = .931$. The fear and happy condition had similar means, $p = .741$. The remaining significant effects consisted of a main effect for cue validity, $F(2, 284) = 369.592$, $p < .001$, $\eta_p^2 = 0.722$, with greater target reporting for valid compared to invalid cues, and a main effect of emotion, $F(6, 284) = 4.663$, $p = .004$, $\eta_p^2 = 0.090$. The post hoc analyses for emotion revealed that the sad condition reported fewer targets compared to both the happy, $p = .003$, and fear, $p = .002$, conditions. All other effects were not significantly different from each other (happy/fear, $p = .875$; happy/neutral, $p = .087$; sad/neutral, $p = .187$; fear/neutral, $p = .061$); though for the trending effects, the neutral condition was associated with fewer reported targets.

In replicating Exp. 2, we examined performance in the absence of distractors, the repeated-measures ANOVA (Cue Validity $\times$ Emotion) revealed a marginal main effect of cue validity, $F(2, 284) = 2.974$, $p = .053$, $\eta_p^2 = 0.021$, and marginal cue validity by emotion interaction, $F(6, 284) = 2.068$, $p = .057$, $\eta_p^2 = 0.042$. Although not anticipated, the interaction was due to the neutral condition reporting more invalid middle targets compared to the happy, $p = .030$, sad, $p = .003$, and fear, $p = .068$ (marginally), conditions. All the other effects for target reporting were nonsignificant. The effect of emotion was not significant, $F(3, 142) = 1.538$, $p = .207$, $\eta_p^2 = 0.031$.

For the remaining results from the omnibus ANOVA, we found significant main effects for all variables: distractor presence, $F(1, 142) = 520.584$, $p < .001$, $\eta_p^2 = 0.786$, cue validity, $F(2, 284) = 362.664$, $p < .001$, $\eta_p^2 = 0.719$, and emotion condition, $F(3, 142) = 4.318$, $p = .006$, $\eta_p^2 = 0.084$. Individuals were more accurate when distractors were not present, and they were more accurate for valid targets than invalid targets. The sad condition reported fewer targets compared to both the happy, $p = .003$, and fear, $p = .002$, conditions, but not for the neutral condition, $p = .120$; and the remaining conditions revealed no significant effects (happy/fear, $p = .971$; happy/neutral, $p = .141$; fear/neutral, $p = .134$). Every interaction was found to be significant: distractor presence by emotion, $F(3, 142) = 4.882$, $p = .003$, $\eta_p^2 = 0.094$; cue validity by emotion, $F(6, 284) = 4.399$, $p < .001$, $\eta_p^2 = 0.085$; and distractor presence by cue validity, $F(2, 284) = 360.029$, $p < .001$, $\eta_p^2 = 0.717$.

General Discussion

Overall, we observed that happiness and fear, compared to sadness, reported more targets in noncued locations when distractors were present. When the distractors were removed, emotion failed to influence the reporting of noncued targets. The overall pattern of findings suggests that happiness and fear, compared to sadness, impaired the suppression of irrelevant locations, which facilitated the detection of targets presented in noncued locations. Conversely, sadness was more successful at suppressing noncued locations, which impeded the ability to redirect attentional resources to noncued targets. Interestingly, when factoring in the findings of Exp. 3, the sadness, compared to the neutral, condition was superior at inhibiting invalid middle targets, but this enhanced ability to suppress noncued locations decreased for far noncued locations. It is quite possible the neutral condition was less effective at suppressing/inhibiting noncued locations compared to the sad condition, but a more effective suppressing/inhibiting noncued locations compared to the fear and happy conditions yielding such differential findings. Thus, fear and happiness appear to facilitate temporal attentional flexibility for both near and far targets to noncued locations, whereas sadness decreased such attentional flexibility by enhancing the ability to suppress noncued locations.

Conceptually, the effects replicate prior findings that happiness "broadens," whereas sadness "narrows" attention (although see Gable & Harmon-Jones, 2008, 2010). However, these findings question the mechanism responsible for the broadening/narrowing of attention. The spotlight model of attention emphasized spatial attention, and the present findings do not support such a model. The simplest analysis of the findings is that all emotional conditions allow for the splitting of attention increasing attentional flexibility with respect to spatial attention. Thus, emotion per se does not impair or limit the ability to produce two spotlights of attention as all conditions demonstrated the ability to reduce report rates for invalid targets and in particular the invalid middle target. If, however, attention was "narrowed" by fear (or any other emotion), then report rates for the invalid middle target would have been similar to report rates for valid targets and potentially higher compared to at least one valid target, but that was not the case. Therefore, these findings argue against a spotlight model of attention when interpreting how emotion is influencing attention.

Instead, we argue the best way to understand the results is to suggest that emotion influenced temporal aspects of attention. The ability to perform well on this task requires suppression/inhibition of noncued locations, which would reduce the reporting of targets presented in noncued location. Conversely, greater success at reporting targets in noncued locations would require a less strong suppression/inhibition of noncued locations. A less active suppression/inhibition mechanism would then foster faster reorientation of attention to noncued locations to detect targets. Thus, we favor the interpretation that sadness resulted in the strongest suppression of noncued locations, whereas fear and happiness fostered a less strong suppression mechanism facilitating faster attentional shifting to targets presented in noncued locations.

Newer research also supports the interpretation that emotion is most likely influencing temporal aspects of attention rather than the breadth of attention (i.e., spotlight). For example, Phaf (2015) manipulated the timing and awareness of distractors and targets on a flanker task to test tenets of the spotlight model. He observed that positive, compared to negative, affect increased interference and the interference was due to worse suppression of task irrelevant entities and these results are not supported by a spotlight model (i.e., greater attentional flexibility; see also Kuhbandner, Lichtenfeld, & Pekrun, 2011). Other research has found evidence that sadness, compared to happiness, facilitated the suppression of irrelevant distractors and reduced the attentional blink duration (Jefferies, Smilek, Eich, & Enns, 2008), suggesting that sadness decreased attentional flexibility.

What about fear? When fear states are induced, fear often narrows attention to a single stimulus, particularly a threatening stimulus (Easterbrook, 1959; Eysenck et al., 2007; Finucane, 2011; Harmon-Jones et al., 2013). However, such tasks may have constrained the breadth of possible findings by relying on the spotlight model of attention and/or paradigms with a single, nonambiguous threat among distractors. Broadening the contexts in which fear and attention are examined may serve to clarify and extend the current mechanistic understanding for how fear influences attention. When we changed the paradigm to examine attention to multiple neutral targets presented in noncontiguous regions of space, we observed that fear increased the detection of such neutral targets presented in noncued locations, which suggests fear may in fact increase attentional flexibility when temporal aspects of attention are examined. Yet, does fear always increase attentional flexibility? Probably not, rather it may be situation dependent. Situations or affective states that signal danger, but do not contain a clear, present danger, may increase attentional flexibility facilitating detection of dangerous entities, particularly in the periphery (see Susskind et al., 2008). For example, the detection of dangerous entities among neutral distractors is often facilitated with fear (e.g., visual search task; Fox, Russo, & Dutton, 2002; Mogg & Bradley, 1999; Öhman & Mineka, 2001). Moreover, the fact that fear increases saccade speed, visual extent, and target detection in the periphery (Susskind et al., 2008) would support a more flexible attentional system to detect dangerous entities. Conversely, nonambiguous situations where the threat is clear (e.g., a person with a gun), attentional flexibility may rapidly decrease as attentional resources are quickly redirected toward the dangerous entity and other entities are ignored or inhibited from being attended to (Easterbrook, 1959; Eysenck et al., 2007).

Future Directions

Across studies, we demonstrated the adaptability of attention as a function of emotional state. However, the exact relationship fear has with attention in terms of switching between a more flexible and less flexible attentional system remains unclear. Prior research has demonstrated that when a single, dangerous entity is present (e.g., a man with a gun) fear narrows attention toward that dangerous entity. Though, how would fear direct attention when multiple dangers are present (e.g., two men each with a gun)? Would fear direct attention only to the most salient person? Alternatively, would fear split the foci of attention perfectly for two threatening stimuli and/or still be flexible to identify a third potential threat? Further, can top-down processes govern how attention is directed? Research is needed within a similar paradigm that manipulates the affective quality of the stimuli or locations (i.e., locations that predict a threatening stimuli) to answer such questions. Relatedly, what mechanism caused fear and happiness to more easily identify invalid targets? We suggest that suppression/inhibition underlie the present effects. The manipulation of distractor presence was the primary argument for suggesting inhibition/suppression as the active mechanism. However, this manipulation also allows for alternative mechanisms beyond inhibition/suppression. For instance, emotions may have influenced attentional capture differently when distractors were present or absent. Or emotion may have influenced the foci of attention by making it more or less sharp (or blurry), which can influence target detection independent from inhibition/suppression effectiveness. Resolution of this issue would require a modified paradigm or the use of neuroimaging techniques to identify suppression of neural pathways to clearly elucidate inhibition/suppression as the operant mechanism.

Another question is whether fear intentionally impairs the suppression of irrelevant locations or whether the arousal associated with fear may redirect resources to other cognitive functions leaving few resources remaining to suppress irrelevant locations. Prior research using similar split attention paradigms has found that attentional resources are necessary for splitting foci of attention (Franconeri, Alvarez, & Enns, 2007; Frey et al., 2014), and it is quite possible that fear demonstrated flexible attention due to a failure to recruit sufficient resources to suppress irrelevant locations/entities. Though the present task was low in demand for attentional resources as there were only two locations, clear distinction between targets/distractors, predictable locations, and partial report, we are therefore skeptical that insufficient resources accounted for the findings. But, such effects may be highly likely when the event is extremely arousing (e.g., man with a gun) within a complex environment (e.g., a dark, unknown alley with extreme clutter or to maintain 4 or 5 cued locations). Lastly, it still remains unclear whether the observed effects were a result of spatial or temporal attention and what the relationship is between the two aspects of attention. Higher flexibility of spatial attention (producing multiple spotlights) requires enhanced suppression of nonrelevant locations/entities, but with greater suppression it may dictate that temporal attention becomes less flexible or that people are less likely to reorient their attention toward novel, unexpected, or emotional relevant stimuli. Thus, future research should investigate whether the effects observed in this study are due to interactions of spatial and temporal attention or whether emotion has a greater influence on one specific aspect.

Conclusion

Previous research on emotion and attention have assumed a spotlight model, constraining targets and distractors to contiguous regions of space. The present study assumed a different model of attention, one where attention can split foci of attention across noncontiguous regions of space. Happiness and fear impaired the splitting of attention and enhanced attentional flexibility, which became advantageous when rapid redeployment of attention was required to detect targets in noncued locations. Sadness, conversely, enhanced the ability to suppress or inhibit noncued locations, impairing the ability to redirect attention flexibly to noncued locations. Thus, the benefit for attentional flexibility would be critical for increasing vigilance and detection of potentially dangerous or rewarding entities and/or increasing cognitive flexibility.

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