Effects of Emotion and Cue Validity on Executive Attention Performance

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INTRODUCTION

Emotional faces are salient enough to disrupt attention performance, particularly executive attention control, even when they are task-irrelevant (Dennis, Chen, & McCandliss, 2008; Dennis & Chen, 2007a; Meinhardt & Peknin, 2003). The perception of emotional information requires rapid allocation of attentional resources, which facilitates the processing of these motivationally significant stimuli (West, Adam, Anderson, & Pratt, 2009).

Motivationally salient emotional faces have the potential to disrupt attention; however top-down processes also have the ability to override this disruption and regulate response behavior by allocating cognitive control processes (Bishop, 2008; Kastner & Ungerleider, 2000). When emotional faces are task-relevant cues during an executive attention task, there is thus potential for them to detract, facilitate, or play little role in attention performance.

In addition, other task characteristics, such as whether cues are valid or invalid, influence performance. Valid cues produce less conflict interference and beget better attention performance than invalid cues (Posner, Snyder, & Davidson, 1980; Posner & Peterson, 1990). However, few studies have examined the impact of emotional faces as valid and invalid cues on attention performance.

One way to clarify whether attentional capture by emotion can account for the effects of valid and invalid emotional cues on executive attention is the use of event-related potentials (ERPs). ERPs such as the P100 and N170 reflect early attentional processing, such as early spatial attention (P1; Mangun, 1995) and face-specific attention processing (N170; Eimer, 2000). In addition, both the P1 and the N170 have been shown to be enhanced to emotional versus neutral faces (Wronka & Walentowska, 2011; Blau, Maurer, Tottenham, & McCandliss, 2007; Bentin, Allison, Puce, & Perez, 1996).

In the present study, we examined whether emotional versus neutral cues facilitated or disrupted executive attention performance, and whether effects depend on cue validity. We further examined scalp-recorded event-related potentials (ERPs) in response to cues to test whether effects differed depending on the degree to which attentional resources were recruited.

Furthermore, the processing of emotional stimuli has also been linked to individual differences in emotionality, such as trait anxiety (e.g. MacNamara & Hajcak, 2010) and motivational sensitivities to reward and threat (e.g., behavioral activation system or BAS; Dennis & Chen, 2007b). Thus, it is important to consider how complementary affective-motivational characteristics such as anxiety and reward sensitivity may play a role in moderating the relationship between neural measures of attention to emotion and attention performance.

HYPOTHESES

1. Valid versus invalid cue trials will produce superior executive attention performance (reduced conflict interference on a flanker task).
2. Executive attention performance following emotional versus neutral face cues will be reduced (greater conflict interference on a flanker task).
3. P1 and N170 amplitudes will be modulated by emotional stimuli such that P1 and N170 amplitudes to angry and happy faces will be larger compared to neutral faces.
4. Larger P1 and N170 amplitudes to angry and happy faces will be associated with disrupted executive attention performance. However, individual differences in anxiety and reward sensitivity may moderate this relationship.
- **a.** Larger P1 and N170 amplitudes to angry versus neutral faces, reflecting greater attentional capture by emotion, will be associated with disrupted attention performance but primarily for individuals with high levels of reported anxiety
- **b.** Larger P1 and N170 amplitudes to happy versus neutral faces will be associated with disrupted attention performance but primarily for individuals with high reward sensitivity.

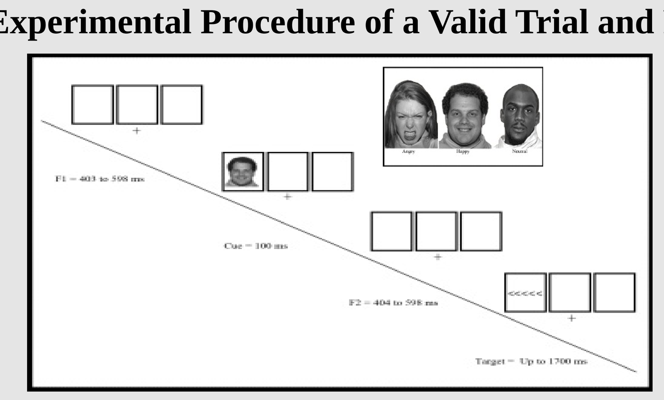
METHOD

Participants
Twenty-five Hunter College students (16 females), aged 18-36 (M = 21.79, SD = 5.27).

Emotional Faces
Emotional faces of 16 actors portraying angry, happy and neutral expressions were shown for a total of 48 stimuli (Tottenham et al., 2009).

The Attention Network Task
- A novel modification of the Attention Network Test (ANT; Fan et al., 2002) was developed for this study. This original ANT combines a cued reaction time (RT) with a flanker task that requires the subject to identify the direction (right or left) of the central arrow that is flanked by either four arrows facing the same direction (congruent trial) or the opposite direction (incongruent trial). The modified version used in the present study included emotional primes (angry, happy or neutral faces). Prior to each trial, an emotional or neutral face stimulus was presented. These face cues are, randomly, valid or invalid in terms of providing information pertaining to the location of the subsequent flanker display.
- The task has a total of nine blocks, with 96 trials per block. There were three blocks for each face condition and the block order was counterbalanced. There were 16 no cue trials, 16 center cue trials, 48 valid spatial cue trials, and 16 invalid spatial cue trials.
- One attention score was generated: **Executive Attention** (RT incongruent – congruent flankers). A higher executive attention score is indicative of greater cognitive conflict, or lower executive attention functioning.

Figure 1. Experimental Procedure of a Valid Trial and Face Stimuli



Trait Anxiety
Participants completed a 20-item trait anxiety questionnaire (Spielberger, 1983) asking about how they generally feel, with higher scores indicating greater levels of trait anxiety (M= 42.79, SD= 12.38).

Reward Sensitivity
Participants completed the BIS/BAS questionnaire (Carver & White, 2004) measuring behavioral inhibition and activation, with higher scores indicating greater reward sensitivity in the following domains: BAS Drive (M = 2.6, SD = .62), Bas Fun Seeking (M = 3.07, SD = .53), and BAS Reward Responsiveness (M = 3.58, SD = .34).

EEG Recordings and Analysis
EEG activity was recorded continuously via 64 Ag/AgCl scalp electrodes at a sampling rate of 512 Hz (BioSemi; Amsterdam, NL). All data preparation after recording was conducted using Brain Vision Analyzer (Version 2.2, GmbH; Munich, DE). The continuous EEG data was filtered with a low cut-off frequency of .1 Hz and a high cut-off frequency of 30 Hz and referenced offline to an average reference. Eye movements were monitored by electro-oculogram (EOG) and ocular artifacts were corrected using the independent components analysis method. Stimulus-locked data were baseline corrected prior to stimulus presentation and segmented between -200ms and 600ms. The P1 was generated by identifying the maximal positive deflection between 90ms and 150ms across P5/P6/P7/P8/PO7/PO8. N170 was generated by identifying the maximal negative deflection between 140ms and 200ms across P5/P7/P6/P8/CP5/CP6.

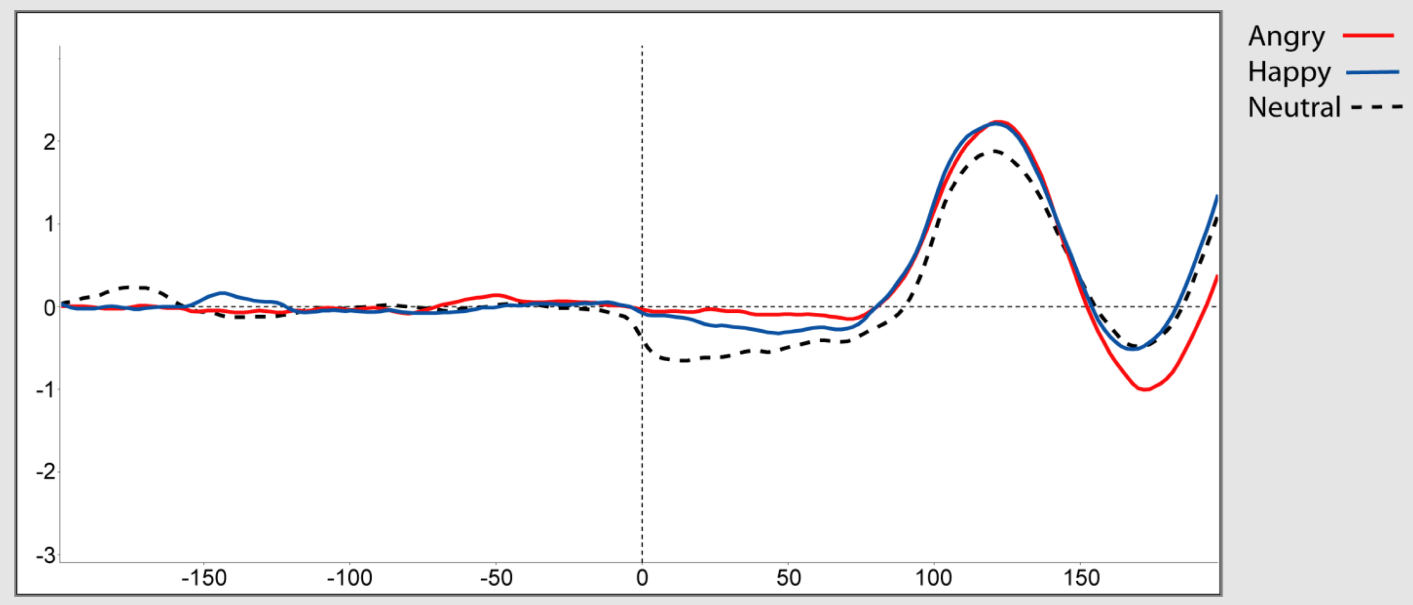
RESULTS

A series of Pearson correlations were conducted between P1 and N170 amplitudes, trait anxiety, BAS subscales, and executive attention performance. P1 happy minus neutral amplitudes were positively correlated with valid executive attention (r = .43, p < .05). No other significant correlations emerged.

Hypothesis 1 and 2
A 4 (Cue: valid, invalid, center, no cue) X 3(Face type: angry, happy, neutral) repeated measures ANOVA was conducted There was a main effect of cue $F(3,69)$ = 8.92, p < .001, partial η^2 = .28. As predicted, valid execution attention performance (M = 147.08, SD = 55.36) was enhanced compared to invalid executive attention (M = 186.55, SD = 64.59), $t(23)$ = -5.28, p < .001, center executive attention (M = 182.44, SD = 55.31), $t(23)$ = -4.84, p < .001 and no cue executive attention (M = 165.35, SD = 78.52), $t(23)$ = -2.63, p < .05. No other significant effects emerged.
Contrary to predictions, emotional faces did not produce greater conflict interference than neutral faces.

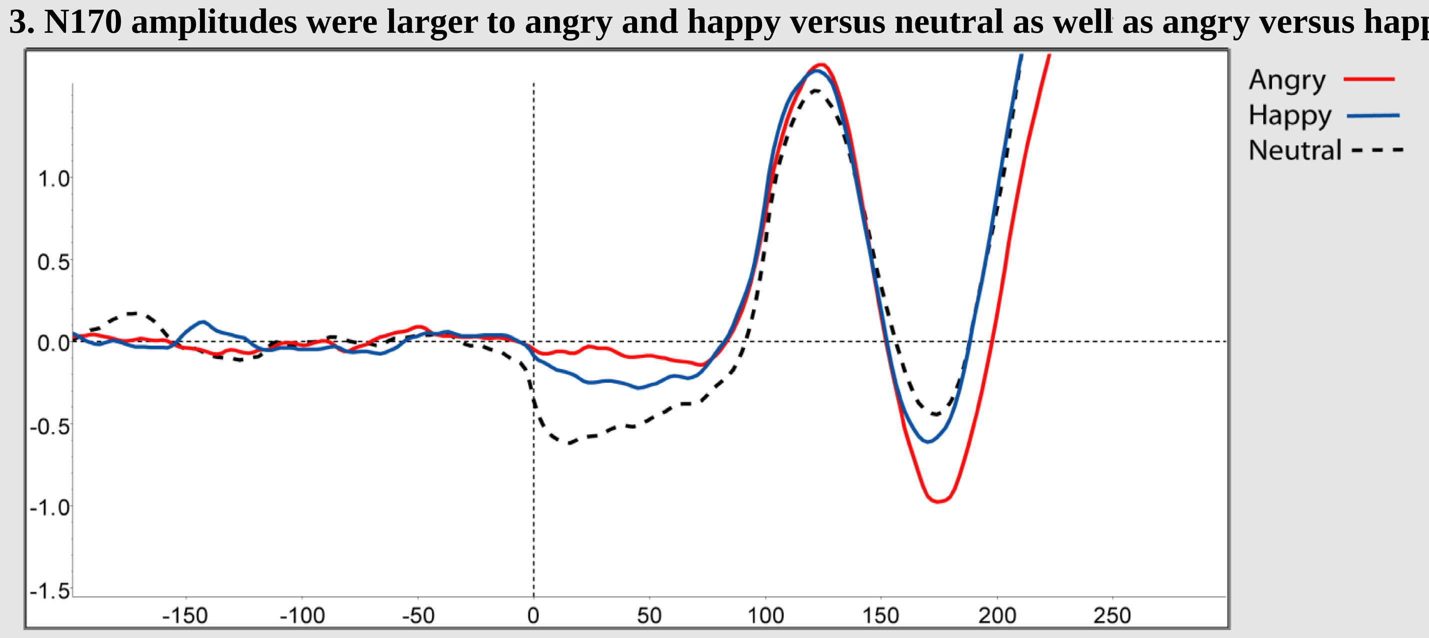
Hypothesis 3
P1
A 3 (Cue: valid, invalid, center) X 3(Face type: angry, happy, neutral) X (Hemisphere: left, right) repeated measures ANOVA was conducted. There was a main effect of emotion $F(2,48)$ = 5.39, p < .01, partial η^2 = .18. As predicted, P1 amplitudes to angry faces (M = 1.84, SD = 1.29) were greater than to neutral faces (M = 1.46, SD = 1.35), $t(24)$ = 3.015, p <.01. In addition, P1 amplitudes to happy faces (M = 1.71, SD = 1.48) were greater than to neutral faces (M = 1.46, SD =1.35), $t(24)$ = 2.031, p = .054. No other significant effects emerged.

Figure 2. P1 amplitudes were enhanced to angry and happy versus neutral face cues.



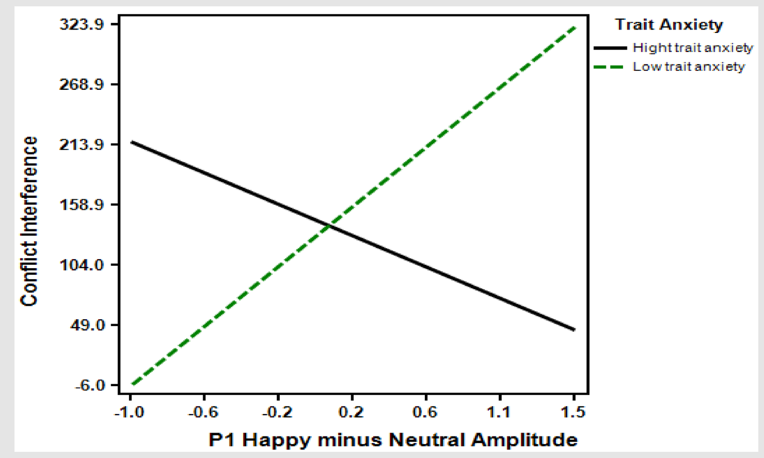
N170
A 3 (Cue: valid, invalid, center) X 3(Face type: angry, happy, neutral) X (Hemisphere: left, right) repeated measures ANOVA was conducted. There was a main effect of emotion $F(1.51,36.36)$ = 7.07, p < .01, partial η^2 = .23. As predicted, N170 amplitudes to angry faces (M = -.37, SD = 1.40) were greater than to happy faces (M = -.17, SD = 1.37), $t(24)$ = -2.24, p < .05 and to neutral faces (M = .05, SD = 1.31), $t(24)$ = -3.01, p < .01. In addition, N170 amplitudes to happy faces (M = -.17, SD = 1.37) were greater than to neutral faces (M =.05, SD = 1.31), $t(24)$ = -2.20, p < .05.
There was a main effect of cue $F(2,48)$ = 14.141, p < .001, partial η^2 = .37. N170 amplitudes to center cues (M = -.63, SD = 1.46) were greater than to valid cues (M = .04, SD = 1.40), $t(24)$ = -4.82, p < .001 and invalid cues (M = .10 , SD = 1.32), $t(24)$ = 4.06, p < .001. No other significant findings emerged.

Figure 3. N170 amplitudes were larger to angry and happy versus neutral as well as angry versus happy faces.



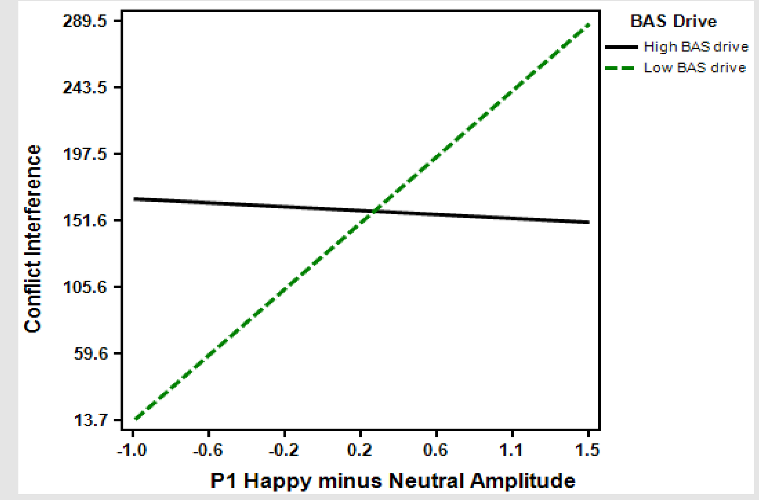
Hypothesis 4a: **P1 X Trait Anxiety Interactions**
Trait anxiety scores and P1 difference scores were entered into the first step of the regression model, followed by the interaction between the two in the second step with valid executive attention scores as the dependent variable. The regression model with P1 amplitudes to happy versus neutral faces and trait anxiety accounted for significant variance in valid executive attention performance, $F(3,19)$ = 3.22, p < .05, R^2 = .34. A simple slopes analysis revealed that the slope for enhanced P1 amplitudes to happy versus neutral faces (-2SD) was significantly different from zero, $t(19)$ = 2.34, p = .015. Contrary to predictions, greater P1 amplitudes to happy as compared to neutral faces were associated with increased conflict interference on valid cue trials, but only for those individuals who reported *lower* trait anxiety.

Figure 4: Greater P1 amplitudes to happy as compared to neutral faces were associated with increased conflict interference on valid cue trials, but only for those individuals who reported lower trait anxiety.



Hypothesis 4b: **P1 x BAS Interactions**
BAS Drive and P1 difference scores were entered into the first step of the regression model, followed by the interaction between the two in the second step with valid executive attention scores as the dependent variable. The regression model with P1 amplitudes to happy versus neutral faces and BAS Drive accounted for significant variance in valid executive attention performance, $F(3,19)$ = 3.21, p < .05, R^2 = .34. A simple slopes analysis revealed that the slope for enhanced P1 amplitudes to happy versus neutral faces (-2SD) was significantly different from zero, $t(19)$ = 2.66, p = .015. Again, contrary to predictions, greater P1 amplitudes to happy as compared to neutral faces were associated with increased conflict interference on valid cue trials, but only for those individuals who reported *lower* reward sensitivity on the BAS Drive.

Figure 5: Greater P1 amplitudes to happy as compared to neutral faces were associated with increased conflict interference on valid cue trials, but only for those individuals who reported lower reward sensitivity on the BAS Drive.



DISCUSSION

- As predicted, conflict interference was significantly reduced on valid cue trials as compared to invalid trials and both ERPs, the P1 and N170, were sensitive to emotion: P1 and N170 amplitudes were larger to angry and happy versus neutral. In addition, the N170 was also differentially sensitive to emotion such that amplitudes were larger to angry versus happy faces.
- Previous research on N170 has shown evidence of emotional sensitivity however it is debated whether this ERP is differentially sensitive (Wronka & Walentowska, 2011; Blau, Maurer, Tottenham, & McCandliss, 2007). Our findings indicate that N170 is modulated by positive and negative emotions.
- In addition, larger P1 amplitudes to happy faces as compared to neutral were associated with increased conflict interference but only for individuals with low trait anxiety and low reward sensitivity. Counter to predictions, these results suggest disrupted attention performance but only for a sample preferentially tuned to happiness with low reported levels of both anxiety and motivation.
- Contrary to predictions, N170 amplitudes were not associated with attention performance even when accounting for individual differences (e.g. trait anxiety and reward sensitivity).
- Collectively, these findings suggest that task characteristics may supersede the effect of low- intensity emotional stimuli on attention, even when emotion effectively recruits attentional resources.
- Individual differences did moderate the relationship between neural measures of attention to emotion and attention performance. As a result, factors such as anxiety and reward sensitivity may be an important element in gating attention interference.
- Future studies should aim to systematically vary the degree to which emotional faces are relevant within an attention task (e.g. primes, cues, or distracters). One example would be to substitute arrows with emotional faces in the flanker task.

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