

Influence of trait behavioral inhibition and behavioral approach motivation systems on the LPP and frontal asymmetry to anger pictures

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Behavioral approach and avoidance are fundamental to the experience of emotion and motivation, but the motivational system associated with anger is not well established. Some theories posit that approach motivational processes underlie anger, whereas others posit that avoidance motivational processes underlie anger. The current experiment sought to address whether traits related to behavioral approach or avoidance influence responses to anger stimuli using multiple measures: ERP, electroencephalographic (EEG) α -asymmetry and self-report. After completing the behavioral inhibition system/behavioral approach system (BIS/BAS) scales, participants viewed anger pictures and neutral pictures. BAS predicted larger late positive potentials (LPPs) to anger pictures, but not to neutral pictures. In addition, BAS predicted greater left-frontal asymmetry to anger pictures. Moreover, larger LPPs to anger pictures related to greater left-frontal EEG asymmetry during anger pictures. These results suggest that trait approach motivation relates to neurophysiological responses of anger.

Keywords: Behavioral inhibition system (BIS); behavioral approach system (BAS); anger; late positive potential; approach motivation; frontal α -suppression asymmetry

INTRODUCTION

One of the fundamental systems in organisms is the motivation to go toward stimuli *vs* the motivation to freeze or move away from stimuli. The distinct motivational responses to approach or avoid are inherent in affective responses, and trait motivational responses are embedded into personality. In affective responses such as fear or excitement, motivational responses to avoid or approach (respectively) are apparent. However, the system associated with anger is less clear; anger responses may be associated with either behavioral approach or withdrawal systems. The current experiment sought to clarify the motivational system associated with anger responses by investigating the relationship of trait motivational systems with multiple measures [ERP, electroencephalographic (EEG) α -asymmetry and self-report] of anger responses.

Approach motivation has been associated with the behavioral approach system (BAS; Gray, 1970, 1987; Gray and McNaughton, 2000), behavioral activation system (also BAS; Fowles, 1987) or a behavioral facilitation system (Depue and Collins, 1999). Functionally, the approach motivational system is thought to modulate reactions to appetitive or rewarding stimuli and generate anticipatory positive affect (Gray, 1994). In contrast, withdrawal motivation has been associated with the behavioral inhibition system (BIS; Gray, 1970, 1987). This system is thought to modulate reactions to aversive stimuli and generate negative affective states such as fear and anxiety.

Related to Gray's (1987) theory of motivation, Carver and White (1994) developed a scale designed to measure the individual difference in trait sensitivity of these two systems (BAS and BIS). [Carver (2009) refers to BAS and BIS as incentive and threat sensitivity. However, these trait measures are empirically related to approach and withdrawal systems, respectively.] BAS is examined along three different expressions of behavioral approach: BAS Drive, BAS Reward Responsiveness and BAS Fun-Seeking. Drive measures persistent pursuit of desired goals. Reward Responsiveness measures positive

responses to the occurrence or anticipation of reward. Fun-Seeking measures a desire for potential new rewards. Expressions of trait BAS relate to achievement goals (Elliot and Thrash, 2002), mania (Meyer *et al.*, 2001), extraversion, (Harmon-Jones *et al.*, 2002), novelty seeking and optimism (Carver and White, 1994). BIS measures reactions to the expectation of punishment. Individuals high in BIS sensitivity report more nervousness before and during an uncomfortable task (Carver and White, 1994) and high levels of anxiety in response to fear-related stimuli (Leen-Feldner *et al.*, 2004).

Because of the strong relationship between motivation and affective states, BAS has been predominantly associated with positive-approach affect, and BIS has been predominantly associated with negative-withdrawal affect (Balconi *et al.*, 2012). However, anger does not completely fit within a positive-approach or negative-withdrawal framework. This raises the question: what is the relationship between anger and trait motivation?

Behavioral approach/avoidance and anger

Some models of emotion posit that anger is related to an avoidance motivational tendency and stems from avoidant systems like fear (Lang *et al.*, 1998). Factor-analytical studies based on retrospective self-reported emotion suggest that anger and other negative affects (e.g. fear) may have the same common source (Watson *et al.*, 1988; Watson, 2009). Situations associated with anxiety may activate more behavioral avoidance in an angry state. For example, the subjective experience of anger may be associated with avoidance, especially under conditions where expressions of anger are related to other negative affects, such as fear from a socially unacceptable situation (Zinner *et al.*, 2008), or when individuals internalize their anger (Stewart *et al.*, 2010).

In contrast, some models suggest that anger relates to the functioning of an approach system (Carver and Harmon-Jones, 2009). For example, anger may arise when approach toward a goal is interrupted or an anticipated reward is blocked (Berkowitz, 1993; Carver and Scheier, 1998, 2008; Rolls, 1999). Functionally, anger is thought to facilitate attempts to remove whatever is impeding goal pursuit (Frijda, 1986; Fischer and Roseman, 2007). For example, in an anger

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state, anger may relate to behavioral measures of approach, such as aggression and goal pursuit (Mikulincer, 1988; Wingrove and Bond, 1998; Carver, 2004). Moreover, neural regions associated with approach and aggression are activated during situational anger (see Harmon-Jones *et al.*, 2010, for a review).

At the trait level, studies have found that both behavioral approach and avoidance relate to anger. Smits and Kuppens (2005) and Cooper *et al.* (2007) found that BIS and BAS were related to trait anger. However, these traits were differentially associated with the way anger is expressed. BAS was positively associated with external expressions of anger, but BIS was inversely related to outward expressions. Other research has also found self-reported anger is related to both BIS and BAS, but controlling for anxiety-related traits eliminates the association between BIS and anger (Harmon-Jones, 2003; Carver, 2004).

If anger is associated with approach or withdrawal motivation, then trait motivation sensitivity should relate to multiple affective responses to stimuli designed to evoke anger. The current experiment assessed how trait motivation relates to multiple anger responses as measured by ERP, EEG α -asymmetry and self-report when viewing anger (*vs* neutral) pictures. Specifically, trait motivation should relate to anger responses assessed by the late positive potential (LPP) and frontal-cortical asymmetry.

Motivation and the LPP

The LPP evoked by picture stimuli is a reliable index of motivated attentional processing (for reviews, see Ferrari *et al.*, 2008; Olofsson *et al.*, 2008; Hajcak *et al.*, 2012). Highly arousing affective pictures evoke larger LPPs than low arousing and non-affective pictures (Cuthbert *et al.*, 2000; Schupp *et al.*, 2000, 2004b), because highly arousing emotional pictures are motivationally relevant (Lang, 1995; Bradley, 2009). Thus, the LPP is thought to reflect motivational intensity rather than a specific motivational direction. Modulation of the LPP by affective pictures also occurs regardless of perceptual differences in complexity, brightness, contrast or spatial frequency that modulate early ERP components (Bradley *et al.*, 2007). Because the LPP is 'the most reliable ERP component modulated by stimulus significance in a passive picture viewing context' (Bradley, 2009, p. 5), the current experiment will focus on the LPP component of the ERP. [Because early ERP components (e.g. N1) are sensitive to affective images, it is likely ERP components occurring earlier than the LPP may be larger to anger than neutral pictures.]

BIS and BAS have been associated with LPP activation. Specifically, LPPs to aversive pictures have been associated with BIS, and LPPs to appetitive pictures have been associated with BAS (Gable and Harmon-Jones, 2010; Balconi *et al.*, 2012). Nijs *et al.* (2007) also found that BAS related to LPPs elicited by non-affective, goal-relevant targets in an oddball paradigm. However, no past research has examined whether the LPP is sensitive to anger pictures, or whether the LPP to anger pictures is associated with trait approach or withdrawal motivation.

Frontal asymmetry and motivation

Frontal cortical asymmetry is one of the most prominent neurophysiological measures of motivational direction. Over 70 years of research using a variety of methods indicate that the left and right frontal cortical regions are asymmetrically involved in positive affect/approach motivation and negative affect/withdrawal motivation, respectively (Goldstein, 1939; Rossi and Rosadini, 1967; for reviews, see Pizzagalli *et al.*, 2003; Spielberg *et al.*, 2008; Harmon-Jones *et al.*, 2010). This research often uses asymmetric activity in right- *vs* left-frontal cortical areas as measured by suppression of the α -frequency band activity derived from EEG recordings (Coan and

Allen, 2003a, 2004). α -Power is inversely related to regional brain activity as evidenced by hemodynamic measures (Cook *et al.*, 1998) and behavioral tasks (Davidson *et al.*, 1990).

Greater left frontal-cortical activation is involved in state approach motivation (Harmon-Jones and Sigelman, 2001; Gable and Harmon-Jones, 2008). In contrast, greater right frontal-cortical activation is involved in state withdrawal motivation (Silva *et al.*, 2002; Buss *et al.*, 2003; Stewart *et al.*, 2010). Moreover, frontal asymmetry relates to motivation at the trait level (Harmon-Jones and Sigelman, 2001; Harmon-Jones, 2006; Gable and Harmon-Jones, 2008; Harmon-Jones *et al.*, 2009, 2010), such that greater BAS is associated with greater left-frontal activation (Harmon-Jones and Allen, 1997; Coan and Allen, 2003b; Amodio *et al.*, 2008), and greater BIS is associated with greater right-frontal activation (Sutton and Davidson, 1997; Balconi and Mazza, 2009; Balconi, 2011).

The current experiment

The current experiment sought to clarify the motivational system associated with anger responses by investigating the relationship of trait motivational sensitivity with the LPP and frontal asymmetry. Trait motivation was assessed using Carver and White's (1994) BIS/BAS scales. To manipulate anger using picture stimuli, we used personally relevant scenes designed to evoke anger (Harmon-Jones *et al.*, 2006). Consistent with the idea that anger is evoked when an expected standard has been violated (Ortony *et al.*, 1988), we selected a series of anti-American pictures (e.g. flag-burning), because pictures of threats toward the United States should evoke greater subjective anger. Previous studies using similar pictures have demonstrated that such stimuli reliably evoke anger (Harmon-Jones *et al.*, 2011).

Despite much evidence associating motivation and frontal asymmetry, some past research has failed to find predicted frontal asymmetry using picture stimuli (Hagemann *et al.*, 1998; Elgavish *et al.*, 2003; see reviews by Murphy *et al.*, 2003; Pizzagalli *et al.*, 2003). This inconsistency may have been due to the pictures evoking different levels of motivation across participants; some participants may have responded with little to no motivation, and others with strong motivation (Harmon-Jones, 2007). In support of this hypothesis, Gable and Harmon-Jones (2008) found that individual differences in motivation (e.g. liking for dessert and time since participants had last eaten) interacted with picture type (desserts *vs* neutral objects) to predict greater left-frontal asymmetry toward dessert pictures. Individual differences in trait motivation sensitivity, as measured by the BIS/BAS scale, should predict frontal asymmetry and LPP amplitudes to anger pictures, but not neutral pictures.

In order to more fully investigate the motivational system associated with anger, several hypotheses were generated. First, because past research is mixed on whether anger is associated with BIS or BAS, we predicted that BIS and/or BAS may relate to more self-reported anger. [Carver and White (1994) conceptualized BAS Drive, BAS Reward Responsiveness and BAS Fun-seeking as being different manifestations of the behavioral approach system. Consistent with this view, we consider BAS to be assessed by any of the three BAS scales and/or a combination of all three scales (i.e. overall BAS). Past research has found that Drive and Reward Responsiveness have been most closely associated with anger responses (Wingrove and Bond, 1998; Harmon-Jones, 2003; Carver, 2004).] Second, if anger evoked by the picture stimuli is associated with approach or withdrawal motivation, then trait BIS or BAS should predict greater LPP amplitudes to anger pictures. Specifically, if anger is related to greater approach motivation, then BAS should relate to LPP amplitudes. In contrast, if anger is related to withdrawal motivation, then BIS should relate to LPP amplitudes. Third, because frontal asymmetry to affective pictures is

influenced by individual differences in motivational direction, we predicted that BIS or BAS would predict EEG asymmetry when viewing anger pictures. Specifically, if anger is related to greater approach motivation, then BAS should relate to greater left-frontal activation. In contrast, if anger is related to greater withdrawal motivation, then BIS should relate to greater right-frontal activation. Finally, because the LPP and frontal asymmetry are related to motivational processes, we predicted that if the LPP and frontal asymmetry are related to the same motivation system, then the LPP should relate to measures of frontal asymmetry.

METHOD

Thirty-two (15 female) right-handed introductory psychology students participated in exchange for partial course credit. Handedness was assessed based on participant self-report of hand dominance and behavioral inspection (e.g. writing and button presses). After completing informed consent, participants completed individual difference measures of approach motivation before EEG electrodes were applied. Two participants were excluded from analyses because they had outlying (>3 s.d. from the mean) BAS scores.

Trait BIS/BAS

The BIS/BAS scales contain 20 items and comprise BAS Drive, BAS Reward Responsiveness, BAS Fun-Seeking and BIS. Drive contains four items that pertain 'to the persistent pursuit of desired goals'. Reward Responsiveness contains five items that 'focus on positive responses to the occurrence or anticipation of reward'. Fun-Seeking has four items 'reflecting both a desire for new rewards and a willingness to approach a potentially rewarding event on the spur of the moment' (Carver and White, 1994, p. 322). Items from all BAS scales were averaged to form an index of overall BAS. BIS comprises seven items that measure reactions to the expectation of punishment.

Procedure

Participants viewed 32 anger pictures taken from the Internet and 32 neutral pictures taken from the Internet and the International Affective Picture System (Lang *et al.*, 2005). [Thirty-two anger images were chosen from a larger collection of images because pilot testing showed they evoked the most anger. Also, past studies examining LPP amplitudes and frontal asymmetry to affective pictures have used 30 or 32 images (Gable and Harmon-Jones, 2008, 2010; Dennis and Hajcak, 2009; Harmon-Jones and Gable, 2009). IAPS picture numbers: 2190, 2210, 2215, 2396, 2440, 2441, 2493, 2499, 2516 and 2595.] Anger pictures depicted anti-American scenes (e.g. flag-burning, 9/11 events) and were selected from a larger sample because they evoked the most anger. Each anger picture was matched with a neutral picture, such that objects (e.g. buildings) were matched by shape and size and scenes were matched for people presence and direct gaze or face presence. Picture sizes (1024×768) were equivalent. All pictures were presented in the center of a 20 inch computer monitor and superimposed over a black background. Each trial consisted of a fixation cross (500 ms) followed by an anger or neutral picture (6000 ms). Intertrial interval was 3 s.

Following picture viewing, participants reported affective reactions to the pictures, indicating how positive (*vs* negative) and arousing (*vs* calming) each picture was (1 = *positive/excited*; 9 = *negative/calm*) by pressing the corresponding numbers on a computer keyboard. Arousal ratings were reverse coded so that high ratings indicated high arousal. Participants also indicated how angry they felt when they viewed the picture (1 = *no emotion*; 9 = *strongest feeling*).

EEG assessment and processing

EEG, recorded with 64 tin electrodes mounted in a stretch lycra cap (Electro-Caps, Eaton, OH, USA), was referenced to the left earlobe. A ground electrode was mounted midway between FPZ and FZ. Electrode impedances were $<5000 \Omega$ and homologous sites were within $\leq 1000 \Omega$ of each other. Signals were amplified with Neuroscan SynAmps RT amplifier unit (El Paso, TX, USA), low-pass filtered at 100 Hz, high-pass filtered at 0.05 Hz, notch filtered at 60 Hz and digitized at 2000 Hz. Artifacts (e.g. aberrant signals due to muscle movement or large non-blink eye movements) were removed by hand. Then, a regression-based eye movement correction was applied to remove blinks (Semlitsch *et al.*, 1986), after which the data were again visually inspected to ensure proper correction. Because of equipment malfunction, data from site CZ on two participants were not included in analyses.

ERP assessment

Data were epoched 100 ms before picture onset until 1200 ms after picture onset and re-referenced using a common average reference. Data were filtered with a low pass of 35 Hz. Aggregated waveforms for each picture type were created and baseline corrected using the pre-stimulus interval.

LPP amplitude was measured as the mean EEG activity within a window of 500–1000 ms (Hajcak and Dennis, 2009; Gable and Harmon-Jones, 2010). An average of 27.75 (86.7%) anger picture trials per participant (888 total anger trials) and 27.53 (86.0%) neutral picture trials per participant (881 total neutral trials) were included in analyses. No participant had fewer than 20 trials per condition.

Based on visual inspection of the aggregated waveforms, it appeared that there were prominent N1 and N2 differences between conditions. Therefore, we also assessed N1 and N2 amplitudes. N1 amplitudes were measured as the minimum amplitude within a window of 60–160 ms and N2 amplitudes were measured as the minimum amplitude within a window of 200–300 ms.

Frontal asymmetry assessment

Consistent with past studies measuring state frontal-cortical activation to affective pictures using α -band power (see Coan and Allen, 2004, for a review; Jackson *et al.*, 2003; Hewig *et al.*, 2004; Harmon-Jones *et al.*, 2006), power spectra epochs 1.024 s in duration were extracted through a Hamming window (50% taper of distal ends). Data were re-referenced using a common average reference. Consecutive epochs were overlapped by 50% to minimize data loss due to windowing. Consistent with previous research showing that high α -power is most reflective of the inverse of cortical activity (Pizzagalli *et al.*, 2005) and emotive processing (Klimesch *et al.*, 1997; Harmon-Jones *et al.*, 2011), power values within the high α -band (10–12.75 Hz) were obtained using a fast Fourier transformation and aggregated across picture type for all 6 s of picture viewing. Asymmetry indexes (\log right – \log left) were computed for all homologous sites. Because α -power is inversely related to cortical activity (Lindsley and Wicke, 1974), higher scores indicate greater left hemisphere activity. An average of 336.38 anger picture sweeps per participant (10 764 total anger picture sweeps) and 331.69 neutral picture sweeps per participant (10 614 total neutral picture sweeps) were included in analyses. No participant had fewer than 226 sweeps per picture type.

RESULTS

Anger pictures were rated as being more negative (mean = 6.67, s.d. = 1.55) and arousing (mean = 4.87, s.d. = 2.05) than neutral pictures (mean = 3.97, s.d. = 1.13; mean = 2.64, s.d. = 1.53), $t_s > 5.97$, $P_s < 0.0001$. Participants also reported feeling more anger toward

Table 1 Correlation coefficients for picture type, picture ratings and BAS/BIS scales

	Anger			Neutral		
	Valence	Arousal	Anger	Valence	Arousal	Anger
Drive	0.35	0.36*	0.47*	-0.13	0.05	0.17
Reward Responsiveness	0.09	0.31	0.24	-0.03	-0.14	0.04
Fun-Seeking	-0.06	-0.04	0.09	0.10	0.51*	0.27
Overall BAS	0.18	0.30	0.38*	-0.02	0.20	0.24
BIS	0.21	0.32	0.46*	-0.12	-0.12	0.18

Correlations marked by asterisks are significant ($P < 0.05$). Higher scores indicate greater negativity, arousal and anger.

anger pictures (mean = 4.84, s.d. = 2.27) than neutral pictures (mean = 1.24, s.d. = 0.30), $t(27) = 9.12$, $P < 0.0001$. Anger ratings to anger pictures related to greater negativity ($r = 0.64$, $P < 0.001$) and arousal ($r = 0.72$, $P < 0.001$) to anger pictures. Greater arousal to anger pictures related to greater negativity to anger pictures ($r = 0.55$, $P = 0.002$). Ratings to neutral pictures were unrelated, $r_s < 0.31$, $P_s > 0.11$. These results indicate that anger pictures strongly evoked highly arousing negative anger.

Correlations between BIS/BAS and picture ratings revealed that Drive related to greater anger and arousal ratings to anger pictures (Table 1). Overall BAS predicted greater ratings of anger toward anger pictures. BIS also related to greater anger ratings to anger pictures. Because Drive was the most sensitive to anger ratings, we regressed Drive and BIS onto anger and arousal picture ratings. To control for ratings to neutral pictures, difference scores were created between affective and neutral picture ratings for subsequent analyses. Drive significantly predicted more anger toward anger pictures, partial $r = 0.41$, $P = 0.03$, controlling for BIS. In contrast, BIS marginally predicted more anger toward anger pictures partial $r = 0.37$, $P = 0.06$, controlling for Drive. These results indicate that BAS was significantly related to subjective anger.

LPP amplitude

Because past research indicates that LPP amplitudes are most prominent at midline sites (Olofsson *et al.*, 2008; Weinberg *et al.*, 2012, unpublished data) and to reduce the number of statistical tests, we examined LPP amplitudes aggregated across picture type at indices of frontal, central-parietal and occipital midline sites (frontal: F1, FZ, F2, FC1, FCZ and FC2; central-parietal: C1, CZ, C2, CP1, CPZ, CP2, P1, PZ and P2; occipital: PO3, POZ, PO4, O1, OZ and O2; see Figure 1). Data were normally distributed as assessed by Shapiro-Wilk test of normality, $W_s > 0.97$, $P_s > 0.66$. A 3 (frontal, central-parietal and occipital indices) \times 2 (picture type) repeated-measures ANOVA revealed a significant interaction, $F(2, 58) = 3.37$, $P = 0.04$, $\eta_p^2 = 0.10$. LPP amplitudes were maximal at central-parietal midline sites, $F(2, 58) = 17.25$, $P < 0.0001$, $\eta_p^2 = 0.37$. Anger pictures evoked larger LPPs than neutral pictures, $F(1, 29) = 13.01$, $P = 0.001$, $\eta_p^2 = 0.31$ (Figure 2). However, follow-up analyses indicated that this was only in the central-parietal index ($P < 0.001$), but not at frontal or occipital indices, $P_s > 0.43$. These results indicate that the LPP is sensitive to affective pictures evoking anger. Because LPP amplitudes at central-parietal sites were maximal and most sensitive to affective pictures, the central-parietal index was used for subsequent LPP amplitude analyses.

To test the prediction that trait motivation would relate to LPP amplitudes to anger pictures, we conducted a regression analysis following the methods of Aiken and West (1991) in which the BIS/BAS scales and picture type were used to interactively predict LPP amplitudes. Drive interacted with picture type to predict larger LPPs to

anger pictures than to neutral pictures, $F(1, 28) = 9.04$, $P = 0.01$, $\eta_p^2 = 0.24$ (Figure 3). Analyses of the interaction slopes revealed that greater Drive predicted larger LPP amplitudes to anger pictures, partial $r = 0.49$, $P = 0.01$, controlling for LPP amplitudes to neutral pictures (Figure 4). In contrast, Drive was marginally related to smaller LPP amplitudes to neutral pictures, partial $r = -0.35$, $P = 0.06$, controlling for LPP amplitudes to anger pictures. Regression interactions with Reward Responsiveness and Fun-Seeking were not significant, $F_s < 1.84$, $P_s > 0.18$. The interaction between overall BAS and picture type predicting LPP amplitudes was marginally significant, $F(1, 28) = 3.60$, $P = 0.06$, $\eta_p^2 = 0.11$. Analyses of the interaction slopes revealed that greater overall BAS marginally predicted larger LPPs to anger pictures, partial $r = 0.33$, $P = 0.07$, controlling for LPPs to neutral pictures. In contrast, overall BAS did not relate to LPPs to neutral pictures, partial $r = -0.23$, $P = 0.24$, controlling for LPP amplitudes to anger pictures. BIS did not interact with picture type to predict larger LPPs to anger pictures than to neutral pictures, $F(1, 28) = 0.07$, $P = 0.79$. These results indicate that LPP amplitudes to anger pictures were related to trait BAS, but not trait BIS.

Larger LPP amplitudes to anger pictures marginally predicted greater arousal to anger pictures, partial $r = 0.33$, $P = 0.08$, controlling for LPP amplitudes and arousal to neutral pictures. Valence and anger ratings did not relate to LPP amplitudes to anger pictures, partial $r_s < 0.29$, $P_s > 0.13$, controlling for LPP amplitudes and ratings to neutral pictures.

N1 and N2 amplitude

Because past research indicates that N1 and N2 amplitudes are most prominent at central-parietal midline sites (Foti *et al.*, 2009; Weinberg and Hajcak, 2010; Gable and Harmon-Jones, 2011, 2013), we examined N1 and N2 amplitudes aggregated across picture type at an index of central-parietal sites (C1, CZ, C2, CP1, CPZ and CP2). Analyses revealed that anger pictures elicited greater N1 and N2 amplitudes than neutral pictures at central sites, $F_s > 9.10$, $P_s < 0.01$.

Valence, arousal and anger ratings did not relate to N1 or N2 amplitudes to anger pictures, partial $r_s < 0.17$, $P_s > 0.38$, controlling for N1 and N2 amplitudes and ratings to neutral pictures. N1 and N2 amplitudes did not relate to the BAS or BIS scales, partial $r_s < 0.14$, $P_s > 0.51$, controlling for N1 and N2 amplitudes to neutral pictures.

Frontal asymmetry

Based on previous research examining asymmetrical EEG activity at lateral-frontal and lateral-frontal-central sites (Harmon-Jones *et al.*, 2002; Harmon-Jones and Sigelman, 2001; Harmon-Jones and Gable, 2009), frontal asymmetry was assessed using an index at lateral-frontal sites (F8/F7, FC6/FC5). Consistent with past research examining the effect of picture type on frontal asymmetry (Harmon-Jones, 2006, 2007; Gable and Harmon-Jones, 2008), comparison of picture type on frontal asymmetry revealed no significant results within the 6 s of picture viewing, $t(29) = 0.49$, $P = 0.63$. However, based on this past work, we tested the prediction that trait motivation and picture type would interactively relate to frontal asymmetry activation to anger pictures. We conducted a regression analysis in which the BIS/BAS scales and picture type were used to interactively predict left-frontal activation. Drive interacted with picture type to predict greater left-frontal activation to anger pictures than to neutral pictures, $F(1, 28) = 5.99$, $P = 0.02$, $\eta_p^2 = 0.18$. [Results were also examined using power values within the low α -band (8–10.25 Hz). There was a marginal interaction between BAS and picture type predicting low α -band left-frontal activation, $F(1, 28) = 3.20$, $P = 0.08$.] Analyses of the interaction slopes revealed that increased Drive predicted greater left-frontal activation to anger pictures, partial $r = 0.40$, $P = 0.03$,

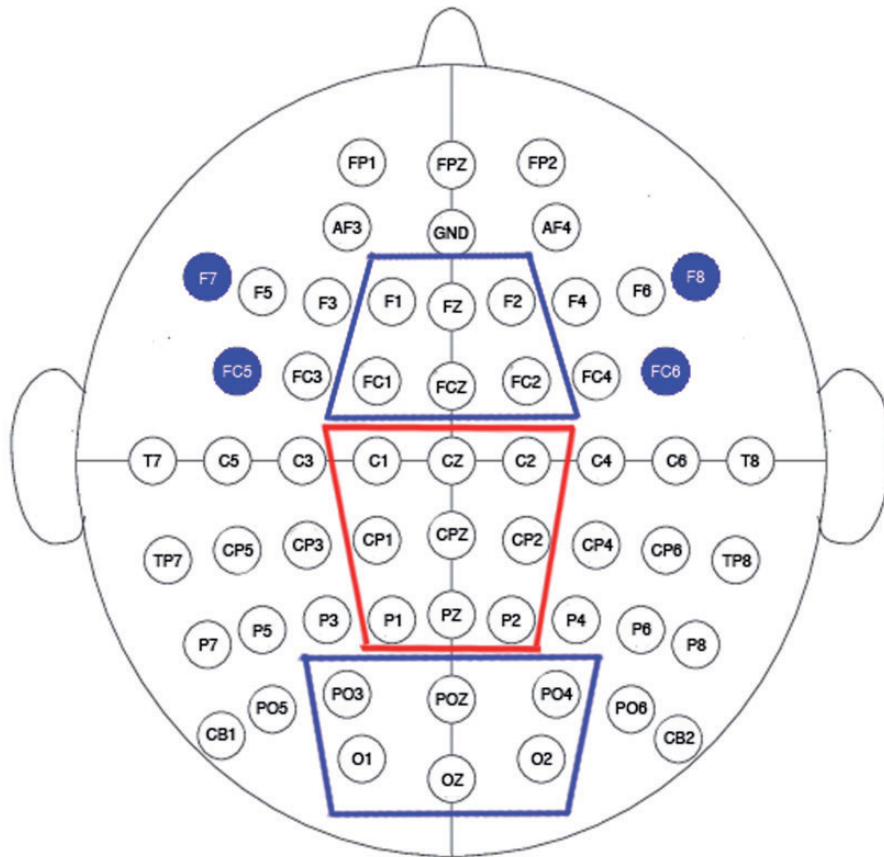


Fig. 1 Electrode configuration with sites of interest. Outlines indicate sites used for LPP indices. Highlighted sites indicate sites used for frontal asymmetry analyses.

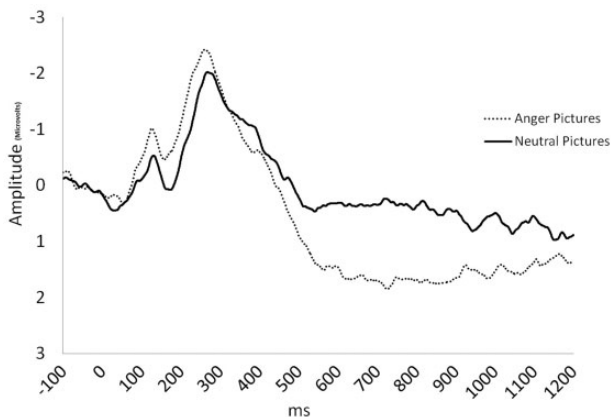


Fig. 2 ERP waveform depicting LPP amplitudes to anger and neutral pictures at the central-parietal index from 100 ms before picture onset to 1200 ms after picture onset.

controlling for responses to neutral pictures. Drive was not related to frontal asymmetry to neutral pictures, $r = -0.20$, $P = 0.28$. Reward Responsiveness also interacted with picture type to predict greater left-frontal activation to anger pictures than to neutral pictures, $F(1, 28) = 7.53$, $P = 0.01$, $\eta_p^2 = 0.21$. Analyses of the interaction slopes revealed that increased Reward Responsiveness predicted greater left-frontal activation to anger pictures, partial $r = 0.45$, $P = 0.02$, controlling for responses to neutral pictures. Reward Responsiveness was not related to frontal asymmetry to neutral pictures, $r = -0.15$, $P = 0.43$. Fun-Seeking did not interact with picture type to predict

greater left-frontal activation to anger pictures than to neutral pictures, $F(1, 28) = 0.43$, $P = 0.52$.

Overall BAS also interacted with picture type to predict greater left-frontal activation to anger pictures than to neutral pictures, $F(1, 28) = 8.64$, $P = 0.01$, $\eta_p^2 = 0.24$. Analyses of the interaction slopes revealed that increased overall BAS predicted greater frontal asymmetry to anger pictures, partial $r = 0.47$, $P = 0.01$, controlling for responses to neutral pictures. Overall BAS was marginally related to frontal asymmetry to neutral pictures, $r = -0.34$, $P = 0.06$. BIS did not interact with picture type to predict greater frontal asymmetry to anger pictures than to neutral pictures, $F(1, 28) = 0.72$, $P = 0.40$. These results indicate that greater left-frontal activation to anger pictures was related to trait BAS, but not trait BIS.

Greater frontal asymmetry to anger pictures predicted greater arousal to anger pictures, partial $r = 0.37$, $P = 0.05$, controlling for greater left-frontal activity and arousal to neutral pictures. Valence and anger ratings did not relate to left-frontal activity to anger pictures, partial $r_s < 0.19$, $P_s > 0.36$, controlling for LPP amplitudes and ratings to neutral pictures.

To further test the relationship between the LPP and frontal asymmetry, LPP amplitudes were regressed onto frontal asymmetry scores. To control for individual differences in LPP amplitudes, we created a difference score between LPP amplitudes to anger pictures and neutral pictures (larger scores indicate larger LPP amplitudes toward anger pictures than to neutral pictures). LPP amplitudes to anger pictures interacted with picture type to predict greater left-frontal activity to anger pictures, $F(1, 28) = 8.17$, $P = 0.01$, $\eta_p^2 = 0.23$. Larger LPP amplitudes toward anger pictures predicted greater left-frontal activation

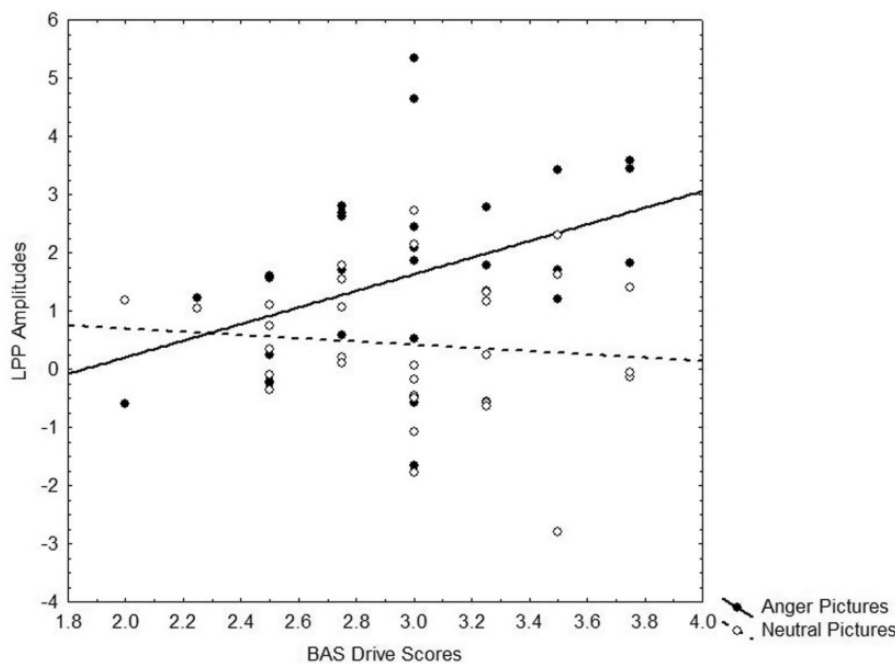


Fig. 3 Relationship between BAS Drive and LPP amplitudes as a function of picture type.

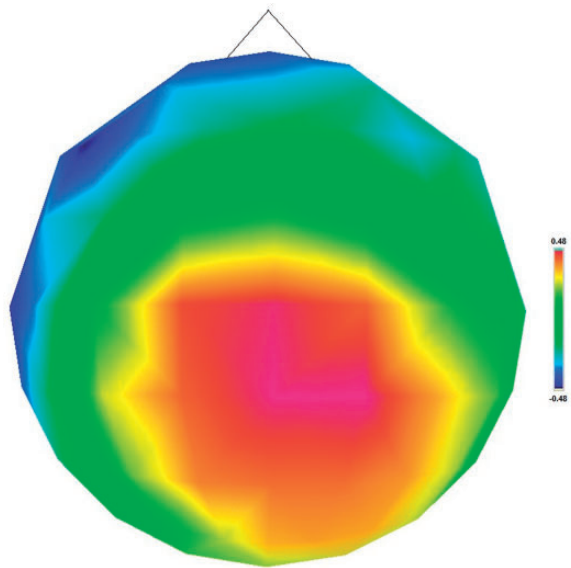


Fig. 4 Topographical map illustrating correlations between BAS Drive and LPP amplitude to anger pictures, controlling for LPP amplitude to neutral pictures.

toward anger pictures, partial $r = 0.71$, $P < 0.001$, controlling for frontal activation to neutral pictures (Figure 5). LPP amplitudes to anger pictures were not related to left-frontal activation toward neutral pictures, partial $r = -0.31$, $P = 0.10$, controlling for frontal activation to anger pictures. These results indicate that LPP amplitudes to anger pictures were related to greater left-frontal activation, a state measure of approach motivation.

DISCUSSION

The current experiment found that trait approach motivation related to neurophysiological anger responses when viewing pictures. Anger

pictures evoked larger LPP amplitudes than neutral pictures, and BAS related to LPP amplitudes to anger pictures. These results suggest that the LPP to anger pictures is related to BAS sensitivity. In addition, trait BAS predicted greater left-frontal activation to anger pictures, suggesting that individuals high in behavioral approach sensitivity had greater state approach motivation during anger pictures. Moreover, LPP amplitudes to anger pictures predicted greater left-frontal activation toward anger pictures but not neutral pictures, suggesting that the LPP to anger pictures is related to state neurophysiological measures of approach motivation. Notably, trait approach motivation related to relatively early (i.e. <1 s) neurophysiological responses as measured by the LPP ERP component to anger pictures, as well as neurophysiological assessments of motivational relevance throughout the entire 6 s of anger picture display.

The current experiment is the first to demonstrate that the LPP is sensitive to pictures evoking anger. These findings extend much past research investigating the LPP to negative affects other than anger. These results also extend previous research on the LPP by suggesting that the LPP to anger pictures is related to approach motivation. Much past research has shown that the LPP is sensitive to aversive as well as appetitive stimuli (Schupp *et al.*, 2004a; Briggs and Martin, 2009; MacNamara and Hajcak, 2009; Gable and Harmon-Jones, 2010; Weinberg and Hajcak, 2010; Harmon-Jones *et al.*, 2011). These past findings suggest that the LPP is related to motivational intensity. In conjunction with these past findings, the current results suggest that the LPP may reflect intensity of the motivational direction engaged by affective stimuli. Recent research has found that BAS relates to LPPs evoked by approach-motivation positive pictures and BIS relates to LPPs evoked by withdrawal-motivation negative pictures (Balconi *et al.*, 2012). The current results suggest that the LPP to anger pictures is related to approach motivation and not to withdrawal motivation. In sum, the LPP may reflect intensity of the motivational direction engaged by affective stimuli.

In the current experiment, BAS and BIS related to subjective ratings of anger. This relationship is consistent with prior research showing that self-reported anger is associated with BAS and BIS

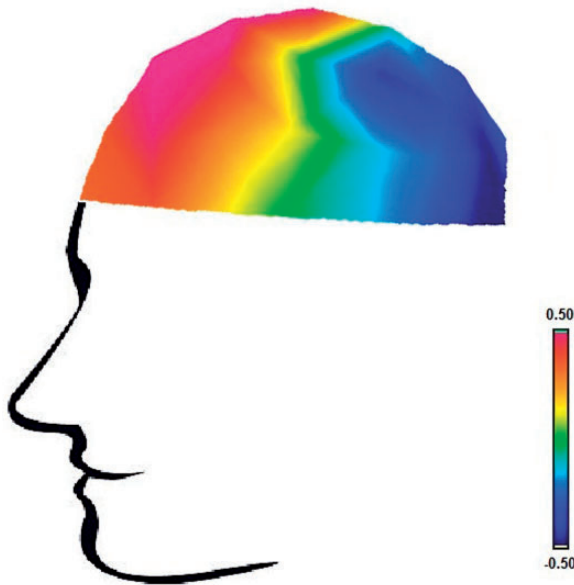


Fig. 5 Topographical map illustrating correlations between LPP amplitude difference scores (anger-neutral) and left-frontal activity difference scores (anger-neutral).

(Harmon-Jones, 2003; Carver, 2004; Smits and Kuppens, 2005). However, when controlling for anger responses to neutral pictures, Drive remained a significant predictor of subjective anger, but BIS did not. Past studies have found that after controlling for trait fear (e.g. anxiety or nervousness), BIS no longer related to anger. In the current experiment, the subjective experience of anger toward threats to the United States may cause avoidant-anger in individuals high in BIS. Future research should incorporate self-report measures of withdrawal-related emotions.

Findings in the current experiment may help tease apart the dimensions of motivational direction as opposed to general arousal in anger. For example, arousal is inherent in both strong approach and strong avoidant affects. Both high BAS and high BIS individuals should experience greater arousal to anger pictures. However, the relationship between BAS Drive and subjective arousal suggests that BAS, but not BIS, was associated with arousal toward anger pictures. Consistent with prominent models of emotion which propose that emotional arousal is an index of motivational intensity (Bradley and Lang, 2007), LPP amplitudes and greater left-frontal activation to anger pictures related to subjective arousal to anger pictures.

Furthermore, by manipulating anger states, the current experiment helps disentangle approach motivation from affective valence. That is, affective valence is typically thought to control motivational direction (De Cesarei and Codispoti, 2011), and positive affects are generally associated with approach motivational intensity. However, results of the current experiment help further link anger with approach motivation (Harmon-Jones and Sigelman, 2001; Harmon-Jones, 2004, 2007; Harmon-Jones *et al.*, 2004, 2008).

Conflict of Interest

None declared.

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