Trait behavioral approach sensitivity (BAS) relates to early (< 150 ms) electrocortical responses to appetitive stimuli

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Abstract

Much past research has focused on how traits related to the behavioral inhibition system (BIS) and avoidance motivation influence the almost obligatory attentional processing of aversive stimuli as measured as early as 100 ms into stimulus processing. These results fit with the functional importance assigned to the negativity bias. But do traits related to the behavioral approach system (BAS) influence attentional processing with similar rapidity? The present study addressed this unanswered question by testing whether trait BAS relates to event-related potentials (ERP) involved in rapid motivated attentional processing to appetitive stimuli. Results indicated that individual differences in BAS were correlated with larger ERP amplitudes as early as 100 ms into the processing of appetitive pictures. These results provide the first evidence linking trait approach motivational tendencies to very early stages of motivated attentional processing.

One of the most important distinctions in motivation is that of motivational direction – the tendency to go toward stimuli vs. the tendency to freeze or move away from stimuli. These distinct motivational responses – approach vs. avoidance -- have been referred to in various ways and have often been posited to be part of a system of responses. These fundamental motivational responses influence attentional responses and are also ingrained into personality. Although much research has suggested that manipulations of both of these motivational systems and assessment of individual differences in avoidance motivation influence early attentional processes, no prior research has tested whether individual differences in approach motivation influence early attentional processes. The present research sought to fill this important void.

Approach motivational responses have been theorized to be part of a behavioral approach system (BAS; Gray, 1970, 1987; Gray & McNaughton, 2000), behavioral activation system (also BAS; Fowles, 1987), or a behavioral facilitation system (Depue & Collins, 1999). The approach motivational system is posited to mediate reactions to appetitive or rewarding stimuli. Consequently, the approach motivational system is involved in the generation of anticipatory positive affect (Gray, 1994) and anger when approach goals are frustrated (Carver & Harmon-Jones, 2009). The approach motivational system is associated with personality characteristics related to optimism, reward responsiveness, and impulsiveness (Carver & White, 1994), which relate to clinical problems such as addictive behaviors, high-risk impulsive behaviors (Alloy et al., 2009), and mania (e.g., Nusslock, Abramson, Harmon-Jones, Alloy, & Hogan, 2007; Urosevic, Abramson, Harmon-Jones, & Alloy, 2008).

The motivational system presumed to underlie avoidance or freezing has been referred to as a behavioral inhibition system (BIS; Gray, 1970, 1987). This system is posited to mediate reactions to aversive stimuli. Consequently, it is involved in the generation of negative affective states such as fear and anxiety. The freezing/avoidance system is associated with personality characteristics associated with worry and anxious rumination, which relate to clinical problems such as anxiety disorders (e.g., Heym, Ferguson, & Lawrence, 2008; Kimbrel, Mitchell, & Nelson-Gray, 2010).[1]

Carver and White (1994) developed a scale designed to measure individual differences in the sensitivity of these two systems (BAS and BIS, which Carver [2009] now refers to as incentive and punishment sensitivity). The BAS scale measures persistent pursuit of desired goals, positive responses to the occurrence or anticipation of reward, and a desire for new rewards and a willingness to approach rewarding events. It has been found to relate to achievement goals (Elliot & Thrash, 2002), mania (Alloy et al., 2009; Meyer, Johnson, & Winters, 2001), anger, physical aggression (Harmon-Jones, 2003), extraversion, novelty seeking, and optimism (Carver & White, 1994).

The BIS scale measures reactions to the expectation of punishment. Individuals high in BIS sensitivity report more nervousness before and during an uncomfortable task (Carver & White, 1994). BIS sensitivity has been shown to predict self-rated levels of anxiety in response to fear-related stimuli (Leen-Feldner, Zvolensky, & Feldner, 2004).

As indicated by much empirical and theoretical work, attentional processes are vital in assisting the organism in mobilizing resources and preparing for action (Bradley, 2009). Given the close connection between motivation and attention, approach and avoidance motivational systems should involve attentional processes. In particular, the avoidance motivational system should relate to attention toward fear- and anxiety-producing stimuli, and the approach motivational system should relate to attention to appetitive stimuli. Moreover, individual differences in the strength of these two systems should relate to attention to motivationally-relevant stimuli of each system. That is, trait approach motivation should relate to attention to appetitive stimuli, whereas trait avoidance motivation should relate to attention to threatening stimuli.

Much research has examined this individual differences prediction, by examining how avoidance motivation traits relate to attention to threatening stimuli. Individuals who score high on avoidance-related traits, such as anxiety, attend more to threat-relevant information (Joormann, Talbot, & Gotlib, 2007; MacLeod, 2007; Watts, McKenna, Trezise, & Sharrock, 1986). Some of these past studies investigated attentional capture/selection using behavioral tasks (MacLeod 1991; Frischen et al., 2008; Posner, 1980; Olivers & Nieuwenhuis, 2006; Raymond, Shapiro, & Arnell, 1992). Other studies have found avoidance-related traits to be associated with event-related potential measures of attentional processes. For example, Hogan, Butterfield, Phillips, and Hadwin (2007) found that children with high trait anxiety had greater attentional capture to novel auditory stimuli (as measured by event-related potentials [ERP]) than children low in anxiety. Along these lines, early ERP components to threatening stimuli are larger in adults high in trait anxiety than in adults low in trait anxiety (Bar-Haim, Lamy, & Glickman, 2005; Li, Li, & Luo, 2005; Mueller, et al., 2009).

The past literature has focused almost exclusively on the relationship between attention to threat-relevant stimuli and traits related to avoidance. Threat-relevant stimuli are important determinants of attention and action, and extreme responses to them may contribute to anxiety and other disorders associated with negative affect. However, appetitive stimuli are also important determinants of attention and action, and extreme responses to them may contribute to mania and other disorders associated with impulses.

Studies examining participants low in BAS (as measured by depressive symptomology) show that depressed individuals show reduced P3/LPP ERP amplitudes to emotional faces (Cavanagh & Geisler, 2006; Foti, Olvet, Klein, & Hajcak, 2010). In line with these studies, Nijs, Franken, and Smulders (2007) assessed BAS in healthy adults and examined ERP responses to novel letters in an oddball task. BAS related to larger P3 amplitudes to infrequent (vs. frequent) letters. These previous studies all examined ERP differences in clinical populations or used manipulations of novelty. The current study extends this past research by examining how BAS relates to ERP components to appetitive pictures and at even early stages of attentional processes.

In passive picture viewing tasks, early visual ERP components are thought to be driven by bottom-up properties of the stimuli themselves (Olofsson et al., 2008), meaning amplitude fluctuates primarily as a function of perceptual stimulus features such as spatial frequency (Carretié, Hinojosa, López-Martín, & Tapia, 2007), color (Cano, Class, & Polich, 2009), complexity (Bradley, Hamby, Löw, & Lang, 2007) or size (Bradley et al., 2007; Cano et al., 2009; Carretié et al., 2007; De Cesarei & Codispoti, 2006). ERPs in this early time range appear to stem from areas of the visual cortex. However, there is also increasing evidence that ERPs in this time-range may also be sensitive to motivated attentional processes.

One of the earliest ERP components related to motivated attention is a negative-going wave, the N1, which peaks around 120 ms after stimulus onset (Keil et al., 2001).

Similar to other ERP components such as the P3, the N1 is larger to affective pictures than non-affective (i.e., neutral) pictures (Foti, Hajcak, & Dien, 2009). This early modulation of the N1 by emotive stimuli has been proposed to be associated with the early allocation of attention stimuli (Keil et al., 2001). Moreover, the N1 is thought to reflect more compulsory (i.e., bottom-up) capture of attention by emotional stimuli than later ERP components, such as the P3 (Foti, Hajcak, & Dien, 2009; Olofsson et al., 2008; Weinberg & Hajcak, 2011). In addition, other research found that manipulations of attentional scope influence the N1 to appetitive stimuli. Specifically, a manipulated local attentional scope, which has been linked with greater approach motivation (Gable & Harmon-Jones, 2008a, 2010), caused larger N1 amplitudes to appetitive stimuli, relative to a manipulated global attentional scope (Gable & Harmon-Jones, 2011).

The current study was designed to extend past research by testing whether individual differences in approach motivation influence motivated attentional processes as early as 100 ms into appetitive stimulus processing. Such a result would be important theoretically and practically as it would suggest that appetitive personality can influence the rapidity with which one processes appetitive stimuli. To investigate the influence of trait BAS on the attentional capture of appetitive stimuli, we examined electrocortical processes related to attention. Specifically, we predicted that appetitive pictures would evoke larger N1 and P3 amplitudes than neutral pictures, consistent with past research showing that these two components are most influenced by affective pictures. Moreover, individual differences in BAS should predict larger N1/P3 amplitudes to appetitive pictures, but not to neutral pictures. Because of the function of BIS (Gray &

McNaughton, 2000), it was not predicted that BIS would relate to these ERP components to appetitive stimuli.

Methods

43 right-handed introductory psychology women participated for course credit. Participants were pre-screened to ensure they liked desserts. After providing informed consent, participants completed the BIS/BAS (Carver & White, 1994) scale. Then, EEG electrodes were applied.

On individual monitors, participants viewed 64 pictures. Each trial consisted of a fixation cross (500 ms) followed by an appetitive (dessert) or neutral (rock) picture (6 s). Pictures were those used in past studies (Gable & Harmon-Jones, 2008a; Gable & Harmon-Jones, 2008b) and appetitive pictures were found to cause higher ratings of approach-motivated positive affect relative to neutral pictures. Pictures were matched for color, brightness, and object size and presented in a mixed design. Inter-trial interval was 3000 ms.

Trait BIS/BAS

To measure individual differences in BIS/BAS, Carver and White's (1994) 20-question scale was administered. The BIS scale has seven items that measure reactions to the expectation of punishment. The BAS scale is comprised of three subscales: BAS drive, which contains four items related to the persistent pursuit of desired goals; BAS reward responsiveness, which contains five items related to positive responses to the occurrence or anticipation of reward; and BAS fun seeking, which has four items related to a desire for new rewards and a willingness to approach rewarding events. The total BAS score is based on the thirteen items comprising the sub-scales.

EEG Collection and Processing

EEG was recorded with 59 tin electrodes in a stretch-lycra electrode cap. All sites were referenced online to the left earlobe; offline, data were re-referenced using the common average reference (Tanaka & Curran, 2001; Curran & Dien, 2003). Eye movements were recorded from the supra- and suborbit of left eye. Electrode impedances were under 5000 Ω. Signals were amplified with Neuroscan SynAmps2, bandpass filtered (0.1-100Hz; 60-Hz filter enabled), and digitized at 500 Hz. Artifacts such as horizontal eye movements and muscle activity were removed by hand. A regression-based vertical eye movement correction was applied (Semlitsch, Anderer, Schuster, & Presslich, 1986).

The data were epoched for 100 ms before picture (dessert or rocks) onset until 1200 ms after picture onset, and filtered with a lowpass of 35Hz. Aggregated waveforms for each picture type were created and baseline corrected using the pre-stimulus activity. Based on visual inspection of the ERP waveform, N1 amplitude was measured as the minimum amplitude within a window of 70-170 ms. P3 amplitude was measured as the maximum amplitude within a window of 300-500 ms. Because past work has found the N1 and P3 to affective pictures to be maximal at midline central-parietal sites (Foti, et al., 2009; Weinberg & Hajcak, 2010), we created composite N1 and P3 variables based on ERPs at midline sites, CZ, CPZ, and PZ.

Results

N1 amplitudes were greater in response to appetitive pictures than neutral pictures, $t(42) = 4.25$, $p < .001$. In order to test the relationship between individual differences in approach motivation and N1 amplitude, we conducted a GLM analysis in which picture type (appetitive and neutral; entered as a within-subjects factor) and BAS (entered as a continuous predictor) were used to interactively predict N1 amplitudes. Results revealed a significant interaction, $F(1, 41) = 4.97$, $p = .03$, $\eta_p^2 = .12$. Analyses of the interaction slopes were conducted using multiple regression. Results revealed that greater BAS scores predicted greater N1 amplitudes to appetitive pictures ($\beta = -.24$, $p = .02$), controlling for N1 amplitudes to neutral pictures. BAS was unrelated to N1 amplitudes to neutral pictures ($\beta = 0.05$, $p = .85$), controlling for N1 amplitudes to appetitive pictures. These results indicate that individuals high in BAS had larger N1 amplitudes to appetitive pictures, but not to neutral pictures. Next, the relationships of the BAS subscales and BIS with N1 amplitudes were assessed. BAS Reward Responsiveness and picture type interactively predicted N1 amplitudes, $F(1, 41) = 4.16$, $p = .04$, $\eta_p^2 = .09$. Greater BAS Reward Responsiveness predicted greater N1 amplitudes to appetitive pictures ($\beta = -.21$, $p = .04$), controlling for N1 amplitudes to neutral pictures. BAS Reward Responsiveness was unrelated to N1 amplitudes to neutral pictures ($\beta = 0.10$, $p = .36$), controlling for N1 amplitudes to appetitive pictures. BAS Drive, BAS Fun-Seeking, and BIS did not interact with picture type to predict N1 amplitudes, *p*s > .10. However, BAS Drive and BAS Fun-Seeking marginally predicted greater N1 amplitudes to appetitive pictures ($\beta = -.20$, $p = .06$; $\beta = -.17$, $p = .10$), controlling for N1 amplitudes to neutral pictures. BIS did not relate to N1 amplitudes to appetitive pictures ($\beta = -.02$, $p = .81$), controlling for N1 amplitudes to neutral pictures.

To provide figures of the ERP waves as a function of trait BAS, BAS scores were split into three groups – a low, moderate, and high BAS group (a tertile split). Then, the waveforms for each group were created for neutral and appetitive pictures. The results are depicted in Figure 1. Moreover, a one-way ANOVA revealed a significant difference in

N1 amplitude to appetitive pictures between low, moderate, and high BAS sensitivity scores, F (2, 40) = 4.16, p = .02, η_p^2 = .17, such that N1 amplitude was greatest in individuals with high BAS, followed by individuals with moderate BAS, followed by individuals with low BAS. Latency analyses across the tertile split revealed no differences between the low (M = 125.14, SE = 5.68), moderate (M = 128.24, SE = 4.96), and high (M = 130.89, SE = 5.68) BAS groups for N1 amplitudes to appetitive pictures, F (2, 40) = 0.26, p = .77, η_p^2 = .01.

P3 amplitudes were greater to appetitive pictures than to neutral pictures, t(42) = 2.51, p = .01. BAS and BIS did not interact with picture type to predict P3 amplitudes, *p*s > .09. BAS did not relate to P3 amplitudes to appetitive pictures, controlling for P3 amplitudes to neutral pictures (β = -.05, p = .65). In addition, BIS did not relate to appetitive P3 amplitudes, controlling for neutral pictures (β =.15, p = .14).

Discussion

Results of the current study indicate that the N1was larger to appetitive pictures than to neutral pictures. These results are consistent with results from previous studies and suggest that the N1 is an early neurophysiological index of motivated attentional processing (Baldauf & Deubel, 2009; Gable & Harmon-Jones, 2011). More importantly, the current study found that greater trait BAS predicted larger N1 amplitudes to appetitive pictures. These results reveal that as early as 100 ms after stimulus onset, individual differences in BAS enhance neurophysiological responses to appetitive stimuli associated with motivated attention.

The influence of individual differences in approach motivation on these early attentional processes may be indicative of the close relationship between systems of approach motivation and early attentional processes related to the N1. That is, greater BAS may enhance an organism's attentional response to rewarding stimuli, and cause greater cognitive resources to be devoted towards an appetitive object or goal. This would likely facilitate goal acquisition, as the organism focuses on the desirable object or goal. Indeed, the relationship between approach motivation and attentional focus is likely bi-directional. Gable and Harmon-Jones (2011) found that compared to a manipulated broad (global) attentional scope, a manipulated narrow (local) attentional focus evoked greater N1 amplitudes to appetitive stimuli. Together with results of the current study, these findings indicate a strong bi-directional relationship between the N1 and approach motivation.

The current results replicate past results indicating that the N1and P3 are reliably modulated by affective stimuli (Foti, Hajcak, & Dien, 2009; Kiel, et al., 2001; Olofsson et al., 2008; Weinberg & Hajcak, 2011). However, the current study found that trait BAS only predicted N1 amplitudes but not P3 amplitudes to appetitive pictures. This result may be conceptually consistent with previous research showing that BIS (as measured by trait anxiety) relates to N1, but not P3 amplitudes (Hogan, et al., 2007). Whereas the N1 is thought to reflect compulsory motivated-attentional processes, ERP components occurring later, such as the P3/LPP, are thought to reflect more elaborative (i.e., top-down) processing of emotional stimuli (Hajcak, Weinberg, MacNamara, & Foti, 2012). Evidence from the current study indicates that trait level processes related to approach motivation facilitated compulsory attentional processing of appetitive stimuli.

Broadly, the current findings have implications for the interaction between personality and neurophysiology. In line with Gray's (Gray & McNaughton, 2000) theory that BAS should facilitate reactions to appetitive or rewarding stimuli and be involved in the generation of anticipatory positive affect, trait BAS influenced early neurophysiological processes associated with the motivated attention. These results provide the first evidence linking trait approach motivational tendencies to very early stages of motivated attentional processing.

Footnotes

1. In addition to the BAS and BIS system, Gray and McNaughton (2000) proposed a third system called the fight-flight-freeze system (FFFS). This system differs from BIS in that FFFS is posited to mediate fear (as opposed to anxiety), and it is designed to reduce the discrepancy between the immediate threat and the desired state of safety.

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Figure

Figure 1: Composite (sites CZ, CPZ, and PZ) ERP waveforms to appetitive and neutral pictures split as a function of trait BAS (e.g., low, moderate, and high BAS total). Circles indicate N1 peaks.