Does arousal per se account for the influence of appetitive stimuli on attentional scope and the late positive potential?

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Abstract

Past research suggests that high approach-motivated positive affects narrow attentional scope and cause greater late positive potential (LPP) amplitudes. However, because arousal is related to motivational intensity, arousal may be responsible for these past findings. The present research investigated whether arousal, manipulated independently of affect using physical exercise, would influence attentional and LPP responses to stimuli. Results revealed that appetitive (vs. neutral) pictures evoked larger LPPs over central and left frontal regions, and caused more attentional narrowing. Individual differences in approach motivation predicted more attentional narrowing following appetitive stimuli. However, manipulated arousal did not influence attentional scope or LPPs to neutral or appetitive stimuli. Results suggest that attentional narrowing and LPPs to appetitive stimuli are related to approach motivation rather than enhanced general arousal.

Descriptors: Arousal, Local-global attention, Approach motivation, Late positive potential, Event-related potentials, Physical exercise

Positive affects vary in the degree to which they are associated with approach motivation, and positive affects of different motivational intensities have distinct effects on attention and cognition (for reviews, see Gable & Harmon-Jones, 2010a; Harmon-Jones & Gable, 2008; Levine & Edelstein, 2009). Positive affective states low in approach motivation cause a relative broadening of attentional scope, whereas positive affective states high in approach motivation cause a relative narrowing of attentional scope (Gable & Harmon-Jones, 2008a, 2010b, 2011; Harmon-Jones & Gable, 2009; Price & Harmon-Jones, 2010).[1] Similar effects have also emerged in past research on motivationally intense negative affect (e.g., Gable & Harmon-Jones, 2010c; Wachtel, 1968; Weltman & Egstrom, 1966). These results suggest that affective states high in motivational intensity cause a relatively narrow attentional scope,

whereas affective states low in motivational intensity cause a relatively broad attentional scope. Consistent with other perspectives (Carver, 2003), we have posited that positive affective states low in approach motivation lead to a broadening of attentional scope because these states signal that all is well and attention broadens so that new opportunities can be discovered. In contrast, positive affective states high in approach motivation lead to a narrowing of attentional scope because, during these states, the organism needs to zero in on the object of desire, so that goal acquisition is more likely.

Arousal and Approach Motivation

In past studies demonstrating that high approach-motivated positive affect narrows attention, one potential and almost inherent confound is arousal. That is, stimuli used to induce high approach positive affect also induce high levels of self-reported arousal (Gable & Harmon-Jones, 2008a, 2008b, 2009, 2010b, 2011). Thus, perhaps arousal per se (i.e., a nonvalenced, nonmotivational arousal) is causing attentional narrowing, rather than motivational intensity, as we have posited (Gable & Harmon-Jones, 2010a; Harmon-Jones & Gable, 2008).

Arousal is a construct that may be closely related to motivation. Many prominent models of emotion consider emotional arousal to reflect motivational intensity. Yet, according to Bradley and Lang's (2007) theory of emotion, "judgments of arousal index (again, roughly) the degree of activation in each motivation system" (p. 585). As illustrated in this quotation, Bradley and Lang regard arousal as only a rough proxy for motivation and probably agree

1. In the seven experiments using the Navon measure of attentional scope, we have found approach-motivated positive affect to slow global reactions (Gable & Harmon-Jones, 2008a, Experiment 3, 2010b; Harmon-Jones & Gable, 2009), or to both slow global and speed local reactions (Gable & Harmon-Jones, 2008a, Experiment 2). That is, the conceptual idea of narrowing could manifest as faster detection of local information or slower detection of global information. Both manifestations may assist with mobilizing energy toward or away from the significant environmental stimulus.

that arousal and motivation are not identical (Harmon-Jones, Gable, & Price, 2011).

Motivational intensity or the impetus to act may be related directly to arousal, but, unlike arousal, motivation always has action implications (even if they are vague). Although these concepts are similar, there are instances in which arousal created by positive affect is divorced from motivational intensity. For instance, amusement can be thought of as an arousing, positive state or a "higher activation state" (Fredrickson & Branigan, 2005, p. 326). We suspect, however, that it is low in motivational intensity and unlikely to urge one to approach something in the environment. Relative to a neutral state, this higher arousal positive affect has been found to cause attentional broadening similar to the attentional broadening caused by contentment, a low-arousal low-motivational state (Fredrickson & Branigan, 2005). Another experiment replicated this broadening effect for amusement but found that a film clip that evoked desire caused a relative narrowing of attentional scope (Gable & Harmon-Jones, 2008a). Both amusement and desire are often thought of as arousing positive affective states, but we posit that desire is much higher in approach motivational intensity than amusement as desire impels movement toward stimuli.[2]

Although these studies suggest that positive affective states that may be high in arousal but low in motivational intensity lead to attentional broadening, it is impossible to arrive at this conclusion without more clear evidence, particularly from an experiment in which arousal is manipulated independently of motivational intensity. Thus, the present experiment was conducted to test whether manipulations of arousal, independent of affective motivation, modulate attentional scope.

Arousal and the LPP

In addition to testing whether an independent manipulation of arousal would influence attentional scope, we also wanted to test whether the manipulation of approach motivation would influence the late positive potential (LPP), and whether this effect would be influenced by the independent manipulation of arousal. The LPP, a component of the event-related potential (ERP) occurring between 300 and 1,200 ms after stimulus onset, is an early neurophysiological measure associated with motivation and arousal. The LPP is likely driven by several structures, including the lateral occipital, inferior temporal, and medial parietal cortex (Sabatinelli, Lang, Keil, & Bradley, 2007) and the temporal parietal junction and lateral prefrontal cortex (Nieuwenhuis, Aston-Jones, & Cohen, 2005). Much past work has demonstrated that the LPP is larger in amplitude to affective than neutral stimuli, and larger for high (vs. low) arousing stimuli (for reviews, see Hajcak, Weinberg, MacNamara, & Foti, 2012; Keil et al., 2001; Olofsson, Nordin, Sequeira, & Polich, 2008). Although the LPP is sensitive to arousal, the LPP is thought to reflect motivated attention (Lang, Bradley, & Cuthbert, 1997), and general manipulations of approach motivational intensity influence LPP amplitude (Price, Dieckman, & Harmon-Jones, 2012).

Some studies have found that the LPP is hemispherically lateralized over the frontal cortex. For instance, greater left LPP amplitudes are related to processing approach-related stimuli, whereas greater right frontal LPP amplitudes are related to processing avoidance-related stimuli (Cunningham, Espinet, DeYoung, & Zelazo, 2005; Gable & Harmon-Jones, 2010b; Graham & Cabeza, 2001; van de Laar, Licht, Franken, & Hendriks, 2004). Lateralization of the LPP over the frontal cortex is consistent with other research using multiple methods that has demonstrated that the frontal cortex is asymmetrically involved in emotive processing (for reviews, see Harmon-Jones, Gable, & Peterson, 2010; Pizzagalli, Shackman, & Davidson, 2003). Specifically, the left prefrontal cortex is involved in approach motivational processing, which is often associated with positive emotions like desire (Gable & Harmon-Jones, 2008b; Harmon-Jones, & Gable, 2009) and negative emotions such as anger (Harmon-Jones, Lueck, Fearn, & Harmon-Jones, 2006; Peterson, Shackman, & Harmon-Jones, 2008). In contrast, the right prefrontal cortex is involved in withdrawal motivational processing, which is often associated with emotions such as fear (Buss et al., 2003).

The Present Experiment

One possible interpretation of past results is that arousal per se (i.e., a nonvalenced, nonmotivational arousal) caused the attentional narrowing when participants viewed appetitive stimuli (e.g., pictures of desserts). Indeed, several individuals who have read our past articles and/or heard our presentations concerning our results have suggested this arousal-based alternative explanation. However, we predict that it is motivational intensity and not general arousal that leads to attentional narrowing. One common method of testing whether arousal alone influences psychological processes is to have participants pedal a stationary bicycle, which has been found to increase heart rate (Cantor, Zillmann, & Bryant, 1975; Zillmann, Katcher, & Milavsky, 1972; for reviews, see Foster, Witcher, Campbell, & Green, 1998; Lambourne & Tomporowski, 2010). For example, Zillmann et al. (1972) asked participants to pedal continuously on a bicycle ergometer. More recent studies used similar exercise manipulations of arousal, and meta-analyses of these studies suggest that sustained cycling manipulations have effects on cognitive performance (Lambourne & Tomporowski, 2010). The present experiment manipulated arousal by asking participants to pedal a stationary bike while viewing appetitive (delicious dessert pictures) and neutral pictures (rocks). Heart rate was assessed throughout the experiment to measure arousal, and LPP amplitudes were assessed to the appetitive and neutral pictures to measure emotive responses to the pictures. Attentional scope was measured using Navon's (1977) local-global stimuli. Prior to picture viewing, individual differences in approach motivation (e.g., Carver & White's, 1994, behavioral inhibition sensitivity [BIS]/behavioral activation sensitivity [BAS] scale and dessert liking) were assessed.

We predicted that the approach motivation induced by appetitive stimuli would cause greater narrowing of attention, replicating past research. We also predicted that pedaling would cause faster heart rates than not pedaling. However, we predicted that the arousal manipulation (pedaling) would not influence attentional scope. That is, increased arousal per se should not cause more attentional narrowing following neutral or appetitive picture primes. In contrast, individual differences in approach motivation and emotive tendencies towards appetitive pictures should relate to attentional narrowing.

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2. Based on this evidence, we believe that amusement is a high arousing state and that it often relates to laughter; however, we believe that amusement (and laughter) does not motivate one to approach the stimulus causing the laughter. Sometimes one wants to keep a safe distance from the amusing stimulus, as in the case of cats jumping around wildly and humorously, or slapstick comedy (e.g., someone smashing fruit).

Method

Participants

Sixty (23 women) unselected right-handed introductory psychology students participated for course credit. Based on a close examination of the past literature, we found three studies that were methodologically similar to the current experiment based on the criteria that these studies used a manipulation of steady state cycling during an attentional reaction time task (Audiffren, Tomporowski, & Zagrodnik, 2008; Pesce, Capranica, Tessitore, & Figura, 2003; Vercruyssen, Hancock, & Mihaly, 1989). Across these three studies, the cycling manipulation produced a large effect (Cohen's $f = .75$) on cognitive performance. This effect size should provide adequate power (.99) to detect an effect in a relatively small ($n = 20$) sample.

Procedure

After providing informed consent, participants completed individual difference measures of approach motivation by rating their liking of dessert and by completing the Carver and White (1994) BIS/BAS questionnaire. Liking of dessert was assessed along with other unrelated attitudes on 1 (*strongly dislike*) to 4 (*strongly like*) scales. The BIS/BAS scale contains 20 questions and is comprised of the BIS and BAS scales. The BIS scale has seven items that measure reactions to 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 subscales. After participants completed these questionnaires in private, electroencephalogram (EEG) electrodes were applied.

Then, arousal was manipulated by having half the participants pedal on stationary bike pedals, which sat on the floor directly in front of the chair (see Figure 1). Participants were told, "While you are viewing the pictures, pedal at an easy-to-moderate speed, one that you can maintain for 15 minutes. Continue to pedal through the entire task at this same intensity. Do not stop until you are instructed to do so. Begin pedaling now." The other half of participants were not given these instructions and kept their feet on the floor, as in our past research (e.g., Gable & Harmon-Jones, 2008a).

Participants viewed 64 trials preceded by 6 neutral practice trials. Each trial consisted of a fixation cross (500 ms) followed by an appetitive (desserts) or neutral (rocks) picture (6 s). The pictures have been used in previous research (Gable & Harmon-Jones, 2008a, 2008b, 2010b, 2011; Harmon-Jones & Gable, 2009). Thirty-two appetitive and 32 neutral pictures were presented in a randomized order. Pictures were matched for color, brightness, and object size. After each appetitive (or neutral) picture prime and another fixation cross (500 ms), a Navon (1977) letters stimulus was displayed until the participant responded. If the participant did not respond within 5 s, the next trial began. Intertrial interval was 3 s.

The Navon letters task (1977) was used to assess local versus global attentional scope, as in past research (Gable & Harmon-Jones, 2008a, 2010b, 2010c, 2011; Harmon-Jones & Gable, 2009). Each picture was a large letter composed of smaller letters. The large letters were made up of five closely spaced local letters on each vertical or horizontal line (e.g., an *H* of *F*s). Participants were asked to quickly identify if the picture contained the letter *T* or the letter *H* by pressing corresponding buttons on a button box. Global targets were those in which a *T* or an *H* was composed of smaller letter *L*s or *F*s. Local targets were those where a large *L* or *F* was composed of smaller *T*s or *H*s. Faster responses to the large target letters indicate a global attentional scope, whereas faster responses to the small target letters indicate a local attentional scope. Thirty-two local and 32 global trials were quasi-randomly presented, so that there were an equal number of local and global trials following neutral and appetitive picture primes.

Following the above 64 trials, participants viewed the appetitive or neutral pictures again (3 s each), and indicated their pleasure (1 = *very unpleasing*; 9 = *very pleasing*) and arousal (1 = *calm*; 9 = *exciting*) on the Self-Assessment Manikin (Bradley & Lang, 1994).

Heart Rate Measurement and Processing

Electrocardiographic (ECG) activity was collected by placing one tin electrode on each upper arm; these two electrodes were referenced in a bipolar montage. A ground electrode was placed on the scalp between FPZ and FCZ, to use the same ground as used for the EEG (see below). Electrode impedances were under 5000 Ω. ECG signals were amplified with Neuroscan SynAmps2, band-pass filtered (0.10–100 Hz), notch filtered (60 Hz), and digitized at 500 Hz. Artifacts (e.g., from arm movements) were first removed by hand and then interbeat intervals (IBI) were calculated and processed using QRS Tool software (Allen, Chambers, & Towers, 2007). Beats per minute (BPM) were calculated for each participant during a resting baseline period of 8 min and during the picture viewing task to assess the effectiveness of the arousal manipulation.

EEG Recording and Processing

EEG was recorded with 58 tin electrodes in a stretch Lycra electrode cap. All sites were referenced online to the left earlobe; offline, data were rereferenced to a common average reference.

Figure 1. Stationary bike pedals used to manipulate arousal.

Electrode impedances were under 5000 Ω; homologous sites were within 1000 Ω of each other. Signals were amplified with Neuroscan SynAmps2, band-pass filtered (0.10–100 Hz), notch filtered (60 Hz), and digitized at 500 Hz. Artifacts (e.g., horizontal eye movements, head movements) were first removed by hand. Pilot testing revealed that pedaling on stationary bike pedals in front of the participant's chair at an easy-to-moderate speed did not increase EEG artifact. Also, the number of artifact-free ERP trials did not differ between the pedaling ($M = 49.85$, $SD = 5.78$) and no-pedaling conditions ($M = 49.89$, $SD = 6.09$), $t(37) = 0.02$, $p = .98$, $d < .01$, suggesting that artifacts were similar between conditions. Then, a regression-based eye movement correction was applied to correct vertical eye blinks (Semlitsch, Anderer, Schuster, & Presslich, 1986).

The data were epoched for 100 ms before picture (appetitive or neutral) onset until 1,200 ms after picture onset, and filtered with a low-pass of 35 Hz. Aggregated waveforms for each picture type were created and baseline corrected using the prestimulus activity. LPP amplitude was measured as the mean EEG activity within a window of 500–1,000 ms, based on visual inspection and consistent with previous research investigating frontal lateralized LPPs (van de Laar et al., 2004; Gable & Harmon-Jones, 2010b; Graham & Cabeza, 2001). Indices at central-parietal midline (CPZ, PZ, CP3, CP4, CP1, CP2, P1, P2), left frontal lateral sites (F3, F5, FC3, FC5), and corresponding right frontal lateral sites (F4, F6, FC4, FC6) were created.

Reaction times (RT) to local and global targets were logarithmically transformed, to normalize the distributions. Incorrect responses (4% of the sample) and those more than 3 standard deviations from the mean (0.3% of the sample) for each stimulus were removed. Two participants' reaction times were not included in RT analyses because they did not follow instructions on the Navon letters task. Due to equipment failure, ECG data from three participants were not collected. One participant was removed from analyses because LPP amplitudes were more than 3 standard deviations from the mean.

Results

Picture Ratings

Consistent with ratings from previous studies (Gable & Harmon-Jones, 2008a, 2008b, 2010b), participants rated the appetitive pictures more pleasing ($M = 6.91$, $SE = 1.13$) and arousing ($M = 4.59$, $SE = 1.89$) than neutral pictures ($M = 5.24$, $SE = 1.20$; $M = 2.13$, $SE = 1.29$), ts > 9.84, ps $< .0001$, ds > 1.31. Higher scores indicate more pleasantness and arousal. Pedaling did not produce a significant main effect on ratings of valence, $F(1,55) = 1.98$, $p = .17$, $\eta_p^2 = .03$, or arousal, $F(1,55) = 0.77$, $p = .38$, $\eta_p^2 = .01$.

Heart Rate

A between-conditions analysis of covariance (ANCOVA) revealed that participants in the pedaling condition had faster heart rates (BPM; $M = 84.53$, $SE = 12.85$) than participants in the control (no-pedaling) condition ($M = 74.12$, $SE = 12.93$), $F(1,52) = 52.69$, $p < .0001$, $\eta_p^2 = .50$. These results confirm that participants in the arousal condition had greater cardiac arousal than participants in the control condition.

Local-Global Reaction Times on Navon Letters Task

The RT results revealed a significant 2 (appetitive or neutral picture) × 2 (local or global target) interaction, $F(1,56) = 9.23$,

$p = .004$, $\eta_p^2 = .14$. Follow-up tests revealed that RTs to global targets were slower after appetitive pictures ($M = 6.68$, $SE = 0.03$) than after neutral pictures ($M = 6.64$, $SE = 0.03$), $p = .001$. RTs to local targets were similar after appetitive ($M = 6.67$, $SE = 0.04$) and neutral pictures ($M = 6.69$, $SE = 0.03$), $p = .41$. After neutral pictures, participants responded faster to global targets than local targets, $p = .0001$. This finding is consistent with previous studies (Gable & Harmon-Jones, 2008a, 2010b, 2010c, 2011; Navon, 1981); participants generally show a global bias on this task when in a neutral state. After appetitive pictures, RTs did not differ between global and local targets, $p = .83$. These results replicate previous results by showing that appetitive stimuli caused a more narrowed compared to broadened attentional scope, as indicated by slower latencies to detect global stimuli and the absence of the usual global bias found in neutral states (e.g., Gable & Harmon-Jones, 2008a).

Consistent with predictions, manipulated arousal did not influence RTs to local and global stimuli following appetitive and neutral stimuli. That is, manipulated arousal exerted no significant main effect, $F(1,55) = 2.85$, $p = .10$, $\eta_p^2 = .05$, 2-way interactions, $F < 0.31$, ps $> .58$, or 3-way interaction, $F(1,55) = 1.77$, $p = .19$, $\eta_p^2 = .03$.

LPP Amplitudes

Replicating past work, LPP amplitudes were greater after appetitive pictures than after neutral pictures at midline central-parietal sites, $t(58) = 2.11$, $p = .03$, $d = 0.28$ (Figure 2). At left lateral frontal sites, LPP amplitudes were greater after appetitive pictures than after neutral pictures, all $t(58) = 2.52$, $p = .01$, $d = 0.33$. In contrast, at right lateral frontal sites, LPP amplitudes were greater after neutral pictures than after appetitive pictures, $t(58) = 2.37$, $p = .02$, $d = 0.31$.

Next, we compared LPPs to pictures between the two hemispheres (Figure 3). For appetitive pictures, LPPs were greater in the left hemisphere than the right hemisphere at lateral-frontal sites, $t(58) = 4.66$, $p < .00001$, $d = 0.61$. For neutral pictures, LPPs did not differ as a function of hemisphere, $t(58) = 0.70$, $p = .48$, $d = 0.09$. These results are conceptually consistent with the results of past research examining lateral-frontal LPP asymmetries (Cunningham et al., 2005; van de Laar et al., 2004; Gable & Harmon-Jones, 2010b).

Arousal did not interact with picture type to influence LPP amplitudes at midline central-parietal sites, $F(1,57) = 2.13$, $p = .15$, $\eta_p^2 = .04$, or at lateral-frontal sites, $F(1,57) = 0.94$, $p = .33$, $\eta_p^2 = .02$.

Analyses with Individual Differences in Approach Motivation

Because of our interest in the effects of appetitive motivation on attentional bias, we conducted a regression analysis in which the approach-motivation individual difference variables (BAS and liking for dessert) and condition were used to interactively predict local or global RTs after appetitive pictures, controlling for RTs to local (global) targets after neutral pictures. These neutral picture prime controls were implemented to control for individual differences in RTs to stimuli, to test whether the predicted correlations were significant after eliminating variance due to RTs to neutral stimuli.

A significant interaction of condition and BAS emerged for RTs to local targets, $F(1,55) = 4.98$, $p = .03$, $\eta_p^2 = 0.08$. BAS significantly predicted faster RTs to local targets after appetitive pictures,
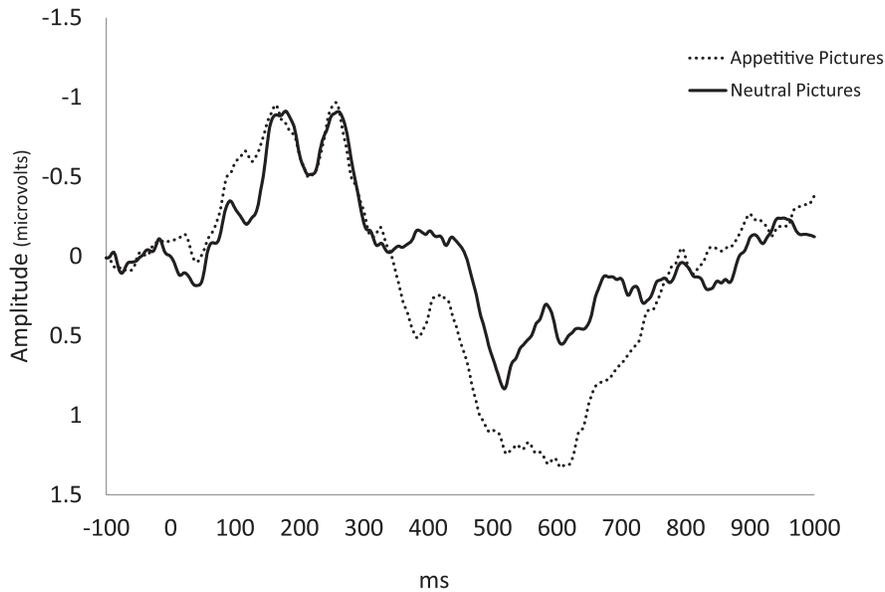
Figure 2. ERP waveform depicting LPP amplitudes to appetitive and neutral pictures at the central-parietal index from 100 ms before picture onset to 1,000 ms after picture onset.

controlling for RTs to local targets after neutral pictures, *partial r* = −.30, *p* = .02. A significant interaction of condition and BAS did not emerge for RTs to global targets, $F(1,54) = 1.68$, $p = .20$, $\eta_p^2 = 0.03$.

In addition, a significant interaction of condition and liking of dessert emerged for RTs to local targets, $F(1,54) = 5.41$, $p = .02$, $\eta_p^2 = 0.09$. Liking of dessert significantly predicted faster RTs to local targets after appetitive pictures, controlling for RTs to local targets after neutral pictures, *partial r* = −.31, *p* = .02. A significant

interaction of condition and liking of dessert did not emerge for RTs to global targets, $F(1,53) = 0.10$, $p = .75$, $\eta_p^2 < 0.01$.

These interactions suggest that individual differences in approach motivation related to more narrowed attentional scope after appetitive pictures. These results stand in contrast to the manipulation of arousal, which did influence attentional narrowing.

Individual differences in approach motivation (i.e., BAS, liking of desserts) did not relate to LPP amplitudes to appetitive or neutral
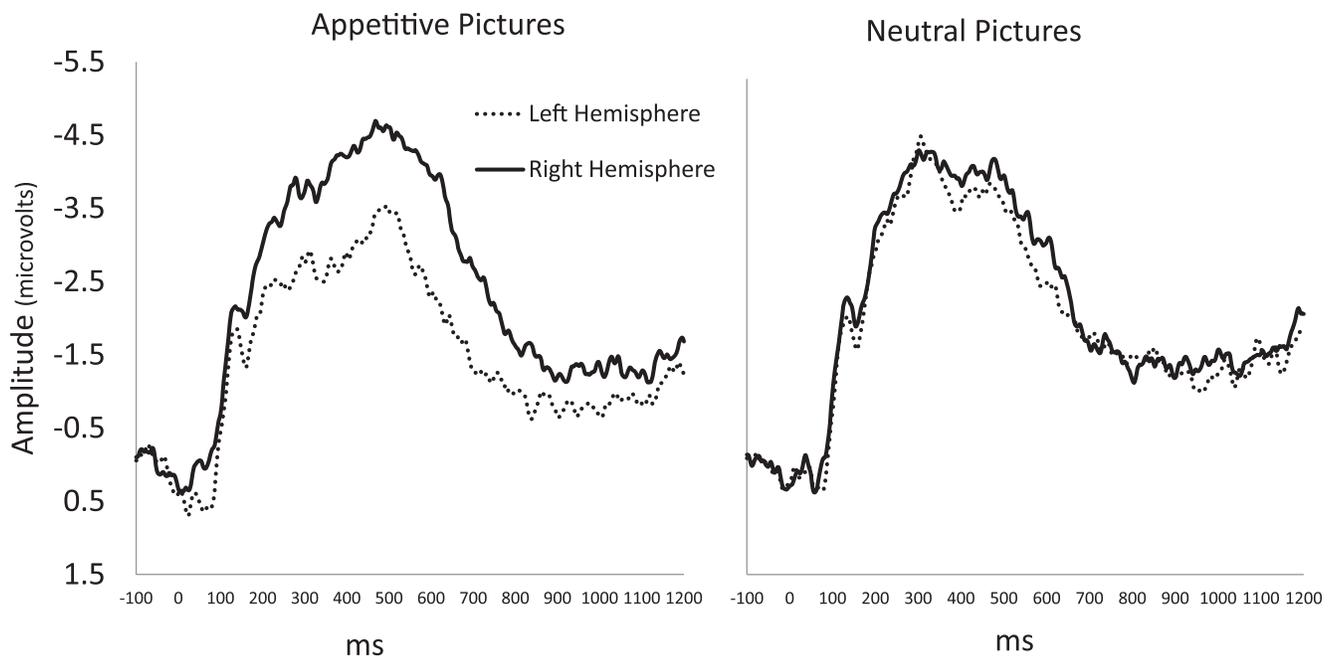
Figure 3. ERP waveform depicting LPP amplitudes to appetitive and neutral pictures at the left and right frontal indices from 100 ms before picture onset to 1,000 ms after picture onset.

pictures at either central-parietal, rs < .12, ps > .38, or frontal sites, rs < .06, ps > .66. BAS and liking of dessert remained significant predictors of faster local target RTs, controlling for LPP amplitudes to appetitive pictures at central-parietal, rs > .28, ps < .04 and frontal sites, rs > .28, ps < .03.

Correlations with Heart Rate

Because some past studies have found relationships between heart rate and measures of BAS (Fowles, 1980; Heponiemi, Keltikangas-Järvinen, Kettunen, Puttonen, & Ravaja, 2004; but see Brenner, Beauchaine, & Sylvers, 2005; Colder & O'Connor, 2004; Schneider & Graham, 2009, for failures to find significant relationships), we tested whether heart rate related to BAS (and other measures) in the current sample. Consistent with past studies investigating heart rate during steady state cycling manipulations of arousal (Heponiemi et al., 2004), we created a difference score between the picture priming/attentional scope task and resting BPM in order to control for resting BPM. Heart rate did not significantly relate to BAS in either the pedaling or the no-pedaling conditions, rs < .26, ps > .18. In addition, heart rate did not relate to local or global RTs in either the pedaling or the no-pedaling conditions, rs < .32, ps > .11.

Next, we examined whether LPPs related to heart rate. Midline LPP amplitudes to appetitive and neutral pictures did not relate to heart rate, rs < .12, ps > .42. Next, we examined LPPs over the frontal cortex. To control for hemispheric differences in LPP amplitudes, we created a difference score between left and right LPPs to either appetitive or neutral pictures. In the pedaling condition, heart rate related to greater relative left frontal LPPs to appetitive pictures, $r = .38$, $p = .05$. In contrast, heart rate did not relate to relative left frontal LPP amplitudes to neutral pictures, $r = .29$, $p = .14$. In the no-pedaling condition, heart rate did not relate to relative left frontal LPP amplitudes to appetitive, $r = -.04$, $p = .85$, and neutral pictures, $r = .18$, $p = .37$. These results provide some evidence, albeit weak, that greater arousal, as measured by heart rate, related to LPP amplitudes to appetitive pictures, another variable associated with motivational intensity and arousal.

Discussion

Replicating the results of over 15 past experiments, appetitive stimuli, as compared to neutral stimuli, evoked relatively more narrowed attention (see Harmon-Jones, Gable, & Price, 2011, for a recent review). Also replicating past results, individual differences in approach motivation interacted with picture type to predict a more narrowed attentional scope after appetitive pictures. Moreover, LPP amplitudes were greater for appetitive pictures than for neutral pictures at midline sites and in the left but not right frontal sites.

The novel contribution of the present research was that cardiac arousal manipulated independently of affective state did not influ-

ence attentional scope. That is, participants in the pedaling condition had faster heart rates than participants in the no-pedaling condition, but participants in the pedaling (vs. no-pedaling) condition did not show a more narrowed attentional scope following neutral or appetitive stimuli. In contrast, attentional narrowing was caused by approach motivation manipulated through appetitive pictures, and attentional narrowing following appetitive stimuli was related to individual differences in approach motivation.

There are many sources of arousal: physical exercise, chemical stimulants, and emotion. In the current experiment, we manipulated physical exercise independently of emotional arousal through stationary cycling and assessed heart rate because much past work has investigated the impact of cardiac arousal on psychological processes (e.g., aggression, sexual arousal; Cantor et al., 1975; Foster et al., 1998; Ma-Kellams, Blascovich, & McCall, 2012; Zillmann et al., 1972). Of note in the present results is that arousal induced by physical exercise influenced heart rate but did not influence attentional scope following neutral or appetitive primes. These results suggest that approach motivation rather than arousal per se underlies the effect of positive affect on attentional narrowing. Together with the present results, these results suggest that arousal manipulated independently of emotion does not lead to a narrowing of attentional scope.

One limitation of the current experiment is the null statistical test or absence of evidence of a difference between the pedaling and no-pedaling conditions on attentional scope. However, the "absence of evidence" in the present experiment is not the same "absence" often encountered. The most common explanations for null effects are: lack of a sensitive measure, low statistical power, and failure to manipulate the constructs of interest (Harmon-Jones, 1999). The attentional scope measure is sensitive as revealed by the effect of neutral versus appetitive pictures on responses to it. The fact that BAS-drive also correlated with local attentional scope following appetitive pictures provides further evidence of its sensitivity. Adequate statistical power existed in the present experiment as revealed by the power analysis reported earlier, the effect size of the heart rate difference between pedaling and no-pedaling conditions, and the effect size of picture type and BAS-drive on attentional scope. Finally, the heart rate results suggested that arousal was appropriately manipulated in the present experiment. Despite this, null effects are difficult to interpret, and this limitation applies to the current experiment.

In conclusion, the current experiment replicates the effects of over 15 past studies that found that appetitive stimuli caused a relative narrowing of cognitive scope (see also Nittono, Fukushima, Yano, & Moriya, 2012). Most importantly, the current experiment extends this program of research by suggesting that the attentional narrowing caused by appetitive pictures is due to approach motivation rather than enhanced general arousal.

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