BRIEF REPORT

Relative left frontal activation to appetitive stimuli: Considering the role of individual differences

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Abstract

Experiments examining asymmetrical frontal activity in response to affective pictures have produced inconsistent results. These inconsistencies may have occurred because the pictorial stimuli may not have evoked strong emotional or motivational tendencies for all individuals. In the current study, participants were asked to indicate their liking for dessert and the time since they had last eaten to assess individual differences in emotion and motivation. Then, they were shown dessert pictures or neutral pictures while EEG activity was recorded. Results indicated that the individual differences predicted greater left than right frontal activity (inverse of the alpha power) within the first second as well as all 12 s of viewing of the dessert pictures.

Descriptors: EEG, Motivation, Frontal asymmetry, Emotion, Individual differences

The prefrontal cortex is asymmetrically involved in emotive processing, with greater relative left frontal activity involved in approach (or positive) emotive processes and greater relative right frontal activity involved in withdrawal (or negative) emotive processes (for reviews, see Davidson, 1992; Harmon-Jones, 2003, 2006; Peterson, Shackman, & Harmon-Jones, in press; van Honk & Schutter, 2006).

Although much research has found asymmetrical frontal cortical activations in response to manipulations of emotion, some past research has failed to produce predicted results (for reviews, see Murphy, Nimmo-Smith, & Lawrence, 2003; Pizzagalli, Shackman, & Davidson, 2003). One area in which failures to find predicted effects has been especially prevalent is in studies using affective pictures (Elgavish, Halpern, Dikman, & Allen, 2003; Hagemann, Ewald, Becker, Maier, & Bartussek, 1998). Affective pictures may not evoke sufficient emotional or motivational intensity to engage asymmetrical frontal cortical activations. In support of this idea, experiments revealed that when approach motivation in response to anger-inducing pictures was increased by an expectancy of action manipulation, the expected relative left frontal activation occurred in response to the anger-inducing pictures (Harmon-Jones, Lueck, Fearn, & Harmon-Jones,

2006). These experiments suggest that increased approach motivation causes greater relative left frontal activity to anger-inducing pictures.

To extend these findings, we conducted the current study to examine whether individual differences in emotive tendencies influence relative left frontal activation to positive affective stimuli. Because approach motivation and positive affect are often confounded when examining reactions to positive affective stimuli, the present study was not designed to test whether approach motivation or positive affect provided a more accurate explanation of the psychological functions of relative left frontal activation. Observing a relationship between emotive individual differences (approach motivation or positive affect) and relative left frontal activation to positive stimuli would be consistent with both affective valence and motivational direction interpretations.

In the present study, we measured individual differences in emotive tendencies toward positive stimuli and then assessed regional brain activation (using EEG) during the viewing of the positive stimuli. We predicted that individuals with stronger emotive tendencies toward positive stimuli would show greater relative left frontal activation to those stimuli but not neutral stimuli, because these individuals may have stronger approach motivation or positive emotional responses to the stimuli. Based on past research, we also predicted that pictures alone would not cause significant shifts in asymmetrical frontal cortical activity.

In addition, we examined whether these predicted asymmetrical frontal cortical activations would occur as early as 1 s into picture viewing. Previous work has only investigated asymmetrical frontal differences over the first 3 s of picture viewing (Harmon-Jones et al., 2006).

Method

Participants

Twenty-six right-handed female introductory psychology students volunteered in exchange for course credit. Only women were included because more were in the participant pool and we sought to avoid a gender-imbalanced sample.

Procedure

Participants completed a measure of liking of dessert. Responses were made along with other unrelated attitude questions on 1 (*strongly dislike*) to 4 (*strongly like*) scales. Time since eaten was measured using the question, "How long has it been since you last ate?" answered in "hours" and "minutes," which were rescored in minutes. Responses for liking for dessert ranged from 2 to 4, $M = 3.54$, $SD = 0.58$; time since eaten ranged from 5 to 780 min, $M = 174.42$, $SD = 227.23$.

Participants viewed 6 neutral pictures and were then randomly assigned to view either 36 dessert pictures or 36 additional neutral pictures. The neutral pictures were of objects that would not evoke motivation (e.g., plastic fork, paper plate). Each picture was displayed 12 s and preceded by a fixation cross for 2 s. ITI varied between 6 and 8 s.

Following picture viewing, participants reported affective reactions. The questionnaire asked participants to indicate how they felt "right now" (1 = *not at all*; 7 = *extremely*) for the following words: afraid, angry, content, down, discouraged, disgusted, distressed, eager, enthusiastic, excited, frustrated, glad, gloomy, good mood, happy, interested, irritated, mad, nervous, pleasant, sad, satisfied, serene, and tranquil. Participants also rated how much they wanted, liked, and desired the objects and how appetizing they found them (1 = *not at all*; 5 = *very*).

EEG Assessment and Processing

To record EEG, 64 Ag/AgCl-sintered electrodes mounted in a stretch-lycra Quik-Cap (Neuroscan, El Paso, TX) were used. A ground electrode was mounted midway between FZ and CZ. An online reference was acquired from an electrode mounted between CZ and CPZ. Vertical eye movements were recorded from the supra- and suborbit of the left eye to facilitate artifact scoring of the EEG. Electrode impedances were under 5000 Ω and homologous sites were within 1000 Ω of each other. Quik Gel (El Paso, TX) was the conducting medium. Signals were amplified with Neuroscan SynAmps2 amplifier unit (El Paso, TX), bandpass filtered (0.1–100 Hz; 60-Hz filter enabled), and digitized at 500 Hz. Processing used Scan 4.3.

First, data containing artifacts were removed by hand (Cohen's Kappa for interrater agreement over subsample = .95). A regression-based eye movement correction was applied (Semlitsch, Anderer, Schuster, & Presslich, 1986). Then, all epochs 1.02 s in duration were extracted through a Hamming window (50% taper of distal ends) and re-referenced using a common average reference. Consecutive epochs were overlapped by 50%, to minimize data loss due to windowing. A fast Fourier transform calculated power spectra. Power values within the alpha band (8–13 Hz) were averaged across epochs for all 12 s, the first second, and 2–12 s of picture viewing. Asymmetry indexes (log right minus log left) were computed for all homologous sites. Asymmetry scores greater than 3 *SD* were removed (2 participants). An average frontal asymmetry index (AF3/4, F3/4, F5/6, and F7/8) was created (see Figure 1), based on past research with fewer electrodes that focused on F3/4 and F7/8. Because alpha
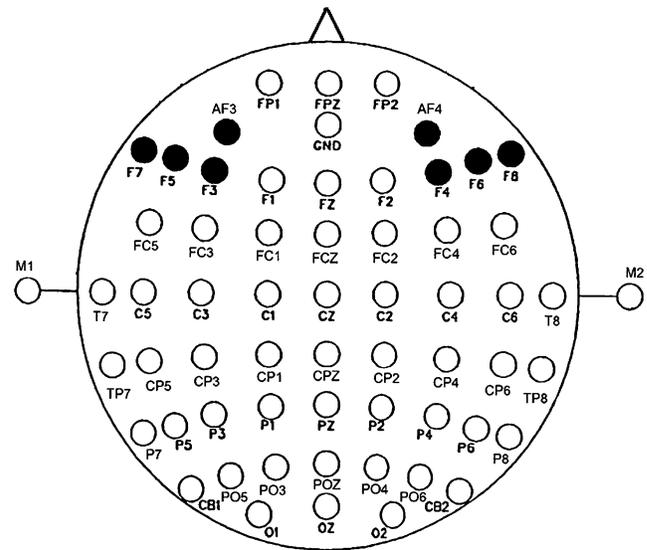
Figure 1. Electrode configuration with highlighted sites of interest.

power is inversely related to cortical activity (Lindsley & Wicke, 1974), higher scores indicate greater left hemisphere activity. Predictions for asymmetrical frontal activity and self-reports of motivation were directional, derived from theory, and specified in advance; they were evaluated using a one-tailed criterion of significance (Rosenthal, Rosnow, & Rubin, 2000).

Results

Dessert pictures were rated as more liked ($M = 4.16$, $SD = 1.40$), wanted ($M = 3.67$, $SD = 1.56$), desired ($M = 3.75$, $SD = 1.54$), and appetizing ($M = 4.25$, $SD = 1.22$) than neutral pictures ($M = 2.23$, $SD = 0.93$; $M = 1.54$, $SD = 0.78$; $M = 1.31$, $SD = 0.48$; $M = 1.39$, $SD = 0.65$), $ts > 4.10$, $ps < .001$, $ds > 0.80$.

After picture viewing, participants indicated how they felt at that moment. Because this affect assessment was not in response to feelings created by the pictures and was given following picture presentation, it is likely to be less sensitive than ratings of the pictures. Thus, we sought to explore whether condition affected any of the affect items. Participants reported feeling more enthusiasm after viewing dessert pictures ($M = 3.75$, $SD = 1.81$) than after viewing neutral pictures ($M = 2.21$, $SD = 1.58$), $t(1,24) = 2.31$, $p < .05$, $d = 0.43$. Also, participants reported feeling more pleasant and good mood after viewing dessert pictures ($M = 4.75$, $SD = 1.35$; $M = 4.92$, $SD = 1.44$) than after viewing neutral pictures ($M = 3.46$, $SD = 1.66$; $M = 3.50$, $SD = 1.65$), $ts > 2.11$, $ps < .05$, $ds > 0.39$. In contrast, participants reported being significantly less mad after viewing the dessert pictures ($M = 1.00$, $SD = 0.00$) than after viewing neutral pictures ($M = 2.14$, $SD = 1.66$), $t(1,24) = 2.38$, $p < .05$, $d = 0.44$. No other items differed between conditions.

Comparison of picture conditions on asymmetrical frontal cortical activation revealed no significant results within the 12 s of picture viewing, second 1, or seconds 2–12, $ps > .26$. It was expected that this comparison would not be significant based on past findings that picture stimuli alone do not evoke asymmetrical frontal cortical activity (Harmon-Jones et al., 2006).

To test the prediction that individuals with stronger approach motivation would respond to dessert pictures with greater rel-
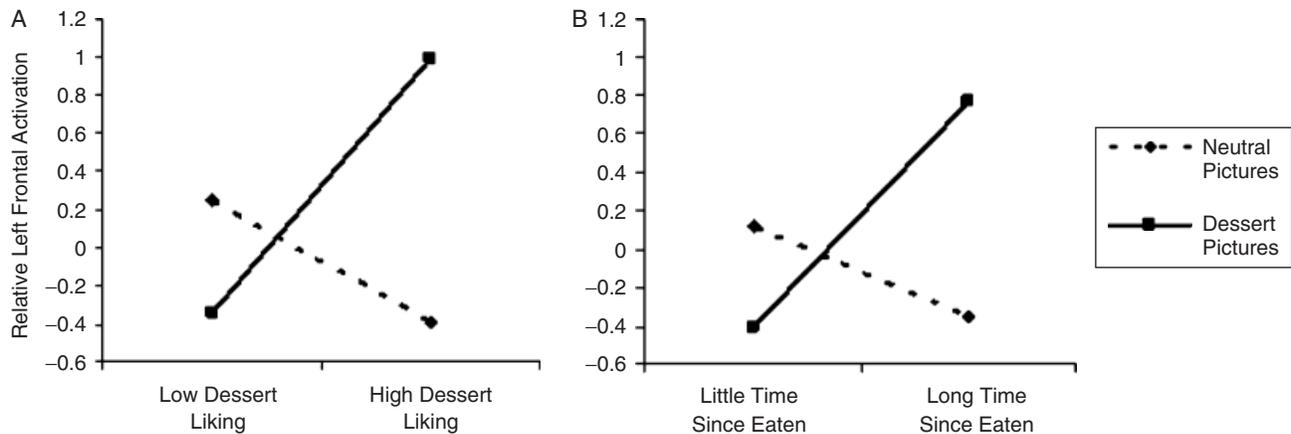
Figure 2. A: Interaction of liking for dessert and picture condition on relative left frontal activation during the entire picture viewing. B: Interaction of time since eaten and picture condition on left frontal activation during the entire picture viewing. Interaction regressions were graphed using methods recommended by Aiken and West (1991).

ative left frontal activation, we conducted a regression analysis in which the emotive individual difference variables (liking for dessert and time since eaten) and condition were used to interactively predict asymmetrical frontal cortical activity. We first examined responses over the 12 s of picture viewing and then examined responses during the first second and during 2–12 s separately.

For the entire picture viewing, a significant interaction of condition and liking for dessert emerged, $F(1,22) = 6.40$, $p < .05$, $\eta_p^2 = .23$. In addition, a significant interaction of condition and time since eaten emerged, $F(1,22) = 4.66$, $p < .05$, $\eta_p^2 = .18$ (see Figure 2). These interactions indicated that more time since eaten (dessert liking) related to greater relative left frontal activation in the dessert pictures condition: liking for dessert, $r = .49$, $p = .05$, and time since eaten, $r = .51$, $p < .05$. For the neutral pictures condition, greater left frontal activation was not related to liking for dessert, $r = -.45$, $p = .11$, and time since eaten, $r = -.29$, $p = .31$.

Next, we tested left frontal activation during the first second of picture viewing and 2–12 s of picture viewing. For the first second, a significant interaction of condition and time since eaten emerged, $F(1,22) = 9.15$, $p < .01$, $\eta_p^2 = .29$. Furthermore, the interaction of condition and liking for dessert approached significance, $F(1,22) = 3.58$, $p = .07$, $\eta_p^2 = .14$.[1] For 2–12 seconds of picture viewing, a significant interaction of condition and liking for dessert emerged, $F(1,22) = 6.28$, $p < .05$, $\eta_p^2 = .22$. In addition, the interaction of condition and time since eaten approached significance, $F(1,22) = 3.75$, $p = .06$, $\eta_p^2 = .15$. These results indicated that more time since eaten and dessert liking related to greater relative left frontal activation in the dessert pictures condition for the first second (time since eaten, $r = .53$, $p < .05$; liking for dessert, $r = .43$, $p = .08$) and 2–12 s (time since eaten, $r = .49$, $p = .05$; liking for dessert, $r = .49$, $p = .05$). In the neutral pictures condition, left frontal activation was not related or was inversely related to liking for dessert ($r = -.31$, $p = .27$;

$r = -.45$, $p = .11$) and time since eaten ($r = -.55$, $p < .05$; $r = -.22$, $p = .44$) during both viewing windows. [2,3]

Analyses then tested whether self-reported ratings of the pictures or self-reported affective states following pictures interacted with picture condition to predict relative left frontal activation. They did not ($ps > .24$).

For self-reported motivation, regression analyses revealed an interaction of liking for dessert and condition in predicting reported desire and want, $F(1,21) = 4.69$, $p < .05$, $\eta_p^2 = .18$; $F(1,21) = 4.86$, $p < .05$, $\eta_p^2 = .19$. Liking dessert related to more desire and want in the dessert pictures condition: desire, $r = .60$, $p < .05$; want, $r = .64$, $p < .05$. For the neutral pictures condition, more liking for dessert was not related to desire or want, $ps > .26$.

For self-reported affect, regression analyses revealed an interaction between picture condition and time since eaten in predicting reported serenity, $F(1,22) = 4.48$, $p < .05$, $\eta_p^2 = .17$ (within dessert condition, $r = .56$, $p = .06$; within neutral condition, $r = -.22$, $p = .45$). All other interactions between condition and individual differences of liking dessert or time since eaten on self-reports were not significant ($ps > .09$).

All nonfrontal asymmetries were not significantly predicted by the interaction of the approach motivated individual difference variables and condition (Bonferroni correction [$p = .001$] was used because of the large number of nonpredicted effects). Also, an index of four parietal asymmetries was not significantly predicted by liking for dessert or time since eaten, $ps > .56$.

Discussion

Emotive tendencies, as measured by liking for desserts or greater time since eaten, related to greater relative left frontal activation

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[1]Relative left frontal event-related desynchronization (ERD) of frontal asymmetry index during the first second of picture viewing related to second 1 frontal asymmetry index derived from FFT, $r = .92$, $p < .001$. For ERD, a significant interaction of condition and time since eaten emerged, $F(1,22) = 8.73$, $p < .01$, $\eta_p^2 = .28$. The interaction of condition and liking for dessert approached significance, $F(1,22) = 3.76$, $p = .07$, $\eta_p^2 = .15$.

[2]In response to neutral pictures, individual differences in approach motivation were mostly nonsignificantly but related to greater right than left frontal activation. When these participants viewed nonrewarding, neutral object pictures, they may have responded with decreased approach motivation because of their heightened general approach motivation.

[3]It is interesting to note that the individual differences in emotives significantly predicted relative left frontal activity even though the range of the individual differences was limited, as most participants liked dessert and none was extremely hungry. It is likely that a greater range in individual difference scores would produce even stronger effects.

to dessert pictures but not to neutral pictures. These effects emerged as early as 1 s into picture viewing and continued throughout the full 12 s of picture viewing. Dessert pictures were evaluated as more appetitive than neutral pictures. In addition, individual differences in emotive tendencies predicted self-reported appetitive motivation toward the dessert pictures.

Participants also felt more enthusiastic, pleasant, and good but less mad after viewing dessert pictures than after viewing neutral pictures. These results suggest that our sample did not show ambivalent or negative feelings about desserts because of health or weight concerns. Furthermore, these self-reported affects were unrelated to emotive individual difference variables or left frontal activation.

As noted earlier, the current results are consistent with both the motivational direction and affective valence model of asymmetrical frontal cortical activity. However, the literature at large has shown that asymmetrical frontal cortical activity is more sensitive to motivational direction than affective valence (Harmon-Jones, 2003). That is, at least 12 studies have shown a relationship between relative left frontal activity and anger, which is negative but approach motivating (for review, see Peterson et al., in press). Moreover, research has shown that whereas high approach-motivated positive affect causes an increase in left frontal activation, low approach-motivated positive affect does not (Harmon-Jones, Harmon-Jones, Fearn, Sigelman, & Johnson, in press).

Our results suggest that past failures to find differences in asymmetrical frontal activity to affective stimuli may have used person–situation complexes that did not evoke strong emotive tendencies. The present study extends other research by showing that asymmetrical frontal activations are potentiated by emotive differences that individuals bring to the laboratory as well as by manipulation of motivational variables within the laboratory (Harmon-Jones et al., 2006).

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