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Replication of Prefrontal Asymmetry in Approach-Avoidance Motivation in fMRI

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Abstract

A large body of research suggests that approach-related emotional states are lateralized to the left prefrontal cortex (Harmon-Jones & Gable, 2018). However, because affective motivation and valence have often been entangled in experimental designs, it is unclear which construct drives this laterality. In one fMRI study designed to dissociate motivation and valence, Berkman and Lieberman (2010) found that approach motivation was more left-lateralized than avoidance motivation in the dorsolateral prefrontal cortex (DLPFC), controlling for valence. Our study did not replicate this key finding from Berkman and Lieberman (2010). Furthermore, whereas Berkman and Lieberman (2010) found that individuals' trait approach motivation predicted the laterality of approach-related DLPFC activity, we found that trait approach motivation predicted the laterality of positive valence, controlling for motivation. Overall, our results do not provide any clear support for the 'textbook' model of affective motivation in the frontal lobes.

Keywords: approach; avoidance; motivation; valence; laterality; fMRI

Introduction

An influential model in affective neuroscience proposes that emotions are lateralized in the brain based on their motivational direction. Specifically, approach-related emotions, such as happiness and anger, are associated with greater activation in the left hemisphere, particularly in the left prefrontal cortex (Davidson, 1992; Harmon-Jones et al., 2010; Harmon-Jones & Gable, 2018). In contrast, avoidance-related emotions, including fear and disgust, show greater activation in the right hemisphere. This model has been supported by a large body of research across different neuroimaging modalities, including electroencephalography (EEG; e.g., Amodio et al., 2008) and functional magnetic resonance imaging (fMRI; see Wager et al., 2003 for a review).

Many EEG studies comparing alpha band activity in the left and right frontal cortices have found that lower left frontal alpha-band power (reflecting increased neural activity) is linked to approach motivation, while lower right alpha power is linked to avoidance motivation (see Harmon-Jones & Gable, 2018 for a review; but see Paul et al., 2025). Complementing these EEG findings, fMRI studies have found left laterality in prefrontal cortex for task-evoked approach states (e.g., Herrington et al., 2005) and trait measures of approach motivation (e.g., Spielberg et al., 2012). However, since approach motivation is often confounded with positive valence (many approach-related emotional states are positively valenced), it is unclear whether left laterality is driven by affective motivation or emotional valence.

Using meta-analytic methods, Wager et al. (2003) found some support for the hypothesis that motivation, rather than valence, drove left laterality across fMRI studies. However, most of those studies did not experimentally dissociate the two constructs. Experiments investigating anger, an approach-related emotion with negative emotional valence, have found left-lateralization (see Harmon-Jones & Gable, 2018 for a review), suggesting that valence cannot fully explain emotional laterality. Additionally, Berkman and Lieberman (2010) found evidence that approach motivation, rather than valence, drove left lateralization in the dorsolateral prefrontal cortex (DLPFC), in a task explicitly designed to dissociate state affective motivation and valence. In their fMRI study, participants read a realistic, but fictional, article about a group of people, called the "Nochmani," who habitually eat insects and sweet things, but do not eat meat or fungus. Then, participants (who were non-vegetarians) were shown images of items in each of these categories, and asked to indicate whether they would eat or not eat each item if they were Nochmani. This task aimed to orthogonalize motivation and valence, evoking the following emotional states: positive-approach; negative-approach; positive-avoidance; negative-avoidance. Additionally, this study found that trait approach motivation correlated with degree of participants' left-laterality during approach states (controlling for valence) but not during positive-valence states (controlling for motivation).

The present study aims to replicate Berkman and Lieberman's (2010) finding that motivation, rather than valence, drives prefrontal laterality, when the constructs are experimentally dissociated. Berkman and Lieberman's (2010) study, which has not been replicated previously to our knowledge, is of particular importance because it is arguably the only neuroimaging study that (a) orthogonalizes motivation and valence and (b) allows both approach and avoidance motivation to be tested within the same task.

Additionally, this replication will lay the foundation to further test a proposal explaining why affective motivation might be lateralized. The Sword and Shield Hypothesis (SSH;

Brookshire & Casasanto, 2012) proposes that systematic asymmetries in hand actions drive the laterality of affective motivation in the cerebral hemispheres. This hypothesis starts with the observation that the dominant hand (the right hand in right-handed individuals) is used disproportionately for approach-related actions, whereas the nondominant hand (the left hand in right-handed individuals) is used for avoidance-related actions; an iconic illustration of this pattern is wielding a sword with the dominant hand to attack an opponent (an approach action) and raising the shield with the non-dominant hand to fend off attack (an avoidance action). Because, for right-handed people, the right hand is controlled by the left motor and premotor cortex, the laterality of approach motivation could be explained by implicit preparation of approach actions or by co-lateralization of affective approach areas with the motor areas that are preferentially involved in approach action. According to EEG (Brookshire & Casasanto, 2012) and tDCS data (Brookshire & Casasanto, 2018), approach motivation is associated with left-hemisphere activity in right-handers, but with right-hemisphere activity in left-handers, consistent with the proposal that hemispheric specialization for affective motivation depends on motor control of the "sword" and "shield" hands (Brookshire & Casasanto, 2012). Replicating Berkman and Lieberman's (2010) fMRI study in right-handers, and then extending it to left-handers, would allow the relationship between motivation and motor control to be examined with greater anatomical precision than in the previous EEG and tDCS studies.

Method

This replication study aimed to approximate the data collection and analysis procedures used by Berkman and Lieberman (2010). Our data acquisition, preprocessing, and analysis procedures had the following differences from the original study:

1. Data acquisition: Berkman and Lieberman (2010) used a Siemens Allegra 3T scanner; we used a GE Discovery MR750 3T scanner.

2. For structural scans, our protocol used a higher spatial resolution with a smaller slice thickness (1 mm vs. 3 mm in the original study), a shorter repetition time (TR = 2174 ms vs. 5000 ms in the original study), and a shorter echo time (TE = 3.55 ms vs. 33 ms). Furthermore, our field of view (FOV) was 30 cm (vs. 20 cm), and the matrix size was 256 × 176 (vs. 128 × 128).

3. For functional scans, both studies employed echo-planar T2*-weighted gradient-echo sequences, but there were differences in some acquisition parameters. Our protocol used a matrix size of 128 × 128 (vs. 64 × 64), a field of view of 21.6 cm (vs. 20 cm) with 44 axial slices (vs. 34), and a slice skip of 3 mm (vs. 1 mm). The echo time (TE) in our scans was longer (27 ms compared to 25 ms), and the flip angle was lower (70° vs. 90°).

4. In the functional task, our participants completed four runs with a total of 32 blocks and 320 trials, instead of two runs with a total of 20 blocks and 200 trials.

5. fMRI preprocessing and analysis: The original study used SPM5 for preprocessing, whereas we used fMRIprep (Esteban et al., 2019). Our preprocessing pipeline included correction for field inhomogeneity. The original study used SPM5 for smoothing, first-level, and ROI analyses, whereas we used SPM12 (http://www.fil.ion.ucl.ac.uk/spm/).

Participants

Twenty-three right-handed participants aged 18–40 were recruited. Participants were pre-screened for right-handedness using the Edinburgh Handedness Inventory (EHI > 40), English fluency, non-vegetarian status, and fMRI safety following Cornell University MRI Facility's guidelines. Left-handed individuals were excluded from this replication study to avoid potential confounding effects of handedness on lateralization (Brookshire & Casasanto, 2012). All participants provided written and informed consent as approved by Cornell University's Institutional Review Board for Human Participants (IRB Protocol IRB0007462).

Materials

Nochmani Task Following the method outlined by Berkman and Lieberman (2010), participants completed the Nochmani task, a 2x2 factorial design that aims to dissociate motivation (approach vs. avoidance) from valence (positive vs. negative; Berkman et al., 2009). The stimuli consisted of images of various foods, including bugs, desserts, meats, and fungi, specifically chosen to evoke distinct motivational and valence responses. These stimuli were presented digitally while participants were in the fMRI scanner. Participants were instructed to decide whether a fictional tribe, the "Nochmani," would "eat" or "not eat" the presented food. According to the fictitious article, the Nochmani enjoy sweets and insects, but dislike meat and fungi. Task blocks varied pseudorandomly across conditions to ensure equal representation of all motivation and valence combinations. Each participant completed four runs, each with eight blocks, separated by 10-14 s of fixation (the Baseline condition). Each block included eight trials of the target condition, and two trials of a distractor condition. Across the four runs, participants completed 32 blocks, with a total of 320 trials (80 trials of each condition). Participants responded "eat" or "not eat" using the left and right buttons of a button box, using the thumb of one hand in each block. Participants switched which thumb they used between blocks. The hand used in the first block, and whether the left button corresponded to "eat" or "not eat", was balanced between participants.

Survey Trait behavioral activation and inhibition were assessed using the Behavioral Inhibition/Behavioral Activation Scales (BIS/BAS; Carver & White, 1994). The BAS consists of three subscales: the Drive subscale with four items, which evaluates the persistent pursuit of goals; the Fun Seeking subscale with four items, which measures the desire for new rewards; and the Reward Responsiveness subscale with five items, which reflects positive reactions to rewards. The BIS contains seven items that aim to measure behavioral inhibition.

Procedure

Before the scan, participants completed the Edinburgh Handedness Inventory (EHI; Oldfield, 1971) to confirm their right-handedness. Following the procedure of Berkman and Lieberman (2010), before the scan, participants read a realistic, but fictional, article about the "Nochmani" tribe (Berkman et al., 2009). Participants were fitted with a clip-on pulse-rate monitor, which was attached to their big toe rather than their finger to avoid interference from button presses during scanning. The scanning session began with localizer and calibration scans, followed by structural and functional imaging. Structural imaging included a high-resolution anatomical scan (MPRAGE, 1 min) and a diffusion-weighted imaging (DWI) scan for incidental findings (30 s). Functional imaging consisted of four runs of the Nochmani task. Participants also complete a finger tapping task and a resting state scan, which were collected for a different analysis, and were not of interest in the present replication study. After the scan, participants completed the BIS/BAS survey (Carver & White, 1994).

fMRI Data Acquisition and Analysis

Scan Parameters T2-weighted structural scans were obtained using a spin-echo sequence with a TR of 2174 ms, a TE of 3.55 ms, a matrix size of 256 × 176, a field of view of 30 cm, 256 sagittal slices, a slice thickness of 1 mm, and a skip of 1 mm. These structural images were used to coregister and normalize functional images. Functional imaging data were acquired using an echo-planar T2*-weighted gradient-echo sequence. Each of the four nochmani task scans lasted 5 min and 16 s. The scans had a TR of 2000 ms, a TE of 27 ms, a flip angle of 70°, a matrix size of 128 × 128, a field of view of 21.6 cm, 44 axial slices, a slice thickness of 3 mm, and a skip of 3 mm. PEPOLAR susceptibility distortion maps were collected before the first functional run.

MRIQC Image quality was evaluated using MRIQC (version 24.0.2, Esteban et al., 2017), which provides detailed quality control (QC) metrics for both structural and functional MRI data. In addition to the automated QC process, images were manually reviewed to confirm they met quality standards. This review involved checking for proper alignment, assessing motion artifacts, and ensuring adequate signal-to-noise ratios. Any images flagged by MRIQC as potential outliers, such as those with high framewise displacement, were inspected to determine if they should be included in the analysis.

Preprocessing Anatomical and functional MRI data for each participant were preprocessed using the fMRIPrep automated MRI workflow (version 24.0.1; Esteban et al., 2019), which included skull stripping, intensity non-uniformity correction, motion correction, coregistration between functional and T1-weighted volumes, and normalization to the MNI152NLin2009cAsym brain template. Fieldmap correction was performed using topup. Spatial normalization was performed using nonlinear registration with ANTs, ensuring alignment to the standardized template. Preprocessing outputs included trial-level beta parameters estimated from the functional time series, which were subsequently analyzed within predefined regions of interest (ROIs).

First-Level Analysis First-level analyses were conducted in MATLAB (version 24.2.0; The Mathworks Inc., 2024) using SPM12 (http://www.fil.ion.ucl.ac.uk/spm/) to model individual participants' average blood oxygen level-dependent (BOLD) response by condition. Preprocessed functional images were analyzed using a generalized linear model, with regressors corresponding to the four experimental conditions in the 2 × 2 factorial design: Approach-Positive, Approach-Negative, Avoidance-Positive, and Avoidance-Negative. Each condition was modeled as a boxcar function convolved with the canonical hemodynamic response function to capture the expected BOLD response. Fixation periods were modeled as a Baseline condition. A high-pass filter was applied to remove low-frequency noise, and an autoregressive model was used to correct for temporal autocorrelations in the data. A whole brain mask was applied to reduce nonbiological noise.

Contrast maps were generated for each participant comparing Approach-Positive to Baseline, Approach-Negative to Baseline, Avoid-Positive to Baseline, and Avoid-Negative to Baseline, as well as the marginal contrasts, Approach vs. Baseline and Avoidance vs. Baseline.

ROI Definition Using methods outlined by Berkman and Lieberman (2010), we defined ROIs for the DLPFC and orbitofrontal cortex (OFC), separately for the left and right hemispheres. These ROIs were created in SPM12 using MarsBaR (Brett et al., 2002) in combination with the Wake Forest University Pickatlas Tool (Maldjian et al., 2003), based on the Automated Anatomical Labeling (AAL) atlas (Tzourio-Mazoyer et al., 2002). The dorsolateral ROIs included the superior and middle frontal gyri, pars opercularis, and pars triangularis from the AAL atlas, cut above the MNI axial plane z = 2. The orbitofrontal ROIs were defined as the orbital portions of the superior, middle, and inferior frontal gyri, including only voxels at or below the MNI axial plane z = 0.

ROI Extraction For each participant and contrast of interest, the voxels within the four resulting ROIs (left and right DLPFC, left and right OFC), were averaged to generate four mean values, which were used in subsequent analyses. The six contrasts of interest were: Approach-Positive vs. Baseline; Approach-Negative vs. Baseline; Avoid-Positive vs. Baseline; Avoid-Negative vs. Baseline; Approach vs. Baseline; Avoid vs. Baseline.

Asymmetry Score Calculation Following Berkman and Lieberman (2010), asymmetry scores were calculated for each ROI pair (DLPFC and OFC) and each contrast of interest, as the difference in mean z-scored fMRI BOLD signal change between the right and left ROIs.

Statistical Analyses of Laterality of Motivation and Valence As preregistered, we aimed to replicate the statistical tests reported by Berkman and Lieberman (2010). Using asymmetry scores from the four contrasts—Approach-Positive, Approach-Negative, Avoid-Positive, and Avoid-Negative vs. Baseline—we specified a linear model with the dependent variable asymmetry score and the predictors motivation (approach vs. avoidance) and valence (positive vs. negative). Participant was modeled as a random effect. For each ROI, we then tested whether mean asymmetry scores were more leftward for approach than avoidance (controlling for valence); whether mean asymmetry scores were more leftward for positive than negative valence (controlling for motivation); and whether the difference in laterality for motivation was significantly different from the difference in laterality for valence (the interaction of motivation and valence). Additionally, we tested for an interaction of motivation by region, to assess whether the laterality of motivation was specific to the DLPFC.

Correlation of Laterality With Trait Approach (BAS) Following Berkman and Lieberman (2010), to test whether trait approach motivation predicted the degree of fMRI BOLD asymmetry in the DLPFC, we tested for partial correlations between BAS score and Asymmetry Score (controlling for BIS), for each contrast of interest (including the marginal contrasts, Approach vs. Baseline and Avoidance vs. Baseline). We tested whether BAS total score, and each BAS subscore, predicted degree of leftward laterality (controlling for BIS), as measured by the asymmetry score from each of these contrasts. We additionally ran simple correlations of BAS scores with asymmetry scores.

Additionally, although the original study did not report such an analysis, we tested for an interaction of BAS total by motivation by valence, to evaluate whether any leftward correlation of BAS with motivational asymmetry was specific to either valence condition. To control for a potential influence of BIS on laterality of motivation, we included the three-way interaction of BIS by motivation by valence in this model. We also included Participant as a random effect. Additionally, this model was used to estimate the effects of motivation and valence, controlling for the potential higher-order interactions of motivation, valence, and BAS scores.

Data Availability and Preregistration

Statistical analyses were run using R 4.2.2 (R Core Team, 2024) with the lme4 (Bates et al., 2015), emmeans (Lenth, 2022), LmerTest (Kuznetsova et al., 2017), and ppcor (Kim, 2015) packages. Stimuli, behavioral data, fMRI summary data, and preprocessing and analysis scripts are available at https://osf.io/jwhab. De-faced source and BIDS-formatted fMRI data are available upon request. This replication study was preregistered with aspredicted (https://aspredicted.org/khc9-m5my.pdf).

Results

Exclusions

All 23 subjects completed the full sequence of four task runs and were included in analyses of laterality of motivation and valence. Two participants did not complete the BIS/BAS survey due to time constraints; the remaining 21 participants were included in the correlation analyses between laterality and trait approach motivation.

Laterality of Motivation and Valence

Dorsolateral Prefrontal Cortex In the DLPFC, we tested for main effects of motivation (approach vs. avoidance) and valence (positive vs. negative), as well as their interaction. No significant main effects were observed for motivation (*estimated z-scored contrast value* $= -0.041$, 95% CI $[-0.110, 0.028]$, $p = .12$, one-sided) or valence ($est = -0.003$, 95% CI $[-0.072, 0.066]$, $p = .46$, one-sided). Controlling for valence, avoidance showed significant rightward laterality ($est = 0.109$, 95% CI $[-0.009, 0.227]$, $p = .034$, one-sided), however, approach showed no significant laterality, with the point estimate numerically indicating rightward laterality, contrary to the predicted direction ($est = 0.068$, 95% CI $[-0.050, 0.186]$, $p = .24$, two-sided).

The interaction of motivation by valence was marginally significant ($est = 0.126$, 95% CI $[-0.012, 0.264]$, $p = .072$, one-sided). Within the positive valence condition, there was no significant effect of motivation ($est = 0.022$, 95% CI $[-0.075, -0.119]$, $p = .33$, one-sided); however, for negative valence, the main effect of motivation was significant and in the predicted direction, showing more rightward asymmetry for avoidance than approach ($est = 0.104$, 95% CI $[0.007, 0.201]$, $p = .018$, one-sided). For negative valence, avoidance showed significant right-laterality ($est = -0.142$, 95% CI $[0.016, 0.268]$, $p = .014$, one-sided), whereas approach showed no significant laterality ($est = 0.040$, 95% CI $[-0.088, 0.165]$, $p = .27$, one-sided; see Figure 1).

Orbitofrontal Cortex In the OFC, no significant effects were found for motivation ($est = -0.000$, 95% CI $[-0.077, 0.077]$, $p = .49$, one-sided) or valence ($est = -0.016$, 95% CI $[-0.093, 0.061]$, $p = 0.34$, one-sided). Controlling for valence, we found no significant laterality for either avoidance ($est = 0.009$, 95% CI $[-0.117, 0.135]$, $p = .88$, two-sided) or approach ($est = 0.009$, 95% CI $[-0.117, 0.134]$, $p = .88$, two-sided). The interaction of motivation and valence was significant, showing greater left-laterality for approach in the negative than positive valence condition ($est = 0.182$, 95% CI $[0.028, 0.336]$, $p = 0.021$, two-sided).

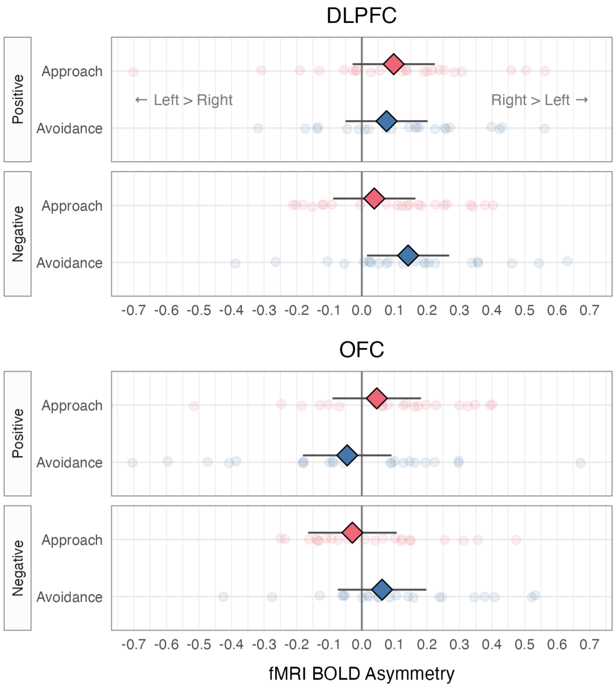

Figure 1: fMRI BOLD asymmetry scores by valence and motivation, for each region. Diamonds show estimated asymmetry scores by condition, with 95% confidence intervals.

Within the negative valence condition, approach showed marginally more leftward asymmetry than avoidance ($est = -0.091$, 95% CI $[-0.200, -0.018]$, $p = 0.05$, one-sided). However, within the positive valence condition, the effect of motivation showed a trend in the other, unexpected direction: approach was associated with more *rightward* asymmetry ($est = 0.091$, 95% CI $[-0.018, -0.200]$, $p = 0.10$, two-sided).

DLPFC vs. OFC The interaction between region and motivation revealed no significant difference in the relationship between motivation and asymmetry in the DLPFC vs. OFC ($est = -0.041$, 95% CI [-0.147, 0.065], $p = 0.22$, one-sided).

Correlation of Laterality with Trait Approach (BAS) We first replicated the original study's partial correlation tests estimating the correlation between BAS score and DLPFC asymmetry, for each contrast of interest, while statistically controlling for BIS score. BAS total score correlated significantly with DLPFC asymmetry for the contrast Approach-Positive vs. Baseline, in the predicted direction (greater approach motivation correlated with more leftward approach asymmetry; ($r(20) = -0.43, p = .029$, one-sided). BAS total score did not correlate significantly with asymmetry in the contrast Approach vs. Baseline ($r(20) = -0.25, p = .14$, one-sided), although the point estimate was numerically in the predicted direction.

Against the hypothesis that BAS should predict laterality of motivation rather than valence, BAS total also correlated with asymmetry in the contrast Positive Valence vs. Baseline ($r(20) = -0.38, p = .047$, one-sided).

Showing a similar pattern to BAS total score, the BAS drive subscale correlated significantly with Approach-Positive vs. Baseline asymmetry ($r(20) = -0.40, p = .041$, one-sided), and trended in the predicted direction for the Approach vs. Baseline contrast ($r(20) = -0.33, p = .071$, one-sided), as well as for Positive Valence vs. Baseline ($r(20) = -0.36, p = .057$, one-sided). The BAS fun seeking and reward responsiveness subscales showed no significant correlations with DLPFC asymmetry. Simple correlations between BAS and asymmetry scores showed a similar pattern of results to the partial correlations, except that the relation between BAS total and positive valence asymmetry was now marginally significant ($r(20) = -0.36, p = .051$, one-sided; see Figure 2).

To further assess whether trait approach motivation predicted laterality of motivation or valence, we conducted exploratory analyses modeling the interaction of BAS total score with motivation, and with valence, statistically controlling for BIS. The three-way interactions of BAS with motivation and valence, and BIS with motivation and valence, were specified in a linear model, and Participant was modeled as a random effect. We found no significant effect of motivation on the relation between BAS and DLPFC asymmetry ($est = -0.003$ *units change in z-scored contrast estimate per raw BAS score unit*, 95% CI $[-0.017, 0.011]$, $p = .35$, one-sided); however, we did observe a significant effect of valence ($est = -0.012$, 95% CI $[-0.026, 0.002]$, $p = .047$, one-sided), with BAS predicting more leftward asymmetry for positive valence.

We found no significant effect of the interaction of motivation by valence on the correlation between BAS and DLPFC asymmetry, ($est = -0.019$, 95% CI $[-0.047, 0.009]$, $p = .088$, one-sided), with the estimate numerically in the direction of a stronger relationship between BAS and motivation with positive valence. Only within the positive valence condition did we find a significant interaction of BAS and motivation, with greater BAS Score predicting greater left-laterality of approach motivation ($est = -0.021$, 95% CI $[-0.042, 0.001]$, $p = .030$, one-sided). Together, these results do not support the hypothesis that the relation between trait approach motivation and laterality is specific to motivation rather than valence.

Discussion

This study sought to replicate Berkman and Lieberman's (2010) pattern of results suggesting that motivation, rather than valence, was lateralized in the DLPFC, and more broadly, to replicate the finding that approach motivation is lateralized to the left cerebral hemisphere and avoidance motivation to the right hemisphere (Harmon-Jones & Gable, 2018), in right-handers (Brookshire & Casasanto, 2012). In contrast to Berkman and Lieberman's (2010) study, we did

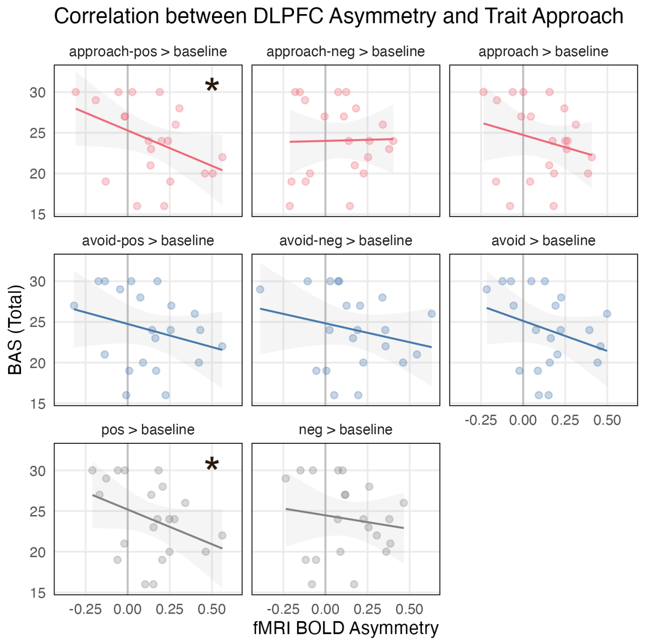

Figure 2: Lines show the estimated simple correlation between BAS total score and DLPFC asymmetry, for each contrast condition. A positive Asymmetry Score indicates greater fMRI activation on the right side. Asterisks indicate conditions in which the relation between BAS and Asymmetry Score was significant at alpha = .05, when controlling for BIS.

not find evidence that affective motivation was left-lateralized in the DLPFC across valence conditions. Although we found that avoidance motivation was significantly right-lateralized (compared to baseline), the laterality of avoidance motivation did not differ significantly from the laterality of approach motivation, and approach motivation was not significantly left-lateralized in any condition. We partially replicated Berkman and Lieberman's (2010) association between DLPFC laterality and trait approach motivation (as measured by BAS), finding a significant correlation between higher trait approach motivation and left-laterality for approach-related DLPFC activity in the positive valence condition, but not across the valence conditions. Unexpectedly, we found that BAS scores also predicted the degree of left-laterality for *valence* across motivation conditions. Together, these results do not corroborate the hypothesis that affective motivation, rather than emotional valence, is lateralized in the DLPFC; specifically, the results do not show the predicted left-laterality of approach motivation, or the dissociation in laterality between approach and avoidance motivation.

Why did our results not corroborate the many previous studies supporting the 'textbook' left-approach / right-avoidance model of motivation in the frontal lobes (Harmon-Jones & Gable, 2018)? The expected laterality of motivation may have been obscured by interactions between valence and motivation in certain conditions. Our finding that approach motivation was more left-lateralized in the negative valence condition may suggest that positive emotion attenuated the expected right-lateralization of avoidance in the positive condition, obscuring the potential difference between approach and avoidance. Similarly, if negative valence attenuated the approach response, the approach-negative condition may not have elicited a strong enough approach response to produce left-lateralization; however, this attenuation would not explain why approach motivation in the positive condition was right-lateralized. The fact that approach was not left-lateralized in any condition is hard to explain in light of many previous studies testing the laterality of motivation in the cerebral hemispheres (Harmon-Jones & Gable, 2018; Wager et al., 2003; but see Kuper et al., 2019; Paul et al., 2025).

Our correlational findings, where trait approach motivation (as measured by BAS) was significantly associated with left-lateralization in the Approach-Positive vs. Baseline contrast but not in the Approach vs. Baseline contrast, raise the question of whether Berkman and Lieberman's (2010) experimental design fully dissociated motivation and valence. Our results are consistent with the possibility that participants were in a truly approach-motivated state when responding that they would eat a positive-valence stimulus (e.g., a cake), but not when responding that they would eat a negative-valence stimulus (e.g., a bug).

Further investigation into the localization of emotional laterality could help explain our results which, despite some unexpected significant findings, were largely null with respect to the 'textbook' model of motivation in the brain. The DLPFC region of interest in the present study covered a large area that includes functionally distinct subregions. Future research could examine specific subregions that are candidates sites for laterality of motivation. For example, the DLPFC subregion with maximal negative connectivity to the anterior cingulate cortex (ACC), which has been proposed as an optimal target for lateral TMS treatment for depression (Lefaucheur et al., 2020), may be a site of laterality in affective motivation. Alternatively (or in addition), according to the Sword and Shield Hypothesis (Brookshire & Casasanto, 2012), frontal areas connected to the motor cortex, premotor cortex, or supplementary motor area should exhibit motivational asymmetry because these areas are involved in performing approach- and avoidance-motivated actions with the dominant and non-dominant hands, respectively.

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