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Frontal Asymmetry in an approach–avoidance conflict paradigm

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Abstract

The frontal cortex appears to be asymmetrically related to approach motivation, avoidance motivation, and motivational conflict. Much past work has investigated approach and avoidance motivation, but little work has investigated frontal asymmetry in the face of motivational conflict in part because of the inherent conflict between avoidance motivation and motivational conflict. The current study sought to disentangle the existing confound between avoidance motivation and motivational conflict. In the study, participants selected the likelihood of viewing negative (vs. positive) images for zero reward points (avoidance only condition), or negative (vs. positive) images for the chance to win reward points (approach–avoidance conflict conditions). Participants exhibited greater relative right frontal asymmetry while making percent likelihood selections in the approach–avoidance conflict conditions relative to the avoidance only conditions. Additionally, participants exhibited greater relative right frontal asymmetry while viewing disgust images during trials with the greatest approach–avoidance conflict relative to trials with the lowest approach–avoidance conflict. Together, these results suggest that motivational conflict, and not avoidance motivation, is associated with greater relative right frontal activity.

KEYWORDS

EEG, emotion, motivation

1 | INTRODUCTION

Human experience is riddled with motivational conflict. Imagine a student selecting classes for an upcoming semester. The course they are most interested in taking is only offered by a professor whose student evaluations are poor, and the student must decide whether they want most to engage with the interesting course content or avoid taking a course with an undesirable teacher. Researchers have been examining motivational conflicts for over 75 years (Elliot & Covington, 2001). Much of this work, however, has confounded motivational conflict and other types of motivational control with behavioral avoidance (Gable et al., 2018). There is a growing concern that presumed neural substrates of avoidance motivation may actually be driven by motivational control (Gable et al., 2018; Kelley & Schmeichel, 2016). Further research into the link between neural activity and motivational conflict is necessary in order to clarify the ambiguous findings surrounding the relationship between motivation and physiology.

While a number of terms have been used to discuss motivational conflicts, this article will use terminology consistent with Gray and McNaughton's (2000) discussions of approach and avoidance motivation in the revised Reinforcement Sensitivity Theory. In this framework, the behavioral approach system (BAS) is thought to facilitate approach motivational tendencies. Approach motivational responses are those which encourage an organism to move toward a desired object (Gray, 1970; Gray & McNaughton, 2000). Conversely, avoidance motivation, or withdrawal motivation, is the tendency or desire of an organism to move away from or withdraw from an object. Avoidance motivation is thought to be facilitated by the flight fight freeze system, along with other types of avoidance behaviors. (FFFS; Gray & McNaughton, 2000).

A third motivational system especially relevant to approach–avoidance conflict is the revised behavioral inhibition system (r-BIS), which is engaged during motivational conflict (Gray & McNaughton, 2000). r-BIS is thought to be superordinate to the other motivational systems. Importantly, it is not conceptualized as a motivational system itself, but serves to moderate conflict either between or within motivational systems. If a conflict arises, the r-BIS assists the organism in managing conflicting desires (Gray & McNaughton, 2000). Importantly, when an approach–avoidance conflict arises, r-BIS is the system that helps the organism make a decision to engage in approach or avoidant action. It is important to note that early conceptualizations of reinforcement sensitivity theory combined both FFFS and r-BIS into one component, simply labeled as the behavioral inhibition system. Because FFFS and r-BIS were initially conflated, some research has struggled to effectively differentiate between these systems following Gray and McNaughton's (2000) revisions (Gable et al., 2018).

1.1 | Frontal asymmetry and reinforcement sensitivity theory

The revised Reinforcement Sensitivity Theory has gained much attention from researchers interested in how these motivational systems affect physiology and patterns of brain activity. One neurophysiological substrate that has offered insight into these motivational systems is frontal asymmetry. Frontal asymmetry is frequently assessed using electroencephalography (EEG) to examine greater relative left or greater relative right frontal activity (Coan & Allen, 2004; Gartstein et al., 2020; Harmon-Jones, 2003; Schutter & Harmon-Jones, 2013).

Early models of frontal asymmetry proposed that frontal asymmetry was driven by emotional valence. In that framework, greater relative left frontal activity was associated with positive affect, while greater relative right frontal activity was associated with negative affect (Davidson, 1984). One problem, however, was that much of this research had confounded affective valence with motivational direction, such that stimuli that induced positive affect were also approach motivating and stimuli inducing negative affect were frequently withdrawal motivating (Harmon-Jones et al., 2010). Seminal findings in the field linked an approach motivating negative affect (anger) to relatively greater left frontal activity (Carver & Harmon-Jones, 2009; Harmon-Jones & Allen, 1998; Harmon-Jones et al., 2010). These important findings began to switch understanding of frontal asymmetry toward a pattern based on motivational direction and not affect. Newer models of asymmetric frontal cortical activity have suggested that approach motivation, not positive affect, is related to greater relative left frontal activity, and that avoidance motivation, not negative affect, is related to greater relative right frontal activity (Harmon-Jones, 2004; Poole & Gable, 2014; van Honk & Schutter, 2006).

It is important to note, however, the hypothesized link between motivational processes and frontal asymmetry is not without flaws. While, greater relative left frontal activity has consistently been associated with approach motivation, past work linking avoidance motivation, and greater relative right frontal activity have been mixed. Some studies have found limited support for this relationship (Buss et al., 2003; Rodrigues et al., 2018; Sutton & Davidson, 1997), but many have failed to replicate this association (for review see, Gable et al., 2018; Harmon-Jones & Gable, 2018). Further complicating this association, one frequently used measure of trait behavioral inhibition, Carver and White's (1994) BIS scale, predates Gray and McNaughton's (2000) revisions differentiating between r-BIS and FFFS. Some research has suggested that this measure may be more susceptible to punishment sensitivity than to motivational conflict (Reznik & Allen, 2018). Research examining this measure may contribute to ambiguous relationships between frontal asymmetry, avoidance motivation, and motivational conflict. Additionally, recent meta-analyses of resting frontal asymmetry have failed to find a relationship between right frontal activity and withdrawal traits (Garrison et al., 2018; Wacker et al., 2010).

In some of the studies linking right frontal activity and avoidance motivation, the experimental manipulation may have introduced confounds between avoidance and motivational control. For example, Canli and colleagues (1998) found that participants' brain activity lateralized toward the right hemisphere, relative to the left hemisphere, when they viewed negative images in a functional magnetic resonance imaging (fMRI) machine. Similar lateralization effects have been found using EEG to measure brain activity in response to negative film clips (Tomarken et al., 1990; Wheeler et al., 1993). In these studies, participants asked to continue to view avoidance-motivating stimuli despite their desire to move away from or disengage with it. In instances like this, participants may not be experiencing true avoidance motivation, but rather motivational conflict. To continue looking at avoidance-motivating images, despite wanting to look away, may have activated r-BIS due to the approach–avoidance conflict.

1.2 | r-BIS and right frontal asymmetry

Based on recent research using fMRI, transcranial direct current stimulation (tDCS), and EEG, researchers have suggested that greater right frontal activity may be related to r-BIS, as opposed to FFFS. That is, perhaps greater effortful control is more strongly related to greater relative right frontal activity than to avoidance motivation. Wacker and colleagues (2003) posited the BIS-BAS model of anterior asymmetry (BBMAA), suggesting that approach tendencies and avoidance tendencies were associated with greater relative left frontal activity and that behavioral inhibition was associated with greater relative right frontal activity. While this initial work did not directly measure r-BIS, additional research seeking to support the BBMAA by directly comparing r-BIS and FFFS did find that participants exhibited greater relative right frontal activation in instances of approach–avoidance conflict relative to instances of withdrawal motivation (Wacker et al., 2008).

Research examining risk-taking and impulsivity suggest that these traits, which are associated with poor motivational control, have been linked with less right frontal activity (Gable et al., 2015; Neal & Gable, 2016; Santesso et al., 2008). Research examining impulsivity and risk-taking with tDCS has found that stimulating the right hemisphere has been associated with diminished impulsivity (Jacobson et al., 2011) and less risky decision making (Fecteau et al., 2007). Inhibiting the right hemisphere, conversely, has been implicated in more risky decision making (Hecht et al., 2013; Knoch et al., 2006). Additionally, work with tDCS manipulating neuronal excitability in the right hemisphere has implicated the right hemisphere in motivational control, self-control, and response inhibition (Kelley et al., 2019; Kelley & Schmeichel, 2016; Stramaccia et al., 2015).

Using EEG, Gianotti and colleagues (2009) found that individuals high in baseline relative right frontal activity were less likely to make risky decisions during a risk-taking task. Conversely, motivational control and less risk-taking has been associated with greater right frontal activation. Neal and Gable (2019) utilized a modified balloon analog risk task in which approach motivating alcohol images were superimposed on balloons. They found that for the second half of trials participants exhibited shifts toward greater relative right frontal activation on cash out trials relative to explosion trials, indicating that right frontal activation was associated with more controlled processing. In addition to experimental evidence, research examining trait personality variables also supports this claim. Neal and Gable (2017) found that greater BIS-Anxiety, a measure of control (Heym et al., 2008), was associated with greater relative right frontal activity, while FFFS was not.

1.3 | Disentangling r-BIS and FFFS

Despite the mounting evidence that relative right frontal activity may be associated with motivational conflict rather than avoidance motivation, few studies have sought to effectively disentangle this confound. One of the biggest challenges to disentangling the avoidance motivation/approach–avoidance confound is effectively manipulating approach–avoidance conflicts without co-activating avoidance or approach motivation. There are a number of ways approach–avoidance conflicts may exist. One of these is when an organism attempts to suppress their initial motivational response toward a stimulus. This suppression of motivational tendencies could include an organism either attempting to disengage from a behavior that it is already engaged in, or attempting to engage in a behavior that it would prefer to avoid. Additionally, approach–avoidance conflicts may exist when an organism simply wants to both approach and avoid an object simultaneously (e.g., getting paid to do a disgusting job). Much past work exploring this type of approach–avoidance conflict has relied on nonhuman subjects using fear conditioning by pairing appetitive stimuli (e.g., food or comfort) with aversive stimuli (e.g., shock or uncomfortable air pressure; Ito & Lee, 2016; McNaughton et al., 2016; Rosenblum & Harlow, 1963). Since this type of fear conditioning would be inappropriate in human studies, researchers must find other alternatives to invoking approach–avoidance conflict states so that they can be examined in conjunction with avoidance or approach only states.

Lacey and colleagues (2020) examined whether greater relative right frontal activity was related to effortful control or avoidance motivation. Study 1 created motivational conflict by asking participants to suppress their motivational responses toward negative sound clips. Participants relative right frontal activity was associated with the effort participants engaged while attempting suppress their affective responses, but not with the experience of negative affect. In Study 2, participants were asked to avoid escaping from aversive images for rewards. Relative right frontal activity was associated with fewer escapes from those images for reward trials, but not for non-rewarding trials. This pattern suggests that the conflict generated by viewing the aversive image to obtain the reward was associated with participants' right frontal activity, but avoidance was not. One limitation of this work, however, is that the results are primarily correlational and not causally manipulated. Empirical EEG studies manipulating approach–avoidance conflicts and avoidance motivation are needed to more clearly establish the role of the right frontal cortex.

1.4 | Current experiment

One experimental task that seems to effectively stimulate approach–avoidance conflict has been developed by Aupperle et al. (2011, 2015). In their task, researchers create approach–avoidance conflict by asking participants to select the percent likelihood that they will view an aversive image for the opportunity to win points, rather than seeing a pleasant image for which they will not receive any points. This paradigm creates approach–avoidance conflict by evoking approach to rewards, while also evoking withdrawal to negative images. In addition, this paradigm creates strong experimental control while still maintaining meaningful approach–avoidance conflict. Aupperle and colleagues (2011) found that participants were more likely to view the negative stimuli in reward approach–avoidance conflict trials relative to non-reward avoidance only trials. Participants' percent likelihood selections were associated with participants' self-reported motivation to obtain rewards.

In addition to behavioral and self-report, this task has also been used with physiological measures. Aupperle and colleagues (2015) examined participants' brain activity with fMRI while they completed the approach–avoidance conflict task. During conflict conditions, participants exhibited greater activity in the right dorsolateral prefrontal cortex (dlPFC) relative to activity in the avoidance only condition or an additional approach only condition. This pattern provides further support that the right hemisphere of the prefrontal cortex may be more active to motivational conflict. These findings associating the dlPFC with motivational conflict are bolstered by additional work utilizing tDCS. Chrysikou et al. (2017) found that increasing neuronal excitability over the dlPFC during this approach–avoidance conflict task led to less behavioral approach behavior during instances of motivational conflict. Despite these promising results, the approach–avoidance conflict task has not yet been examined in conjunction with frontal asymmetry.

The current experiment used a modified version of this task to evoke motivational conflict. In this task, participants were asked to select the percent likelihood of viewing a very negatively valenced image instead of a positively valenced image. Approach–avoidance conflict was generated by asking participants to decide between viewing a negative image that would earn them (one, three, or six) points, or viewing a positive image worth 0 points. In some instances, avoidance only trials were created by allowing participants to choose between viewing the negative image for 0 points or the positive image for 0 points.

After making the choice to view pictures, participants viewed disgust inducing, negative images (e.g., decapitated body) or positive images (i.e., delicious desserts). Engaging with (i.e., continuing to view) a negative image was expected to increase motivational conflict, because it takes effort to continue looking at the image as opposed to looking away. This conflict should decrease as point value for viewing the negative image increases. Asking participants to engage with stimuli they find aversive may induce motivational conflict (Lacey et al., 2020), and this conflict is thought to be greatest when participants have the least to gain from engaging with the stimulus. Zero points negative images were anticipated to induce the most conflict when actually viewing the image, as participants have no incentive to view them outside of being asked to do so. However, earning points when viewing a negative image should reduce the conflict. Increasing the value of these points should further reduce the motivational conflict of looking at negative images.

We hypothesized that participants would select higher likelihoods of viewing negative images when reward values were higher, because the points would increase approach motivation. When deciding whether to view a negative or positive image, it was anticipated that participants would exhibit greater relative right frontal activity during approach–avoidance conflict trials relative to avoidance only trials. When participants are viewing the images, it was expected that participants would have less relative right frontal activity while viewing positive images relative to viewing negative images, regardless of the trial type. When viewing negative images for 0 points, participants should exhibit greater relative right frontal activity, because there is greater conflict to continue looking at the negative images without points. When viewing negative images for points, participants should exhibit less relative right frontal activity, because there is less conflict (more approach motivation) to continue looking at the negative images while earning points.

2 | METHOD

2.1 | Procedure

Sixty-three (43 female) undergraduate introductory psychology students participated for partial course credit. All participants were verified as right handed prior to beginning the study (Gable & Poole, 2014). Upon arrival at the lab, participants consented to participate in the experiment and completed a variety of personality questionnaires. Following the completion of these questionnaires, EEG electrodes were applied. Four minutes of resting baseline EEG were recorded.

As part of a within subjects design, participants were asked to complete a modified version of the approach–avoidance conflict (ACC) task (Aupperle et al., 2011). The task was programed using Millisecond Inquisit 4.0 software. Participants completed four practice trials before beginning the experiment to introduce them to the task and to ensure that they understood all of the instructions. In this task, participants made choices regarding the likelihood that they would see either an image that is pleasant to look at or an image that is unpleasant to look at. Participants were given the opportunity to win a variable level of reward points by viewing negative images, but viewing positive images was always associated with receiving zero reward points.

On each trial, participants viewed a selection of response choices. There were nine response choices organized across a spectrum ranging from highest probability of a positive image to highest probability of a negative image. On either side of the scale were icons representing the outcome of the trial. One side of the scale had an icon of a sun, indicating that the outcome of the trial would be viewing a positive image. The opposite side of the scale had an icon of a skull and crossbones, which indicated that the outcome of the trial would be a negative image (see Figure 1). The side each image appeared on was counterbalanced throughout the study, such that half of the time the selection was presented higher likelihood of positive responses were on the left side of the scale, and half of the time the selection was presented higher likelihood of positive responses were on the right side of the scale. In addition to the positive and negative icons, each side of the scale also had a reward bar indicating how many points (indicated in red) could be earned for each of the outcomes. Positive image trials were always associated with zero reward points. Negative image trials were associated with zero, one, three, or six reward points. The midpoint of the scale was 50%, indicating a 50% chance that either of the outcomes will appear. The percentages increased in 10% increments as the scale moved out from the midpoint, ending in 90% on either end of the scale. The further toward the end of the scale the participant chose, the higher the likelihood was that they would see the image and receive the point values predicted by the icon on that end of the scale.

Positive images were of appetitive desserts from used and rated in numerous studies and have been shown to be very positive (Gable & Harmon-Jones, 2008; Juergensen & Demaree, 2015). Negative images were disgust inducing images of mutilated bodies taken from IAPS and collected through an online search tool (Lang et al., 1997). These images have been used and rated in prior studies and have been shown to be highly negative in valence (Gable & Harmon-Jones, 2010; Gable et al., 2016). The reward points associated with the image created two types of trials: avoidance only and approach–avoidance conflict. In avoidance only trials, both positive and negative outcomes were associated with zero reward points. In all approach–avoidance conflict trials, positive outcomes were associated with zero reward points and negative outcomes were associated with either one, three, or six reward points. These trials manipulated an approach–avoidance conflict because the negative, unpleasant images were associated with the positive experience of earning points.

After the participant selected the percent likelihood that they would see a certain image type, an image type consistent with their percent likelihood selection immediately appeared on the screen. For example, if a participant selected a 70% chance of a positive image appearing, there was a 70% chance they saw a positive image and a 30% chance they saw a negative image. Participants were given a percent likelihood choice rather than a dichotomous choice to maintain consistency with the original approach–avoidance conflict task (Aupperle et al., 2011, 2015). Images were presented for 6,000 milliseconds. Half of the time the image was presented, participants were asked to use the mouse to trace the outline of the image. The other half of the time images were presented, participants were instructed to watch the image for the entire time it was presented on the screen. These methods were used in order to ensure sustained engagement with the image. After the image was presented, the points won on the trial appeared on the screen. The number of points awarded on the trial appeared for 2,000 milliseconds. There were 72 total trials, 18 of these were avoidance only trials (zero reward points for viewing either a positive or negative image), and 18 trials of each level of approach–avoidance conflict (zero reward points for viewing a positive image, and one, three, or six reward points for viewing a negative image). After all trials were completed, participants viewed the total number of points earned. Points were redeemable for candy after the debriefing session.

2.2 | EEG recording and processing

Electroencephalography (EEG) was recorded from 64 tin electrodes using a stretch Lycra cap (Electro-Caps, Eaton, OH). Sensor placement was based on the international 10–20 system with a ground electrode mounted midway between FPz and Fz. Impedances were kept under 5 kΩ. Sensors were referenced online to the left earlobe and were re-referenced offline to an average linked ears reference. Data were collected using a Neuroscan SynAmps RT amplifier unit (El Paso, TX) and digitized at 500 Hz. Data were processed using BrainVision Analyzer 2.1 software (Brain Products GmbH, Munich, Germany). Signals were low-pass filtered at 100 Hz, high-pass filtered at 0.05 Hz, and notch filtered at 60 Hz. All data were visually inspected and artifacts (e.g., muscle movement, horizontal eye movement) were removed. Eyeblinks were removed with the ICA-based ocular artifact rejection function in the BrainVision Analyzer software (Brain Products, 2013).

A Hamming window was used to extract epochs 1 s in length during the time period in which participants made a

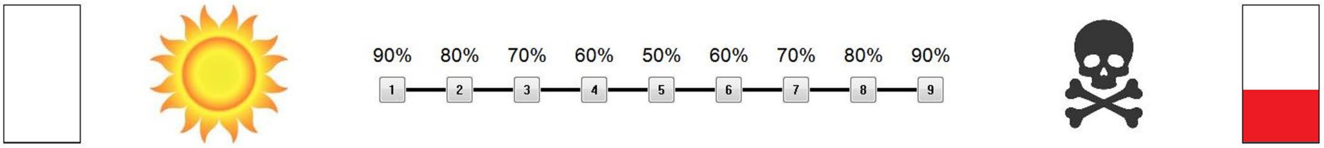

FIGURE 1 Example trial from modified approach–avoidance conflict task

decision on the probability that they would see a pleasant or unpleasant image. Epoching began when participants viewed the response spectrum and ended when they entered their probability selection. Each consecutive epoch overlapped by 50%. Additionally, a Hamming window was also used to extract epochs 1 s in length while participants engaged in the image viewing task. Epoching began when participants were presented with the image, and continued for the length of image presentation. Each consecutive epoch overlapped by 50%. Because the amount of time spent deciding to view a positive or negative image varied by trial, participants varied in the number of epochs analyzed per condition. Similarly, because participants viewed images based on their percent likelihood selections, the number of epochs per participant also varied in image viewing condition. Means and standard deviations for the number of epochs per condition are shown in Table 1.

After epoching, power spectra were calculated for alpha band activity (8–13 Hz) using a fast Fourier transform, and were averaged across all epochs. Asymmetry scores were calculated at frontal sites by subtracting the natural logarithm log (base e) transformed alpha power for an index of the right frontal (F8, F6, F4) from an index of the left frontal (F7, F5, F3) sites. Because alpha power inversely relates to cortical activity (Laufs et al., 2003), lower asymmetry scores indicated greater relative right frontal activity.

3 | RESULTS

3.1 | Preliminary analysis

All data were analyzed with TIBCO Statistica, IBM SPSS statistical software, and BrainVision Analyzer 2.1 software (Brain Products, GmbH, Munich, Germany). The alpha level for all analyses was set to .05. The methods, hypotheses, and projected analyses relevant to this study were preregistered online via AsPredicted (http://aspredicted.org/) using the websites standardized preregistration forms. Data will be made available to the scientific community upon publication.

TABLE 1 Epochs per condition

	Mean	Standard Deviation
Decision-making avoidance only: 0 point	136.50	60.60
Decision making: 1 point	134.32	63.74
Decision making: 3 point	137.93	64.87
Decision making: 6 points	137.00	65.92
All dessert images	441.27	177.42
All negative images combined	430.43	200.87
Disgust images: 0 points	46.07	38.72
Disgust images: 1 point	115.87	63.43
Disgust images: 3 points	135.03	64.44
Disgust images: 6 points	140.63	65.44

3.2 | Main data analysis

3.2.1 | Self-report analyses

Participants reported being more motivated to avoid the negative images than the positive images $t(57) = -13.14$, $p < .001$, $d = 2.66$. Participants reported more negative emotion to disgust images relative to dessert images $t(57) = 11.08$, $p < .001$, $d = 2.28$. Additionally, participants reported greater difficulty making a decision when there were points available for the trial ($M = 2.71$, $SD = 1.44$) relative to when points were not available for the trial ($M = 2.07$, $SD = 1.56$), $t(58) = -2.62$, $p = .01$, $d = 0.43$. Post hoc comparisons using the Fisher's LSD test indicated that participants self-reported similar levels of difficulty making a decision across the 1 point ($M = 2.63$, $SD = 1.80$), three point ($M = 2.85$, $SD = 1.77$), and 6 points conditions ($M = 2.66$, $SD = 1.99$).

3.2.2 | Behavioral percent likelihood selection and latency analyses

A dependent samples *t* test was conducted to determine if differences existed among reward value trials in the likelihood participants selected of seeing a negative image type (e.g., 10%–90%). The test indicated differences between the avoidance only condition ($M = 2.45$, $SD = 1.53$) and the approach–avoidance conditions ($M = 6.09$, $SD = 2.50$) on participant's percent likelihood selections $t(60) = -10.65$, $p < .001$, $d = 1.76$. Additionally, a repeated measures ANOVA was conducted to determine if differences existed in participant percent likelihood selections across levels of approach–avoidance conflict trials $F(2, 120) = 25.92$, $p < .001$, $\eta_p^2 = 0.30$. Follow-up analyses revealed that participants differed in their selections across all conditions with highest percent likelihood selections of seeing a negative image occurring during 6 points trials ($M = 6.58$, $SD = 2.65$), followed by three point trials ($M = 6.16$, $SD = 2.58$), and then, 1 point trials ($M = 5.53$, $SD = 2.52$). Similarly, a dependent samples *t* test was conducted to determine if differences existed in latency among reward value trials.

3.2.3 | Frontal asymmetry to approach–avoidance conflict trials

The critical analysis to test our hypothesis was to determine whether differences existed in frontal asymmetry between the avoidance only condition and the approach–avoidance conflict conditions. A dependent samples *t* test revealed that the approach–avoidance conflict condition evoked greater right frontal activity than the avoidance only condition, $t(51) = 2.41$, $p = .02$, $d = 0.06$ (see Figure 2).

Additionally, a one-way ANOVA was conducted to determine if differences existed among approach–avoidance conflict trials in participants' relative right frontal activity scores during the approach–avoidance task. Since this analysis is meant to differentiate between the one, three, and 6 points approach–avoidance conflict trials, the 0 points avoidance only trial is not included. There was a significant difference in relative right frontal activity across conditions $F(2, 120) = 3.40$, $p = .04$, $\eta_p^2 = 0.062$. Post hoc comparisons using the Fisher's LSD test indicated significant differences in relative right frontal activity while making percent likelihood selections between the 1 point condition ($M = 0.19$, $SD = 0.35$) and the three point condition ($M = 0.24$, $SD = 0.38$). The 6 points condition ($M = 0.21$, $SD = 0.37$) did not differ significantly from either the one or three point condition. Participants' relative right frontal activity scores while making percent likelihood selections were not associated with their behavioral selections (all *r*'s > −0.17 or <0.21; all *p*'s > .14).

3.2.4 | Frontal asymmetry to pictures

Participants did not vary in frontal asymmetry in response to traced versus non-traced images for either dessert images or disgust images ($t(40) = 1.63$, $p = .11$ and $t(39) = 0.72$, $p = .47$, respectively), so traced and non-traced images were combined. A dependent samples *t* test revealed no significant differences in frontal asymmetry while viewing positive images relative to negative images $t(51) = 0.15$, $p = .88$. A repeated measures ANOVA was conducted to determine whether differences in relative right frontal activity existed across negative image trials. There was a significant difference in frontal asymmetry scores across conditions $F(3, 132) = 2.69$, $p = .05$, $\eta_p^2 = 0.058$ (see Figure 3). Post hoc comparisons using the Fisher's LSD test indicated significant differences in relative right frontal activity during the 0 points condition ($M = 0.18$, $SD = 0.37$) relative to the 6 points condition ($M = 0.26$, $SD = 0.38$). The 1 point condition ($M = 0.24$. $SD = 0.42$) and three point condition ($M = 0.23$, $SD = 0.40$) did not differ significantly from either the 0 or 6 points condition.

4 | DISCUSSION

The current study sought to disentangle whether relatively greater right frontal activity is most closely associated with motivational conflict or avoidance motivation. The first part of the Approach–Avoidance Conflict Task utilized in this study required participants to engage in a motivational conflict task in which they made decisions regarding the likelihood of seeing a negative image for a variable number of reward points, as opposed to a positive image for zero reward points. The purpose of this task was to examine participants' relative right frontal activity during an avoidance only state relative to an approach–avoidance conflict state. Participants exhibited greater relative right frontal activity during approach–avoidance conflict trials relative to avoidance only trials. Participants reported that

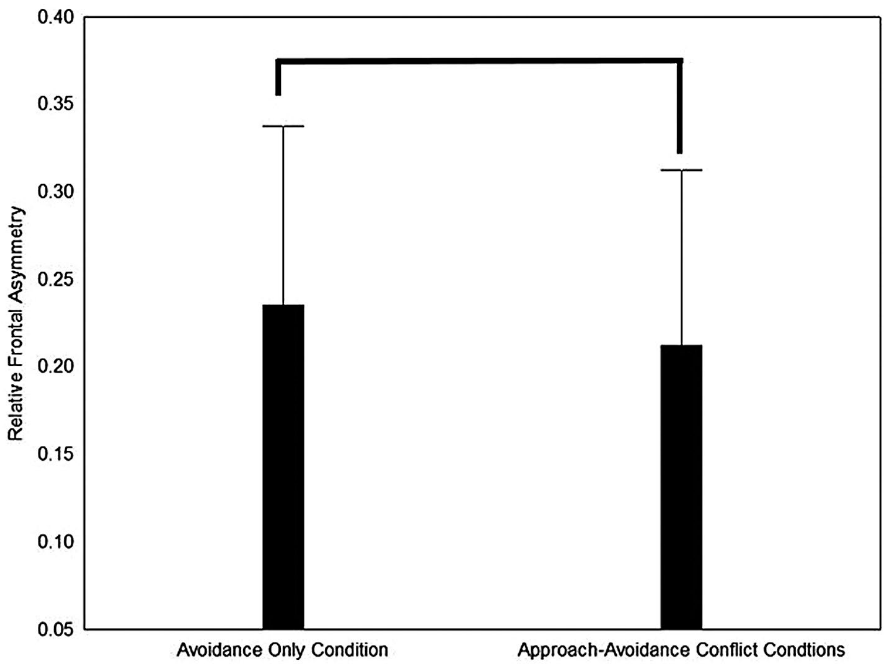

FIGURE 2 Relative right frontal asymmetry between avoidance only and approach–avoidance conflict conditions. Smaller relative frontal asymmetry scores indicate greater relative right frontal activity. Brackets connecting bars indicate significant differences between conditions ($p < .05$). Vertical whisker bars indicate 95% confidence intervals

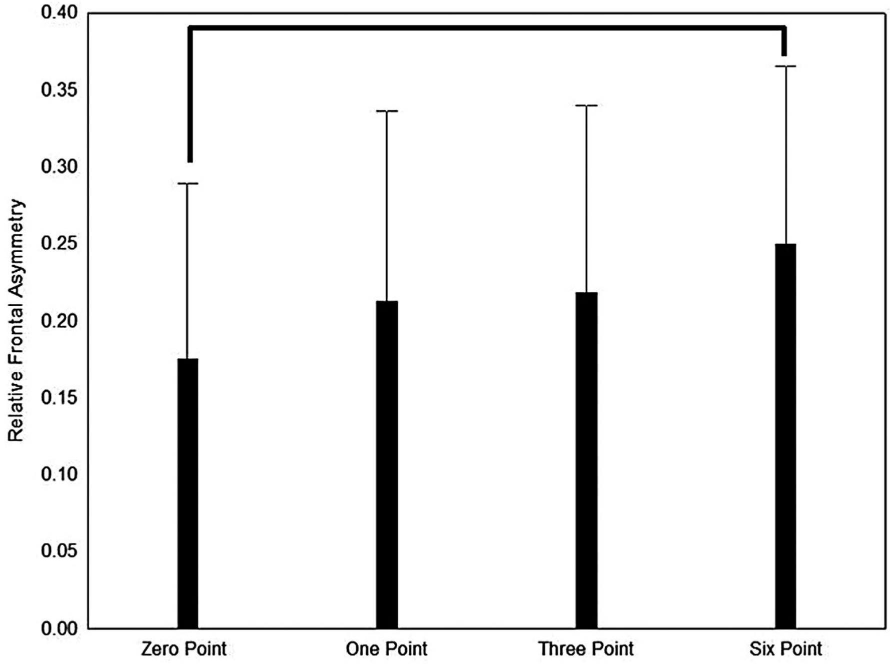

FIGURE 3 Relative right frontal asymmetry across negative image viewing conditions. Smaller relative frontal asymmetry scores indicate greater relative right frontal activity. Brackets connecting bars indicate significant differences between conditions ($p < .05$). Vertical whisker bars indicate 95% confidence intervals

it was more difficult to make percent likelihood selections in the approach–avoidance only conditions relative to the avoidance only condition, indicating that they did experience greater motivational conflict in those conditions. This suggests that it may be motivational conflict, and not avoidance motivation, that is most closely associated with greater relative right frontal activity.

In addition to making percent likelihood selections during task trials, participants also engaged in image viewing trials following percent likelihood selections. In these image viewing trials, participants viewed positive images for zero reward points and negative images for zero, one, three, and six reward points. This image viewing task also provides valuable information regarding participants' relative brain activity during approach–avoidance conflict conditions, particularly during negative image viewing. Participants showed relatively greater right frontal activity to negative images in the 0 points condition, where conflict was the greatest, compared to the 6 points condition, where there was the least amount of conflict. Having to engage with (i.e., continue looking at) a negative picture increased motivational conflict, because of the effort necessary to continue looking at it. Zero points approach–avoidance trials created no or low conflict when making decisions, but 0 points disgust images created high conflict when actually viewing the images, because participants did not have an incentive to view them outside of being asked to do so. As negative image point values increase, motivational conflict while viewing disgust images is thought to decrease. Participants exhibited greater relative right frontal activity during picture viewing when motivational conflict was high relative to when motivational conflict was low, which provides further support for the idea that relatively greater right frontal activity is associated with motivational conflict and not avoidance motivation.

Results of the current study suggest that a ratio may be one way to conceptualize the motivational conflict occurring when making decisions versus actually viewing pictures. During the decision-making phase, points associated with potentially viewing negative images increased the ratio of approach to avoidance motivation, thus, creating more approach–avoidance conflict. In contrast, during the viewing phase, points earned by looking at negative images decreased the approach–avoidance conflict of looking at negative pictures by increasing approach motivation to continue looking at the pictures. Manipulating the ratio of approach to avoidance motivation through the number of points participants knew they were eligible to receive during these motivational conflicts resulted in changes in participants' relative frontal activity when viewing the negative images. Shifts toward relatively greater right frontal activity are observed when conflict is high (e.g., when choosing whether to engage in an aversive task for points, or when engaging in an aversive task for little reward) and toward relatively greater left frontal activity when conflict is low (e.g., when a conflict does not exist or when the benefits of engaging in an aversive task outweigh the negatives).

In order to stimulate varying levels of approach–avoidance conflict, the current study used reward points in conjunction with aversive images. While this does allow for controlled comparisons of levels of conflict, it also introduces new complications by necessarily confounding experiences of conflict with reward points. If the presence of reward was the driving factor for changes in frontal asymmetry, we would have expected participants in approach–avoidance conditions to exhibit shifts toward relatively greater left frontal activity, due to the approach motivating presence of the reward. However, because the reward created approach–avoidance conflict, we saw shifts toward relatively greater right frontal activity. The benefits of being able to directly compare various levels of conflict seem to outweigh the disadvantages of this confound. Our findings provide additional support for other research that has also examined the relationship between rewards and frontal asymmetry. Miller and Tomarken (2001) examined participants' brain activity while they completed a task offering monetary incentives. They found that greater rewards, or reduced losses, were associated with relatively greater left frontal activity. It should be noted, however, that this research did not examine how approach–avoidance conflict factors into this relationship. In this way, the current study replicates and extends previous research examining the relationship between asymmetric cortical activity and rewards.

A second potential limitation to the current research is the use of the linked ears reference. Recent research examining methodological practices in frontal asymmetry research has suggested that the reference montages commonly used in frontal asymmetry research may allow frontal alpha to be influenced by distal alpha power from other sources (Smith et al., 2017). Because of this, some researchers have suggested applying a current source density (CSD) transformation instead of using a reference montage (Allen et al., 2018), however, this approach is not without limitations (Hagemann et al., 2001), and the use of the CSD transformation would limit the extent to which the findings of the current study could be directly compared to other studies examining frontal alpha asymmetry. Relatively few studies utilize this reference free method (Hagemann et al., 2001), while the linked ears reference is a common methodological practice (Davidson, 2004). In order to make our studies directly comparable with previous research examining motivation and frontal asymmetry we utilized a linked ears reference, but it should be noted that this may limit the extent to which inferences can be drawn about frontal activity.

Although we note some limitations to the current study, it should be noted that it also has two considerable strengths. One challenge to investigating motivational conflicts and untangling avoidance motivation from approach–avoidance conflict is finding tasks that allow for differentiation between motivational conflict and avoidance states. The methods used in this experiment allowed for the examination of motivational conflict (making choices) separate from actual avoidance motivation (viewing aversive pictures). This separation allowed examination of frontal asymmetry when participants are not currently engaged with aversive stimuli. Paradigms which entangle motivational conflict and avoidance motivation create confounds about what is activating relatively greater right frontal activity (Gable et al., 2018).

An additional strength of the current design is that it differentiates between an anticipatory phase and an engagement phase. Motivational conflicts can occur in each of these stages. In the anticipatory phase, participants are asked to make a decision about the type of stimuli that they want to interact with under a variety of circumstances. There is a clear differentiation between instances of approach–avoidance conflict and instances of avoidance motivation. During the image viewing phase, participants experience approach–avoidance conflict while already engaging with the stimulus. The motivational conflict arises when participants are required to force themselves to engage with an aversive stimulus that they would prefer to avoid (Lacey et al., 2020).

The current study provides support for a growing body of literature suggesting that motivational conflict and not avoidance motivation is related to greater relative right frontal activity. This is important not only for guiding future research, but also in aiding our understanding of psychophysiological processes. Gaining greater insight into the association between frontal cortical activity and motivation is necessary so that researchers studying motivation and psychophysiology have a better understanding of the psychological processes underlying neurophysiological activity. A better understanding of the neural processes underlying motivational conflict is beneficial to understanding how patterns of brain activity may lend insight into decision-making processes. Frontal asymmetry may be a reliable mechanism for providing deeper insight into how individuals resolve conflict and may be particularly helpful in understanding poor conflict resolution abilities.

AUTHOR CONTRIBUTION

Micayla F. Lacey: Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Project administration; Validation; Visualization; Writing-original draft; Writing-review & editing. **Philip A. Gable:** Conceptualization; Methodology; Supervision; Validation; Visualization; Writing-original draft; Writing-review & editing.

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