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Effortful control of motivation, not withdrawal motivation, relates to greater right frontal asymmetry

Micayla F. Lacey[a], Lauren B. Neal[b], Philip A. Gable[a,c,*]

[a] The University of Alabama, United States of America
[b] University of Texas of the Permian Basin, United States of America
[c] University of Delaware, United States of America

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ABSTRACT

Past models of frontal asymmetry have associated greater relative right frontal cortical activity with greater withdrawal motivation and greater relative left frontal cortical activity with greater approach motivation. However, this traditional model of frontal asymmetry leaves little to no room for the control processes that engage and regulate these emotional and motivational systems. A growing body of literature suggests that greater relative right frontal activation may be associated with greater regulatory control (Gable et al. 2018). However, this work confounded regulatory control and motivational direction. The current studies sought to test the competing hypotheses that currently exist in the literature by examining whether greater right frontal activation is more closely associated with regulatory control or withdrawal motivation. In Study 1, participants listened to negative and neutral sounds while suppressing their emotional reactions or listening naturally. Greater relative right frontal activation during the sound clips was associated with participants' reported effort when attempting to suppress their motivational responses to negative stimuli. Greater relative right frontal activation did not relate to experiencing negative affect. In Study 2, participants could win money by looking at a negative or neutral image or escape from looking at them for no reward. Greater relative right frontal activation was associated with looking at the negative pictures longer when there was a possibility of reward, but not when the possibility of reward was absent. Together, these studies suggest that it is the affective control of emotion rather than negative affect driving greater relative right frontal asymmetry. Additionally, these studies suggest that motivational conflicts engage effortful control.

Motivational drives to move toward or away are fundamental to the behavior of all organisms. Jeffery Gray and colleagues conceptualize interconnected motivational systems in the Reinforcement Sensitivity Theory (Gray, 1970). According to the revised Reinforcement Sensitivity Theory (RST, Gray and McNaughton, 2000), the behavioral approach system (BAS) is activated by appetitive stimuli and facilitates approach. The Fight Flight Freeze System (FFFS) is activated by aversive stimuli and responds to threat. The third system, the revised Behavioral Inhibition System (r-BIS), is activated by conflicts that arise from motivational urges with the other systems. The role of r-BIS is to help an organism make decisions about what behavioral actions to take in situations when there is conflict between or within motivational systems. According to RST, r-BIS is seen as superordinate to the other motivational systems. It is theorized to be engaged in instances of motivational control, such as mediating approach and avoidance conflict or suppressing motivational responses (Gable et al., 2018; Gray and McNaughton, 2000). R-BIS is related to the effortful control of motivational systems in that when engaging effortful control, individuals are attempting to resolve conflicts between or within motivational systems, which we understand to be the primary function of r-BIS.

Based on the framework of two motivational drives (approach and avoidance), research in hemispheric lateralization has associated activation of the left frontal cortex with the approach motivation, and activation of the right frontal cortex with withdrawal motivation. This hemispheric lateralization, or hemispheric asymmetry, has most frequently been studied through electroencephalography (EEG), by examining alpha band frequency (Coan and Allen, 2004; Harmon-Jones et al., 2010). The prevailing model of asymmetric frontal activity suggests that greater left frontal asymmetry is related to approach motivation, and greater right frontal asymmetry is related to withdrawal motivation (Harmon-Jones and Gable, 2018; Kelley et al., 2017; Papousek et al., 2014; Poole and Gable, 2014; Honk and Schutter,

* Corresponding author at: The University of Alabama, United States of America.
E-mail address: pagable@gmail.com (P.A. Gable).

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2006).

Despite the large number of studies that have successfully linked the behavioral approach system and greater relative left frontal cortical activity, many studies have failed to link withdrawal motivation (FFFS) and greater relative right frontal cortical activity. A growing number of studies have failed to link withdrawal motivation at either the state or trait level with greater right frontal activity (Amodio et al., 2008; Berkman and Lieberman, 2010; Coan and Allen, 2003; Coan et al., 2001; De Pascalis et al., 2013; Wacker et al., 2008). In addition, a recent meta-analysis of over 112 published and unpublished frontal asymmetry studies found that greater trait approach motivation related to relatively greater left frontal asymmetry at rest. In contrast, trait avoidance motivation was unrelated to relatively greater right frontal asymmetry at rest (Garrison et al., 2018). These mixed findings have caused some researchers to question whether linking right frontal asymmetry with only withdrawal motivation is correct and to develop new models of right frontal activity (Gable et al., 2018; Wacker et al., 2010).

One potential reason for these failures to link greater relative right frontal activity to withdrawal motivation could be that another system is more strongly associated with greater relative right frontal activity. Past models of frontal asymmetry have considered the two motivational drives, but failed to account for r-BIS, which is responsible for regulating conflicts between approach and withdrawal motivational drives. In many of the studies examining right frontal asymmetry and withdrawal motivation r-BIS has been confounded with withdrawal motivation. Effortful control of the motivation systems generated by r-BIS might be more closely associated with greater right frontal asymmetry than withdrawal motivation (Gable et al., 2018).

Past work examining laterality has linked inhibitory processes related to motivational control to the right hemisphere. Using tDCS to increase neuronal excitability in the right frontal cortex results in better response inhibition and less risky decision making (Fecteau et al., 2007; Jacobson et al., 2011; Stramaccia et al., 2015). In contrast, inhibiting the right frontal cortex results in riskier decision making (Hecht et al., 2013; Knoch et al., 2006). Kelley and Schmeichel (2016) found that stimulation to the right frontal cortex facilitates responses to motivationally incongruent trials. After right frontal stimulation, participants were better at approaching avoidance-motivated stimuli and avoiding approach-motivating stimuli. A recent review by Kelley et al. (2019) examines a wide body of research using tDCS that implicates the right frontal cortex in a variety of self-regulatory behaviors, including perseverance, delay behaviors, and impulse control. Importantly, many of the self-regulatory behaviors enhanced by increasing relative right frontal activity involve instances of approach-avoidance conflict. Activating the right frontal cortex appears to mitigate motivationally conflicting behaviors.

A large body of research linking right frontal activity with r-BIS has focused on individual differences. Neal and Gable (2017) found that individual differences in BIS-Anxiety, a measure of motivational conflict that requires engagement of motivational control, were related to greater relative right frontal asymmetry while at rest, but that avoidance motivation (FFFS) was not. Traits indicative of poor motivational control, such as risk taking and impulsivity have been linked with diminished right frontal activity (Gable et al., 2015; Neal and Gable, 2016, 2019; Santesso et al., 2008). Additionally, greater right frontal activity relates to more controlled task performance, such as acceptance of more unfair offers in an ultimatum game (Knoch et al., 2010). In the ultimatum game, an opponent divides money either equally or unequally with a participant. In this version of the ultimatum game, accepting a suggested offer for an unequal and temporarily disadvantageous distribution of funds from an opponent resulted in the maximal financial gain for the participant, even if it means their opponent will receive more money than they will. Additionally, greater right frontal activity has been associated with less risky behavior in a risk task (Gianotti et al., 2009).

Despite this past work linking greater right frontal activity with r-BIS, past studies that have observed right frontal asymmetry in response to either effortful control or avoidance motivation have not tested whether r-BIS and FFFS may have been co-activated. It could be that activation of both avoidance and effortful control are in fact causing right frontal activation. For example, much of the research linking right frontal asymmetry with trait avoidance motivation has used Carver and White's (1994) BIS scale. This scale has been shown to assess dimensions of both withdrawal and effortful control (Heym et al., 2008), making it difficult to determine which is actually driving greater relative right frontal activation (Neal and Gable, 2017). Additionally, studies that include manipulations of withdrawal motivation in the laboratory setting may also be activating effortful control. For example, asking participants to view negatively valenced images while remaining seated in front of a screen may unintentionally cause participants to engage in effortful control simply to keep looking at the pictures (Gable et al., 2018). Perhaps negative emotional sound clips would require less effortful control (Papousek et al., 2011).

1. Current studies

Based on the review of past work, two potential systems could be related to greater relative right frontal activity: 1) Greater relative right frontal activation could be associated with withdrawal motivation as part of the FFFS system, or 2) Greater relative right frontal activation could be association with effortful control as part of the r-BIS system. The current studies sought to test these two possibilities by activating both effortful control and withdrawal motivation. If right frontal activity is related to withdrawal motivation in such situations, then individual differences related to withdrawal motivation should relate to greater right frontal activity. In contrast, if right frontal activity is related to regulation of the motivational drives, then individual differences related to control should relate to greater right frontal activity.

The current studies were designed to create situations evoking both withdrawal motivation and effortful control. In past work, experimenter or task demands for initial and continued engagement with aversive stimuli may have caused participants to exert more effort to engage with the aversive stimuli than they would in situations where they could freely disengage with the aversive stimuli. Research has shown there are a variety of ways participants may disengage with negative stimuli throughout the course of a laboratory experiment. For example, Bebko et al. (2011) demonstrated that when participants attempted to regulate their emotions they viewed emotional areas of stimuli less during the middle and end of the presentation relative to the beginning. Participants may also choose to view more or less arousing parts of a negative image in an attempt to control their experienced emotions (Ferri et al., 2013).

Even when participants are not instructed to attempt to control their emotions, eye tracking research indicates they may avoid looking at unpleasant stimuli. Mason and Richardson (2010) found that participants spent less time viewing disgust inducing images relative to neutral images. Other work has found that participants will spend less time viewing a disgust inducing video relative to a control video (Armstrong et al., 2015). These drives to look away are so strong that they have even been used to condition participants to look away from unrelated images (Armstrong et al., 2015; Mason and Richardson, 2010). Some previous researchers have even conceptualized long term attention to aversive stimuli as form of exerted effort (Lang et al., 1996). It is reasonable, then, to expect that it will be more effortful for participants to view images that they desire to look away from.

Two studies were designed to discern if right frontal asymmetry was due to negative affect, a proxy of withdrawal motivation, or due to the effortful control necessary to stay engaged with the stimuli. In Study 1, participants listened to negative (vs. neutral) sounds clips. Effortful control was enhanced by asking participants to suppress their emotional expressions (vs. naturally listen) during the sound clips. In Study

2, an approach-avoidance conflict was manipulated in order to activate the r-BIS system (Gray and McNaughton, 2000). This approach-avoidance conflict was created by presenting negative affective images in a reward paradigm that incentivized greater engagement (e.g. approach) with the negative images.

2. Study 1

One way of engaging control processes is emotion regulation, and more specifically, effortful suppression of emotion (Ochsner and Gross, 2005). Although little research has considered the idea that effortful control of emotion may be a driving force behind greater right frontal activity, it has been theorized that emotion regulation may be related to activity in the prefrontal cortex (Dennis and Solomon, 2010). There has been little consensus, however, regarding emotion regulation and hemispheric lateralization. One reason for this lack of consensus may be due to the confound between negative affect and effortful control when *viewing* negative pictures. Study 1 attempted to disentangle this confound by evoking negative affect using sounds. Having participants passively listen to negative sound clips, as opposed to watching negative pictures or films should not engage effortful control of emotion. Past work examining frontal asymmetry has used sound clips with great success. Papousek et al. (2011) found that when examining frontal cortical activity in response to emotionally contagious sounds, only participants high in emotion regulation exhibited shifts toward greater relative right frontal activation while listening to anxiety inducing stimuli. It may be that the effortful control participants engaged in through emotion regulation led to greater relative right frontal activation.

In order to activate effortful control, participants in the current study were asked to suppress their emotional reaction during the sound clips or listen naturally to the sound clips. If right frontal activity is associated with r-BIS, self-reported effort while engaging in motivation regulation to the negative sound clips should be associated with greater right frontal activity. If right frontal activity is associated with FFFS, self-reported anxiety while listening to the negative sound clips naturally should be associated with greater right frontal activity. If right frontal activity is associated with both r-BIS and FFFS, then self-reported effort and anxiety should be associated with greater right frontal activity.

2.1. Procedure

Eighty-three undergraduate introductory psychology students (56 female) participated for partial course credit. Data collection was halted at the close of the participant pool. A sample of this size gave us 0.80 power to detect a medium sized effect ($r = 0.27$) of negative affect or effort on frontal activity. All participants were verified as right handed (Gable and Poole, 2014). Upon arrival at the lab, participants consented to participate in the experiment and EEG electrodes were applied.

During the experiment, participants listened to two different types of sound clips from the emotionally contagious sound clips database (ECOS; Papousek et al., 2012). The sound clips were designed to induce feelings of anxiety (ECOS-X) or no feelings at all (i.e., neutral; ECOS-N). Prior to listening to the anxiety sound clip, participants were told they would listen to a sound clip from the cabin of a plane on fire prior to a successful emergency landing. Prior to listening to the neutral sound clip, participants were told they would be listening to a sound clip of a bank lobby (ECOS-N). These descriptions were added to prevent participant misattribution of the sound clips to alternative situation (e.g., screaming while on a roller coaster). Each sound clip was presented for 90 s. While listening to these sound clips, participants were instructed to either listen naturally, or to attempt to suppress their emotions in such a way that someone watching them would not know that they were experiencing any emotions at all. Expressive suppression was chosen over other forms of emotion regulation because it requires sustained effort while engaging with the stimuli (Bebko et al., 2011; Gross and John, 2003).

All participants listened to each of the sound clips. The order of presentation of the sound clips was counterbalanced across participants to account for any potential order effects. The condition in which the sounds were presented were staggered so that participants did not hear the same sound twice in a row, or were not required to engage in the same listening style back-to-back. After engaging with each sound clip, participants reported the amount of effortful control they engaged in by responding to the question, “How effortful was it for you to hide your emotions?” In order to assess withdrawal motivation related to negative affect, participants also responded to the question, “Please indicate to what extent you feel anxious.” To assess whether participants followed task instructions, participants were asked to report the extent to which they attempted to hide their emotions during the block and the extent to which they felt successful in hiding their emotions. All items were rated on a five point Likert scale, (1 “very slightly or not at all” to 5 “extremely,”). After all experimental blocks were completed, participants rated the sound clips for how motivationally stimulating they were (e.g. “To what extent did you want to move away from these sounds?”) and their perceived emotional valence (e.g. “How negative do these sounds make you feel?”). These items were rated on a seven point Likert scale, (1 “very slightly or not at all” to 7 “extremely”).

2.2. EEG recording and processing

Electroencephalography (EEG) was recorded from 32 Ag/AgCl electrodes using a BrainVision actiCAP snap system (EASYCAP GmbH, Herrsching, Germany). EEG was recorded while participants listened to the presented sound clips. Sensor placement was based on the international 10–20 system with a ground electrode mounted at FPz. Impedances were kept under 30 kΩ. Sensors were referenced online to the left earlobe and re-referenced offline to an average linked ears reference. Data were collected using a BrainVision ActiCHamp amplifier (Brain Products GmbH, Munich, Germany) and were 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 by hand. Eye blinks 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 throughout the sound clips (90 s). Each consecutive epoch overlapped by 50%. Then, 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 the right frontal (F8) from the left frontal (F7) sites. Because alpha power inversely relates to cortical activity (Laufs et al., 2003), lower asymmetry scores indicated greater relative right frontal activity.

3. Study 1 results

Participants' reported self-reported anxiety and effort while listening to the sound clips were analyzed using 2 (stimuli type: anxiety vs. neutral) × 2 (listening type: natural vs. emotional suppression) repeated measures ANOVAs. In order to test whether individual differences in effort or anxiety related to right frontal activity, correlations were conducted between frontal asymmetry and reported effort and reported anxiety in each condition. To determine whether expressive suppression influenced frontal asymmetry, EEG data were compared using 2 (stimuli type: anxiety vs. neutral) × 2 (listening type: natural vs. emotional suppression) repeated measures ANOVAs. Correlation analyses were used to determine whether participant effort while using an expressive suppression strategy was associated with greater relative right frontal activation. Where predictions were directional, one-tailed criterion tests were used (Rosenthal et al., 2000).

3.1. Sound ratings

Sound ratings revealed that the sound clips had the intended emotional effects. Anxiety sounds were rated as more withdrawal motivating ($M = 5.97$, $SD = 1.87$) than neutral sounds ($M = 3.71$, $SD = 1.98$), $t(77) = 8.73$, $p < .001$, $d = 0.98$. Anxiety sounds were also rated as more negative ($M = 5.88$, $SD = 1.68$) than neutral sounds ($M = 2.65$, $SD = 1.78$), $t(77) = 13.91$, $p < .001$, $d = 1.58$.

3.2. Self-report analyses

Participants reported experiencing more anxiety during the anxiety inducing clips relative to the neutral clips $F(1, 78) = 13.86$, $p < .001$, $\eta_p^2 = 0.15$. Additionally, participants reported greater anxiety during the listening naturally conditions relative to the expressive suppression conditions $F(1, 78) = 27.66$, < 0.001, $\eta_p^2 = 0.26$. There was a significant 2 (sound type: anxiety vs. neutral) × 2 (listening engagement: listening naturally vs. expressive suppression) interaction, $F(1, 78) = 41.49$, $p < .001$, $\eta_p^2 = 0.35$, indicating the conditions had the intended effect on participants negative affect.

Participants reported engaging more effort to suppress their emotions during the anxiety inducing clips relative to the neutral clips, $F(1, 78) = 34.45$, $p < .001$, $\eta_p^2 = 0.31$. Additionally, participants reported using more effort to suppress their emotions during the expressive suppression conditions relative to the listening naturally condition $F(1, 78) = 10.09$, $p < .01$, $\eta_p^2 = 0.11$. The interaction was non-significant, $F(1, 78) = 3.14$, $p = .08$, $\eta_p^2 = 0.04$, however, a post-hoc t-test revealed that participants still reported using significantly more effort during the anxiety expressive suppression block relative to the anxiety just listen block, $t(78) = 3.21$, $p < .01$, $d = 0.36$. Means and standard deviations for reported anxiety and reported effort across the sound blocks are reported in Table 1.

3.3. Frontal asymmetry analyses

Greater relative right frontal activation was associated with the amount of effort participants' reported exerting while attempting to suppress affective responses during the anxiety sound clip ($r = -0.20$, $p = .04$; see Fig. 1). Greater relative right frontal activation was not associated with experiencing anxiety while listening to the anxiety sound clip naturally ($r = -0.05$, $p = .69$). Greater relative right frontal activation was not associated with the effort participants' reported exerting while attempting to suppress affective responses during the neutral sound clip ($r = -0.07$, $p = .53$). The remaining associations between self-report variables and frontal asymmetry were also non-significant (see Table 2). Importantly, the correlation between participants' reported effort exerted while attempting to suppress affective responses during the anxiety inducing sound clip was statistically different from zero, but the correlation between participants' reported anxiety while listening to the anxiety inducing sound clip naturally was not. A corrected Pearson-Filon statistic (Raghunathan et al., 1996) revealed that the correlation between relative right frontal activity and effort while suppressing ($r = -0.20$) and the correlation between relative right frontal activity and anxiety while listening naturally ($r = -0.05$) were not significantly different from one another ZPF ($N = 77$) = 1.15, $p = .12$. Additionally, a 2 (sound type: anxiety vs. neutral) × 2 (listening engagement: listening naturally vs. expressive suppression) repeated measures ANOVA was conducted to test for differences in relative frontal asymmetry values. This test was not statistically significant. $F(1, 76) = 0.80$, $p = .37$, $\eta_p^2 = 0.01$.

Table 1
Means and standard deviations for self-reported effort and anxiety.

Variable	Anxiety sounds		Neutral sounds	
	M	*SD*	*M*	*SD*
Listening naturally				
Reported anxiety	2.87	1.37	1.79	1.09
Reported effort	1.90	1.25	1.41	1.01
Expressive suppression				
Reported anxiety	1.65	1.16	1.81	1.10
Reported effort	2.49	1.47	1.75	1.20

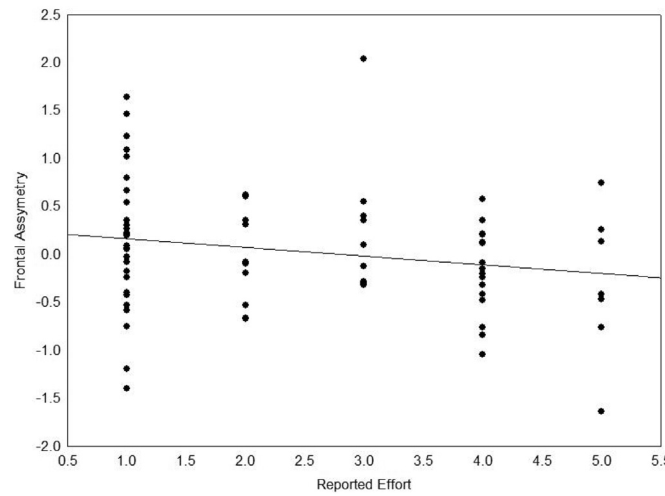

Fig. 1. Correlation between relative frontal activity and reported effort in the anxiety suppression condition.
Note: Relative frontal activity is the difference in alpha-band activity between sites F8 minus F7. Smaller scores indicate more right frontal activity. Reported effort is the amount of effort participants reported while viewing the pictures. The regression line represents the relationship between participant effort and relative frontal activity. Greater right frontal activity (smaller asymmetry scores) are related with more effort.

Table 2
Correlations with relative frontal activity.

Variable	Anxiety sounds		Neutral sounds	
	r	*p*	*r*	*p*
Listening naturally				
Reported anxiety	−0.05	.69	0.00	.99
Reported effort	0.09	.45	0.01	.91
Expressive suppression				
Reported anxiety	−0.08	.50	−0.12	.31
Reported effort	−0.20*	.04	−0.07	.53

Note: Correlations are between self-report variables and relative right frontal activity. Relative right frontal activity is the difference in alpha-band activity between sites F8 minus F7. Smaller right frontal activity scores indicate more right frontal activity.
* $p < .05$.

4. Study 1 discussion

In the current study, greater relative right frontal activation was associated with the amount of effort participants reported using to suppress their affective responses. In contrast, relative right frontal activity was unrelated to the amount of anxiety one felt. Consistent with the expectation that negative stimuli are effortful, participants in Study 1 reported engaging in some level of effort across anxiety conditions relative to the neutral condition. However, while this interaction did not reach conventional significance levels, the analysis did display the anticipated pattern that participants reported engaging in significantly more effort in the anxiety expressive suppression block, relative to the anxiety listen naturally block. Individual differences in effort, but not in negative affect related to greater relative right frontal activity. This study suggests that greater relative right frontal activity is associated with individual differences related to r-BIS, the motivational control system and not with individual differences related to FFFS, the withdrawal motivation system.

The connection between expression suppression and right frontal activity is consistent with past work on emotion regulation. Emotion regulation in general, and expressive suppression in particular, has previously been associated with inhibitory control (Carlson and Wang, 2007; Schmeichel and Tang, 2015). In light of this emerging line of research, the relationship between regulation and right frontal activity may be due to the role of r-BIS.

5. Study 2

Whereas Study 1 linked individual differences in self-reported effortful suppression with greater right frontal asymmetry, Study 2 was conducted in order to examine whether greater right frontal activity was associated with behavioral measures of withdrawal or effortful control of motivation. In addition, Study 2 used a different form of negative affective manipulation (e.g. affective pictures). An approach-avoidance conflict was manipulated by incentivizing participants to engage with (i.e., continue looking at) disgust images in a reward paradigm. Participants had the choice to either make a disgusting pictures disappear (escape) or continue viewing a disgusting picture for a monetary reward (motivational conflict). Choosing to engage with the negative picture and not escape from viewing the picture should activate greater effortful control. The study employed a within-subjects design with four conditions manipulating withdrawal or motivational conflict. If right frontal activity is associated with r-BIS, fewer escapes should be related to greater right frontal activity when viewing a disgusting picture for a monetary reward. If right frontal activity is associated with FFFS, more escapes should be related to greater right frontal activity when viewing a disgusting picture without a reward.

5.1. Participants

Participants were recruited through the University of Alabama subject pool. A total of 68 participants were recruited for participation in the study. Data collection was halted at the close of the participant pool. A sample of this size gave us 0.80 power to detect a medium sized effect ($r = 0.29$) of effortful control on frontal activity. All participants were verified as right handed (Gable and Poole, 2014). Eight participants started but did not complete the study. EEG data from an additional 4 subjects was not analyzed because it contained excessive artifacts based on visual inspection. Therefore, data from 56 participants were included in final analyses. The final sample consisted of 56 (43 females) participants with an average age of 18.55 ($SD = 1.17$).

5.2. Procedure

Participants were brought into the lab and gave informed consent. Participants completed measures of demographics and personality. Then, a stretch-lycra EEG cap with 64 sensors was applied. Participants then completed a picture viewing task.

Participants completed a task with two within-subjects conditions: non-reward trials and reward trials. Participants engaged in a picture viewing task of injury pictures and matched neutrals (see Fig. 2 for sample trial). Pictures were taken from the International Affective Picture Set (IAPS; Lang et al., 1997). On non-reward trials, participants were instructed to view the pictures throughout the time they are on the screen, but told that there is no possibility of reward on this trial. On the reward trials, participants were told that they would be rewarded for viewing the images for a longer amount of time. This reward was intended to create a conflict between avoidance (viewing a disgust-inducing stimulus) and approach (monetary reward).

Prior to the beginning of each trial, participants were shown a trial cue that indicated whether it would be a non-reward or reward trial. Trial cues were a green circle or a blue square. For both trials types, an escape option was presented halfway through picture presentation on 80% of the trials. The escape option was signaled using a white circle cue that was superimposed over the image for 100 ms. On all but 20% of trials, after 6 s of picture presentation, participants were given an option to press the space bar on the keyboard and escape from the picture. The no escape trials were included to avoid habituation of the escape response. If pressed, the image was erased from the screen and replaced with a fixation cross until the next trial began. If the space bar was not pressed, the image remained on the screen for another 6 s, and then was replaced by a fixation cross. Inter-trial interval varied between 3 s, 6 s, and 9 s to avoid predictability of picture presentation. Participants were presented with 32 disgust and 32 neutral images in randomized order for a total of 64 trials. There were equal numbers of each trial type: 16 disgust reward, 16 disgust non-reward, 16 neutral reward, and 16 neutral non-reward. The behavioral dependent variable was the summed number of pictures escaped from in each category. Number of escaped pictures was predicted to be higher for disgust images than neutral images and higher for non-reward trials than reward trials.

Following completion of the picture viewing task, participants answered a number of manipulation check questions. First, they reported how much they looked at the pictures while they were on the screen on a scale from 1 (not at all) to 5 (always). They also reported how motivated they were to get a reward and how disgusted they felt during the task on a scale from 1 (not at all) to 5 (extremely). Then, each picture used in the study was rated on dimensions of arousal and valence using the self-assessment manikin (SAM; Bradley and Lang, 1994).

5.3. EEG recording and processing

EEG data were recorded while participants completed the picture viewing task and was analyzed during picture presentation. Data were recorded from 64 Ag/AgCl active electrodes in an actiCap (BrainProducts, Munich, Germany) based on the International 10/20 system using the actiCHamp system. Electrode impedances were kept below 20 kΩ. EEG data was recorded at a sampling rate of 500 Hz. Offline analyses were performed using BrainVision Analyzer software (BrainProducts). Because these data had a high density of channels, data were rereferenced to a common average reference and band-pass filtered at 0.1–100 Hz with a notch filter at 60 Hz. Blink correction was applied using an ICA-based artifact rejection function. Following blink removal, artifacts related to muscle movement were removed using an automated algorithm to reject artifacts exceeding ± 200 μV, and data was hand scored to remove additional artifacts. Data during picture presentation was segmented into 1000 ms epochs, with segments overlapping by 50%. A Fast Fourier Transformation (FFT) with a Hamming window of 50% was applied. Power spectra from the traditional alpha band (8–13 Hz) was extracted. Asymmetry difference scores were calculated for a homologous pair of frontal sites (F8-F7) by subtracting the natural log of alpha power for the left site from the natural log of alpha power from the right site. Because alpha power inversely relates to cortical activity (Laufs et al., 2003), lower asymmetry scores indicated greater relative right frontal activity.

6. Study 2 results

6.1. Picture ratings

Picture ratings revealed that the pictures had the intended emotional effects. Disgust pictures were rated as more arousing ($M = 5.42$,

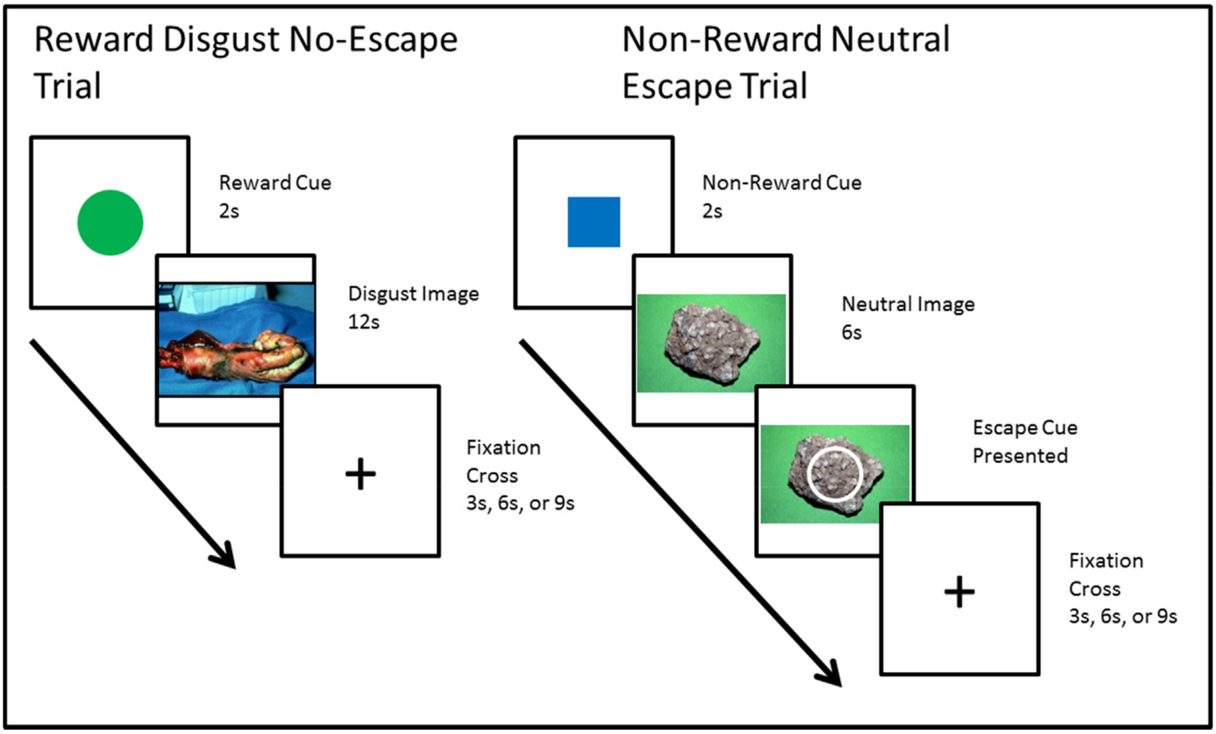

Fig. 2. Example trials from picture viewing task.

SD = 2.18) than neutral images (*M* = 7.72, *SD* = 1.66), $t(53) = -6.26$, $p < .001$, $d = 0.85$. Disgust pictures were also rated as more negatively valenced (*M* = 7.72, *SD* = 1.23) than neutral images (*M* = 3.12, *SD* = 1.50), $t(53) = 18.02$, $p < .001$, $d = 2.44$.

6.2. Behavioral analyses

A 2 (Reward: non-reward vs. reward) × 2 (Picture type: affective vs. neutral) repeated measures ANOVA with average number of pictures escaped as the dependent variable revealed a significant main effect of reward, $F(1, 55) = 11.15$, $p = .002$, $\eta_p^2 = 0.17$ (see Fig. 3). Additionally, there was a significant main effect of picture type, $F(1, 55) = 15.84$, $p < .001$, $\eta_p^2 = 0.23$. There was no significant interaction of reward and picture type, $F(1, 55) = 2.36$, $p = .267$, $\eta_p^2 = 0.02$.

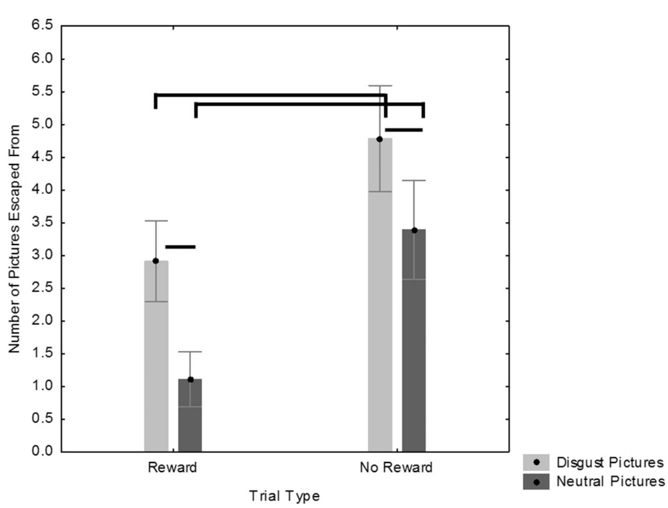

Fig. 3. Average number of images escaped from by trial and picture type. Note: Brackets connecting bars indicate significant differences between conditions ($p < .05$).

Participants escaped from more pictures in the disgust no reward (*M* = 4.79, *SD* = 6.07) than any other condition, followed by no reward neutral (*M* = 3.45, *SD* = 5.67), disgust reward (*M* = 2.91, *SD* = 4.61), and reward neutral (*M* = 1.11, *SD* = 3.15). Fisher's post hoc tests revealed that all picture type and reward types were significantly different from one another except for reward disgust and no reward neutral.

6.3. Frontal asymmetry analyses

Frontal asymmetry was correlated with behavioral outcome variables of number of escapes from each picture type. There was a significant positive relationship between frontal asymmetry to reward disgust pictures and escapes from reward disgust pictures ($r = 0.24$, $p = .03$; see Fig. 4), such that greater right frontal activity related to fewer escapes. Additionally, there was a significant positive relationship for reward neutral pictures and reward neutral escapes, $r = 0.33$, $p = .01$. There were no significant relationships between frontal asymmetry score and escape options for no reward disgust trials ($r = 0.08$, $p = .58$) or no reward neutral trials ($r = 0.06$, $p = .67$). Participants who exercised controlled processing were able to continue to view the aversive images during reward trials and had accompanying higher levels of right frontal activation. There was no significant interaction of trial type and picture type on frontal asymmetry, $F(1, 54) = 0.45$, $p = .50$, $\eta_p^2 = 0.01$.

Behavioral outcome variables of number of escaped pictures were then correlated with the manipulation check variables (see Table 3). The more motivated toward the reward an individual reported feeling, the fewer pictures they escaped from in the reward disgust condition. Greater overall self-reported disgust during the task related to more escaped pictures in the reward disgust, no reward disgust, and no reward neutral conditions. Greater average arousal reported during disgust pictures related to greater escaped pictures in the reward disgust, no reward disgust, and no reward neutral conditions. Last, average self-reported valence of disgust pictures related to escaped pictures in the reward disgust and no reward disgust conditions. Participant's disgust feelings, perceived negativity of the images, and motivation to win the

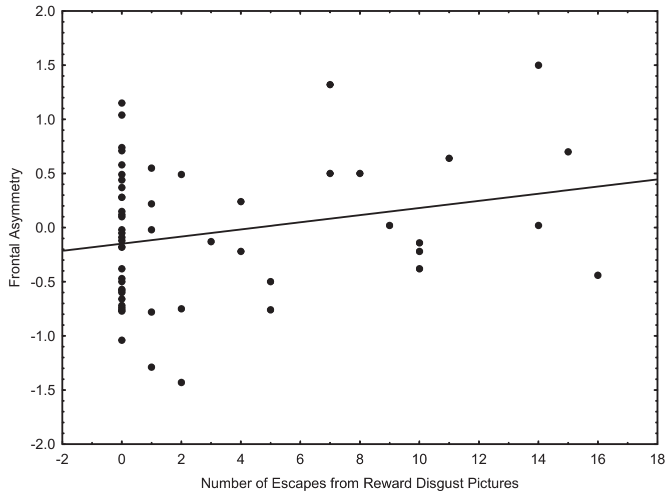

Fig. 4. Correlation between relative right frontal activity and number of escapes from reward disgust trials.
Note: Relative frontal activity is the difference in alpha-band activity between sites F8 minus F7. Smaller scores indicate more right frontal activity. The regression line represents the relationship between the number of escapes and frontal activity. Greater right frontal activity (smaller asymmetry scores) are related to fewer escapes.

reward predicted behavioral response patterns.

7. Study 2 discussion

Behavioral results revealed that participants were more likely to escape from disgust pictures than neutral pictures and that rewards decreased the number of escapes from disgust pictures compared to non-reward trials. Additionally, the amount of pictures escaped from in the approach-avoidance conflict condition of interest (reward disgust trials) were predicted by how motivated the participant felt to get the reward, their overall feelings of disgust during the task, and their disgust picture ratings of arousal and negative valence. These manipulation checks suggest that participants did indeed feel a conflict between motivation to get the reward and heightened aversion to the disgust pictures. Individual differences in these approach and avoidance motivations appeared to affect behavioral outcomes.

Greater right frontal asymmetry to disgust pictures with rewards (e.g. approach-avoidance conflict trials) related to fewer escapes from these trials. In other words, participants engaged in greater effortful control to continue looking at these pictures. In contrast, right frontal asymmetry to disgust pictures without rewards (e.g., avoidance trials) did not relate to more escapes when escaping would have indicated greater behavioral withdrawal. This relationship between frontal asymmetry and behavioral outcome was not present for no reward disgust trials. These findings suggest that participants who engaged in more motivational control during a conflict between approach and avoidance showed greater engagement to continue looking at aversive images. Greater right frontal activity related to behaviors requiring greater effortful control, but not to behavioral avoidance.

8. General discussion

Study 1 examined individual differences in self-reported effort while attempting to suppress affective responses to anxiety inducing and neutral sound clips. Greater relative right frontal activation was associated with reported effort used while suppressing affective responses, but not with the experience of negative affect. Study 2 examined individual differences in behavior to either escape from aversive images or engagement with aversive images. Participants escaped most frequently from aversive images in non-reward trials. Greater relative right frontal activation was associated with fewer escapes from aversive images in reward trials.

The results from Study 1 suggest that individual differences in r-BIS through effortful control of motivation, not individual differences in the FFFS system, related to greater right frontal asymmetry. Notably, greater relative right frontal activation was not associated with participants' reported effort suppressing their reactions to neutral stimuli, suggesting that it is not just attempted suppression that relates to right frontal activity, but rather the effortful, affective control of negative emotions that relates to right frontal asymmetry. The results from Study 2 suggest that individual differences in r-BIS through effortful control of motivation by escaping fewer times from aversive images, not individual differences in the FFFS system as evidenced by more escapes from the no reward disgust images, related to greater right frontal asymmetry. Greater right frontal activity observed in these studies is consistent with the theory that it is r-BIS driving greater relative right frontal asymmetry and not FFFS.

Critically, these patterns of frontal activity in both studies did not emerge when frontal asymmetry was considered across participants. There were no differences in frontal asymmetry scores between task conditions or trial types. These studies highlight the importance of examining the role that individual differences may play in driving lateralization of alpha power in the prefrontal cortex.

EEG asymmetry is a dynamic, complex measure influenced by a myriad of state and trait processes (Hagemann et al., 2002). Frontal asymmetry is frequently studied as a correlate of cognitive task performance, personality variables, and emotional processes (Reznik and Allen, 2018). Individuals respond in meaningfully different ways to affective stimuli (Coan et al., 2006; Papousek et al., 2014), thus it is common that frontal asymmetry findings are relationships between variables rather than differences between conditions. It may be that examining frontal asymmetry as a predictor of behavioral outcomes is a better methodological approach than examining broad differences between conditions. Consistent with many hallmark past findings in the frontal asymmetry literature, our frontal asymmetry results did not yield differences between condition. Instead, frontal asymmetry relates to individual differences in attitudes, personality, and behavior rather than differences in conditions (for a review, see Harmon-Jones and

Table 3
Correlations between picture escapes and emotive ratings in Study 2.

Emotive rating	Reward disgust escapes	Reward neutral escapes	No reward disgust escapes	No reward neutral escapes
1. Time looking at pictures	−0.47**	−0.17	−0.42**	−0.25
2. Motivation to reward	−0.33*	−0.25	−0.02	0.05
3. Overall disgust	0.30*	0.11	0.40**	0.32*
4. Arousal to disgust pictures	−0.40**	−0.15	−0.47**	−0.36**
5. Motivation to disgust pictures	0.21	0.15	0.18	0.08
6. Valence to disgust pictures	0.27*	0.11	0.29*	0.21

Note: The numbers in the table report correlation r-values between picture escapes and emotive ratings.
* $p < .05$.
** $p < .01$.

Gable, 2018). Future research should examine how non-affective control processes differ from affectively motivated control processes. Additionally, it is imperative that future researchers examine how individuals vary in their trait personality and reactions to stimuli. Since individual differences seem to be fundamental in the frontal asymmetry literature, shifts in hemispheric lateralization should be examined for individuals, not just groups.

The current studies fit well with the premise of the special issue: motivation and affect are inextricably tied. Reinforcement Sensitivity Theory points to the essential role of affect in motivating human behavior. The regulatory r-BIS system cannot be engaged without conflict that arises from affectively laden motivational drives of BAS and FFFS. Across two studies in the current article, relationships between individual differences and behavioral outcomes were only observed when r-BIS responded to affective stimuli, not to neutral stimuli. This suggests that mere control processes are not enough to drive this lateralization of alpha activity. Conflicts between approach-avoidance, approach-approach, and avoidance-avoidance motivation that require effortful control seem to be critical in engaging these patterns of asymmetric cortical activity. The r-BIS system is essential in managing emotive responses to aversive stimuli, and this system appears to be linked to the right frontal cortex.

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