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Resting beta activation and trait motivation: Neurophysiological markers of motivated motor-action preparation

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ABSTRACT

Based on Reinforcement Sensitivity Theory (Gray and McNaughton 2000), human behavior is influenced by systems of approach motivation, avoidance motivation, and a third regulatory system presiding over the other two. These systems mediate action and are likely related to neurophysiological markers of motor-action preparation. Previous research has found that lower levels of beta activity over the motor cortex are associated with greater motor-action preparation. The current study sought to test whether trait approach, avoidance, and regulatory control would relate to resting beta activity over the motor cortex, a measure of motor-action preparation. One hundred twenty-eight individuals completed measures of trait behavioral approach motivation and trait behavioral avoidance motivation (BIS/BAS; Carver and White 1994), as well as regulatory control (UPPS-P Impulsive Behaviour Scale; Whiteside et al. 2005). Then, resting EEG was recorded. Greater trait approach was negatively associated with resting beta activity. In contrast, greater trait impulsivity was associated with greater resting beta activity. Lower levels of resting beta activity in the motor cortex appear to be associated with traits related to deliberate motivated motor behaviors. Trait motor-action preparation seems to be an indicator of tendencies toward planful motivated behavior.

1. Introduction

Much of human behavior is predicated on the motivation to act. Individual differences in motivation may underlie an organism's readiness for action. Because personality produces general patterns of behaviors within organisms, it seems likely that heightened sensitivity of personality systems associated with action would correspond to an individual's preparation for motor movement. Neural processes underlying motor-preparation are likely to be associated with dimensions of personality related to planned motor-action.

1.1. Core personality systems

The revised Reinforcement Sensitivity Theory (Gray and McNaughton 2000) outlines three fundamental systems governing human behavior: the Behavioral Approach System, the Fight-Flight-Freeze System, and the Behavioral Inhibition System. The Behavioral Approach System (BAS) is thought to govern individual differences in approach motivation (Gray 1970, 1987; Gray and McNaughton 2000). Activation of this system is thought to engage goal pursuit, causing individuals to begin movement towards a goal (Carver and Scheier 2008). The Fight-Flight-Freeze System (FFFS) is theorized to govern individual differences in avoidance motivation (Gray and McNaughton 2000). This system is engaged in response to fear and activates escape and avoidance behaviors (Kelley and Schmeichel 2016; Peterson et al. 2008; Sutton and Davidson 1997).

The revised Behavioral Inhibition System (rBIS) is the third and final system.[1] RBIS is thought to regulate conflicts between the BAS and FFFS (Gray and McNaughton 2000). Individual differences in rBIS are thought to reflect regulatory ability to generate effortful control (Carver et al., 2008; Carver and Connor-Smith 2010; Gable et al. 2018). For example, individuals with low rBIS are thought to be higher in trait impulsivity (Gable et al. 2016a; Gable et al. 2018; Mechin et al. 2016). RBIS is also able to trigger actions when motivational systems are not engaged, such as overriding a tendency of inaction or overcoming predominate emotional responses (Carver et al. 2008). Thus, rBIS engages executive resources required for planful regulation of action (Kochanska and Knaack 2003).

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[1] In Gray's (1970) original theory, the Behavioral Inhibition System (BIS) encompassed both FFFS and BIS processes. However, Gray and McNaughton's (2000) revised theory greatly revised the role of BIS, distinguishing it from the FFFS. To reduce confusion between definitions of original and revised BIS, we will use the term "rBIS" when discussing the revised BIS system.

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1.2. Core personality and motor-action preparation

BAS, FFFS, and rBIS orchestrate functional behavior through movement and motor-action. For example, BAS activates motor-actions to obtain a desired object or goal (Gray 1994). Approach-motivated action requires planned motor movements to move towards and acquire the object. Because approach motivation requires planned motor-action, heightened approach motivation should relate to greater preparation for motor-action. Similarly, rBIS regulates whether an action is either a deliberate interaction with the environment, or an impulsive, unplanned reaction (Braver 2012; Ullsperger et al. 2014). RBIS would likely engage planned motor-control in order to manage action forecasting, vigilance, and proactive control (Braver 2012; Schmid et al. 2015). Because rBIS functioning relates to planning and controlling motivational behaviors, it seems likely that heightened rBIS would relate to greater motor-action preparation.

In contrast to BAS and rBIS, the FFFS is unlikely to be related to tendencies toward motor-action preparation. FFFS becomes activated in response to aversive or threatening stimuli (Coan and Allen 2004; Davidson 1998). Thus, this system engages motor-action in order to *react* to aversive stimuli, rather than engage in deliberate, planned motor behaviors (Amodio et al. 2008). These avoidant reactions often do not have planned behaviors, and may not have specific goals (e.g., the motivation to move away to anywhere but here). Because these types of avoidant reactions would not utilize pre-planned actions, it is unlikely that trait avoidance motivation would relate to motor-action preparation.

1.3. Beta activity over the motor cortex

Beta activity over the motor cortex appears to be a neural correlate of motor-action preparation (Pfurtscheller et al., 1996; Sanes and Donoghue 1993). During preparation for movement, suppression of beta oscillations occurs over the motor strip (McFarland et al. 2000; Pfurtscheller and Da Silva, 1999). Decreases in beta activation relate to preparation for movement before a target stimulus (Doyle et al. 2005). Increasing beta activity over the motor cortex using transcranial alternating-current stimulation slows the onset of future hand and finger movements (Pogosyan et al. 2009; Wach et al. 2013). Finally, McFarland et al. (2000) demonstrated that beta activation not only decreases when participants make motor movements, but also decreases when participants *visualized* making motor movements. Thus, drops in beta activation occur during both real and imaginary movement. In sum, this past work suggests that lower levels of beta activation index greater motor-action preparation, or “motor readiness” (Jenkinson and Brown 2011).

Past work has linked reduced beta activity over the motor cortex with greater approach motivation. Gable et al. (2016b) used a monetary incentive delay paradigm to manipulate high (pregoal) versus low (postgoal) approach-motivated positive affective states. Pregoal positive states occur during the pursuit of a goal and likely prepare an individual to act, while postgoal approach-motivated positive states occur after a goal has been achieved, and throttle back motivational intensity. Results revealed that beta activation was lowest in pregoal positive states, relative to postgoal positive and neutral states. This suggests that higher levels of motor-action preparation occur during high approach-motivated states. Other research has found that increasing motivation through higher monetary incentives decreased beta activation (Meyniel and Pessiglione 2014). As incentive levels increased, individuals became more motivated to act, leading to decreased beta activity. Beta activity over the motor cortex seems to be sensitive to approach motivation.

Other past work has suggested that beta activation in the motor cortex may be related to regulatory control of the rBIS. For example, when there is more uncertainty about a future action, beta power increases, suggesting there is less motor-preparation when goal-directed action is unclear (Tzagarakis et al. 2010). In contrast, lower levels of beta activity may reflect when individuals are better able to plan their course of action because of greater regulatory control. Engel and Fries (2010) argue that increased beta activation hinders cognitive control. For example, children with combined inattentive and hyperactive/impulsive ADHD show greater resting beta activity than those with inattentive ADHD (Clarke et al. 2001). Children with combined inattentive and hyperactive/impulsive ADHD tend to have less emotional control (e.g., more prone to temper tantrums and more moody), as well as greater deficits in self-regulation and inhibition control than children with inattentive ADHD. Presumably, when individuals have greater impulsive control, they may also show reduced beta activation. The likelihood of acting impulsively decreases, because there is greater action preparation. In contrast, when individuals display more impulsive behaviors, they exhibit greater beta activation. When unexpected stimuli and situations appear, impulsive individuals do not have planned motor behaviors.

Some past work has examined beta activation over the motor cortex in a resting state. This work has primarily focused on clinical populations, such as Parkinson's disease. For example, individuals with Parkinson's disease exhibit chronic high levels of beta activity (Brown 2007; Uhlhaas and Singer 2006). Excessive beta synchronization at rest relates to greater bradykinesia and rigidity in Parkinson's disease (Brown 2007; Hammond et al. 2007). When given deep brain stimulation in the basal ganglia, individuals with Parkinson's disease showed less beta activity at rest in the motor cortex, and consequently, better motor performance in a later task (Kühn et al. 2008). Beta activity associated with action preparation may depend on the motivation to initiate planned, deliberate movement towards a goal. Some researchers have argued that the slowing of movement in Parkinson's disease occurs because of the lack of implicit motor motivation (Baraduc et al. 2013; Tan et al. 2015). This is likely brought about by a dearth of dopamine in the striatum, a region in the basal ganglia (Mazzoni et al. 2007). If individual levels of beta activity in the motor cortex represent motor-action preparation, it should be the case that differences in baseline beta activity relate to individual differences in personality measures associated with planned motor activity.

1.4. The current study

While the previously discussed research has examined the relationship between beta activity in the motor cortex and state measures of motivation and impulsivity, to our knowledge, no research has examined the relationship between core personality systems and resting beta activity in the motor cortex in healthy populations. The current study sought to fill this gap by examining whether resting beta activity related to individual differences associated with BAS, FFFS, and rBIS. Trait BAS and FFFS were measured using Carver and White's (1994) BIS/BAS scales. The BAS scale, along with its subscales, measure varying dimensions of general BAS activation.[2] The UPPS-P scales are designed to measure impulsive personality traits and likely reflect a lack of planful action. The UPPS-P scales have been used to measure the inverse of rBIS functioning, which would produce planned motor-action behaviors (Gable et al. 2018; Neal and Gable, 2017). Individual differences in rBIS functioning were measured using the UPPS-P Impulsive Behaviour scale (Cyders and Smith 2007; Whiteside et al. 2005). Based on past research, trait BAS was predicted to relate to lower levels of beta activity in the motor cortex. Additionally, measures of impulsivity related to the pursuit of goals, such as Lack of Premeditation and Lack

[2] Carver and White's (1994) BIS/BAS scales have not always been found to nominally map on to Gray and McNaughton's (2000) revised Reinforcement Sensitivity Theory (for a thorough review of the BIS/BAS scales weaknesses, see Corr, 2016). This is likely because Carver and White (1994) developed their scales under the auspice of Gray's original theory published in 1970. For example, Gray and McNaughton's (2000) revision separates between FFFS and rBIS; however, the BIS scale lacks this distinction.

of Perseverance, were predicted to be positively related to resting beta activity. Such results would be theoretically and practically important, as they would suggest that individual difference in thoughtful approach-motivated action relate to patterns of neural activity of motor-action preparation.

2. Methods

One hundred and twenty-eight introductory psychology students participated in exchange for partial course credit. Informed consent was obtained prior to the experiment. Three participants did not indicate a rating on at least one of the items. These individuals were excluded from analyses where they had missing data, causing variation in the degrees of freedom for those analyses.

2.1. Procedures

Participants came into the lab and completed measures of handedness and the BIS/BAS Behavior Scale. Upon completion of these measures, EEG electrodes were applied, and 8 min of resting baseline activity was recorded (4 min with eyes open, 4 min with eyes closed).

2.2. Measures

Handedness was assessed by having participants report with which hand they performed 13 tasks (e.g., use a hammer, write, etc.; Chapman and Chapman 1987). Right-handedness was defined as performing no more than one item with their left hand. All participants were right-handed.

The BIS/BAS scale consists of 20 items assessing trait levels of behavioral approach and inhibition (Carver and White 1994). The BAS scale consisted of 13 items related to three facets of the approach motivation system: BAS Reward Responsiveness (BAS RR), BAS DRIVE, and BAS Fun-Seeking (BAS FUN). Each of these scales is used to measure related aspects of the behavioral activation system. BAS DRIVE measures persistent pursuit of desired goals. BAS Reward Responsiveness measures positive responses to the occurrence or anticipation of reward. BAS Fun-Seeking measures a desire for new rewards and a willingness to approach a potentially rewarding event on the spur of the moment. All BAS items for each subscale were averaged together to create an overall index score of BAS (BAS Total); higher scores on BAS Total and its subscales indicate greater levels of approach motivation. The BIS scale consisted of seven items and relates to responses in anticipation of punishment. In sum, five scales were created and assessed: BAS Total, BAS RR, BAS DRIVE, BAS FUN, and BIS.

The UPPS-P Impulsive Behaviour Scale consists of 59 items related to five facets of impulsivity: Negative Urgency, Positive Urgency, Lack of Premeditation, Lack of Perseverance, and Sensation Seeking (Cyders and Smith 2007; Whiteside et al. 2005). The Lack of Premeditation and Lack of Perseverance scales capture deficits in tendency to exhibit conscientiousness in the pursuit of some object or goal. Positive Urgency and Negative Urgency reflect the tendency for rash decisions in positive and negative emotional states, respectively. Sensation Seeking refers to openness to exciting experiences, but has been found to relate less to the other subscales (Simons et al. 2010). Although the individual subscales were originally intended to reflect theoretically and empirically distinct traits (Whiteside et al. 2005), much past work has found the combined UPPS-P subscales reflect a trait measure of general impulsivity (Cirilli et al., 2011; Kipper et al. 2010; Klonsky et al. 2013; Neal and Gable 2017). Therefore, scores across all subscales were averaged together to form an average index of impulsivity (UPPS-P Total). Higher scores on UPPS-P Total and its subscales indicate greater levels of trait impulsivity.

2.3. EEG assessment and processing

Electroencephalography was recorded from 64 tin electrodes mounted in a stretch lycra Quick-Cap (Electro-Cap, Eaton, OH) and referenced online to the left earlobe. A ground electrode was mounted midway between FPz and Fz. The electrode cap was based on the 10–20 system, and a sodium chloride-based conductance gel was used to assist in the decrease of impedances. Electrode impedances were kept under 5000 Ω. Signals were amplified with a Neuroscan SynAmps RT amplifer unit (El Paso, TX), low-pass filtered at 100 Hz, high-pass filtered at 0.05 Hz, notch filtered at 60 Hz, and digitized at 500 Hz. Artifacts (e.g., horizontal eye movement and muscle) were removed by hand. Then, a regression-based eye movement correction was applied (Semlitsch et al. 1986), after which the data were visually inspected again to ensure proper correction.

Epochs 1.024 s in durations were extracted through a Hamming window and re-referenced to a common average reference that utilized all scalp electrodes as an estimate of the activity at the reference site (for an in depth discussion, see Dien 1998). Consecutive epochs were overlapped by 50% to avoid data loss. Next, power values corresponding to beta (13–30 Hz) were extracted using a Fast Fourier Transformation. Beta activity was log transformed and then averaged across sites corresponding with the motor cortex (C1, C2, C3, C4, C5, C6, CP1, CP2, CP3, CP4, CP5, and CP6; McFarland et al. 2000; Muthukumaraswamy et al. 2004; Pfurtscheller et al. 2005). Lower beta activity indicates greater tendencies to motor readiness.[3]

All data were checked for outliers (> 3 standard deviations from the mean). One participant was excluded because their baseline activity was > 3 SDs from the mean.

3. Results

Inter-correlations and inter-item reliability for all variables are presented in Table 1. To examine whether trait BAS related to trait beta activation, we correlated BAS Total with resting beta activity in the motor cortex. As predicted, greater BAS Total was correlated lower levels of resting beta activity in the motor cortex. However, none of the BAS subscales (BAS RR, BAS DRIVE, and BAS FUN) or BIS were correlated with beta activity in the motor cortex.

To examine whether trait impulsivity related to trait beta activation, we correlated UPPS-P Total and each of the UPPS-P subscales with resting beta activity in the motor cortex. As predicted, Lack of Perseverance was correlated with beta activity in the motor cortex. Additionally, Lack of Premeditation was marginally correlated with beta activity in the motor cortex. However, none of the other UPPS-P subscales (Sensation Seeking, Positive Urgency, and Negative Urgency), as well as UPPS-P Total, were correlated with beta activity in the motor cortex.[4]

Past research has found that women exhibit higher levels of beta activation than men (Jaušovec and Jaušovec 2010). Therefore, we conducted a multiple regression analysis to investigate whether the various personality subscales predicted trait beta activation, controlling for the individual differences in gender and personality traits. Sex (dummy-coded with females as the reference group) was entered as a predictor in a multiple regression analysis with all personality scales predicting trait beta activation.[5] Gender was entered into the regression

[3] Beta activation was examined between homologous sites over the motor cortex to assess whether activity differed by hemisphere. All asymmetries produced non-significant contrasts, $ps > 0.097$.

[4] In order to determine whether these effects were specific to the motor cortex, bivariate relationships were examined between the personality indexes (BAS Total and UPPS-P Total) and beta activation at frontal (F1-F8) and parietal-occipital sites (PO3-PO6). All correlations were non-significant, $ps > 0.101$.

[5] Five participants did not indicate their sex. They were excluded from analyses, causing variations in the degrees of freedom.

Table 1
Summary of Inter-correlations and Inter-item Reliability of All Variables.

Measure	1	2	3	4	5	6	7	8	9	10	11	12	Cronbach's Alpha
1. BAS Total	–												0.755
2. BAS RR	0.73***	–											0.668
3. BAS DRIVE	0.76***	0.37***	–										0.745
4. BAS FUN	0.64***	0.21*	0.18*	–									0.587
5. BIS	0.09	0.33***	−0.04	−0.08	–								0.587
6. UPPS-P Total	0.10	−0.02	−0.08	0.42***	−0.07	–							0.881
7. Negative Urgency	0.12	0.05	−0.03	0.26**	0.20*	0.75***	–						0.875
8. Lack of Premeditation	−0.09	−0.29**	−0.11	0.21*	−0.31***	0.54***	0.13	–					0.790
9. Lack of Perseverance	−0.23*	−0.23*	−0.29**	0.04	−0.22*	0.52***	0.13	0.48***	–				0.794
10. Sensation Seeking	0.33***	0.12	0.07	0.54***	−0.03	0.51***	0.27**	0.07	−0.16	–			0.800
11. Positive Urgency	0.05	−0.03	−0.06	0.22*	−0.05	0.82***	0.65***	0.25**	0.32***	0.25**	–		0.925
12. Beta activation over motor cortex	−0.19*	−0.11	−0.13	−0.08	−0.0004	0.08	0.05	0.15	0.20*	−0.10	0.02	–	0.920

Note. Values in the first twelve columns are Pearson *r*-values. Values in the last column are Cronbach's alpha.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Table 2
Multiple Regression of Trait Beta Activation on Gender and Personality Subscales.

Predictor	ΔR^2	β	*p*
Step 1	0.080 (p = 0.002)		
Gender		−0.28	0.002
Step 2	0.055 (p = 0.070)		
Gender		−0.32	0.001
BAS RR		−0.16	0.090
BAS DRIVE		−0.13	0.188
BAS FUN		0.03	0.793
Step 3	0.059 (p = 0.166)		
Gender		−0.36	0.000
BAS RR		−0.13	0.189
Bas DRIVE		−0.06	0.532
BAS FUN		−0.06	0.581
Negative Urgency		0.14	0.209
Lack of Premeditation		0.01	0.903
Lack of Perseverance		0.24	0.037
Sensation Seeking		0.06	0.572
Positive Urgency		−0.08	0.531

model on step one, the BAS subscales were entered on step two, and the UPPS-P subscales were entered on step three. The overall model was significant, $R^2 = 0.19$, $F(9, 109) = 2.91$, $p = 0.004$ (see Table 2). Both sex ($p < 0.001$) and Lack of Perseverance ($p = 0.037$) were significant predictors of trait beta activation. However, none of the other subscales were significant predictors of trait beta activation, $ps > 0.189$.

In the current sample, the BAS Total scale had greater internal consistency than all of the BAS subscales. Additionally, the UPPS-P Total scale had greater internal consistency than all but one of the UPPS-P subscales. These reliability estimates suggest that BAS Total measured general approach motivation, and UPPS-P Total measured general impulsivity. Because predictions were that general trait approach motivation and impulsivity would relate to resting beta activity, BAS Total and UPPS-P Total were included in analyses.

A multiple regression analysis was conducted to investigate whether the overall personality indexes predicted trait beta activation, controlling for sex and the other personality scales. Sex was entered on step one, BAS Total was entered on step two, and UPPS-P Total was entered on step three. The overall model was significant, $R^2 = 0.16$, $F(3, 115) = 7.53$, $p < 0.001$ (see Table 3). All three variables significantly predicted trait beta activation.

To examine how the relationship between specific personality variables and trait beta activation in the motor cortex differed between males and females, we conducted regression analyses in which the personality indexes and gender were used to interactively predict trait beta activity. When examining the interaction between BAS Total and

Table 3
Multiple Regression of Trait Beta Activation on Gender and Overall Personality Indexes.

Predictor	ΔR^2	β	*p*
Step 1	0.080 (p = 0.002)		
Gender		−0.28	0.002
Step 2	0.041 (p = 0.022)		
Gender		−0.29	0.001
BAS total		−0.20	0.022
Step 3	0.044 (p = 0.016)		
Gender		−0.35	0.000
BAS Total		−0.23	0.010
UPPS-P Total		0.22	0.016

Table 4
Multiple Regression of Trait Beta Activation on the Interaction between Gender and BAS Total.

Predictor	ΔR^2	β	*p*
Step 1	0.121 (p = 0.001)		
Gender		−0.29	0.001
BAS Total		−0.20	0.022
Step 2	0.000 (p = 0.853)		
Gender		−0.12	0.897
BAS Total		−0.21	0.022
BAS Total X Gender		−0.17	0.853

gender, the change in R-squared was not significant when adding the interaction between gender and BAS Total, $F(1,117) = 0.03$, $p = 0.853$ (see Table 4).

In contrast, when examining the interaction between gender and UPPS-P Total, the change in R-squared was significant when adding the interaction between gender and UPPS-P Total, $F(1,117) = 5.05$, $p = 0.027$ (see Table 5). Simple slopes analysis using the full regression model revealed that higher trait impulsivity related to greater trait beta

Table 5
Multiple Regression of Trait Beta Activation on the Interaction between Gender and UPPS-P Total.

Predictor	ΔR^2	β	*p*
Step 1	0.104 (p = 0.001)		
Gender		−0.32	0.001
UPPS-P Total		0.21	0.026
Step 2	0.039 (p = 0.022)		
Gender		1.38	0.063
UPPS-P Total		0.12	0.202
UPPS-P Total X Gender		−1.69	0.022

activation in females ($\beta = 0.35$, $p = 0.002$), but not in males ($\beta = -0.09$, $p = 0.545$). The difference in slopes was significant, $t(120) = 3.41$, $p < 0.001$.

4. Discussion

The present study found that greater trait BAS was inversely related to resting beta activity over the motor cortex. Additionally, measures of trait impulsivity, based on the UPPS-P scale, related to greater resting beta activity over the motor cortex. Consistent with predictions, greater resting beta activity inversely related to trait approach motivation. Additionally, greater resting beta activity directly related to greater trait impulsivity. Together, these new findings suggest that less resting beta activity over the motor cortex may be a neurophysiological marker of tendencies towards deliberate motivated motor-action.

The current findings suggest that beta activity may be a neural signature of individual differences in approach-motivated motor readiness. Past research has found that resting beta activity provides a measure of motor readiness, such that higher resting beta activity is associated with less motor readiness (Engel and Fries 2010; Jenkinson and Brown 2011). Other work suggests that this motor readiness may be modulated by approach motivation, as seen by lower beta activity during high approach-motivated states compared to low approach-motivated or neutral states (Gable et al. 2016b). The approach motivation system appears to engage neural circuits related to motor-actions that allow individuals to better able initiate goal pursuit from a general resting state, when there is no goal pursuit in process.

The present results suggest that trait beta power in the motor cortex is related to general BAS functioning rather than a specific facet of BAS. Individual differences in BAS Total related to general trait motor-action preparation. No specific BAS subscale significantly related to beta activation in the motor cortex. BAS Total measures general BAS functioning. The three subscales measure specific facets of BAS functioning, all of which are manifestations of approach-motivated behavioral tendencies. Because beta activation reflects general preparation to act, this general action preparation related to general approach motivation reflected by BAS Total. In addition, two of the BAS subscales had low internal reliability, but BAS Total had high internal reliability. The high internal consistency in BAS Total suggests this scale measures general BAS functioning.

The results of the current study suggest that trait approach motivation and control may explain only a small amount of variance in resting beta activity (Cohen 1988). Psychology studies often have small effect sizes (Hemphill 2003; Richard et al., 2003). However, these small effect sizes may have immense theoretical importance, since, over time, effects may have tremendous influence on behavioral output (Abelson 1985). In the current study, it may be the case that, while the effects are statistically small, the relationship between trait approach and control and neural correlates of motor readiness has a profound impact on behavior, especially when considering the possible theoretical and functional relationships that may exist between these variables. Additionally, it is important to note that some unknown third variable could be influencing these relationships. For example, variances in state influences could be making these effects stronger or weaker. Future research should examine the relationship between core personality systems, motor cortex EEG activity, and other potential influential variables.

Our results suggest that resting beta activity in the motor cortex is related to both trait approach motivation and trait control. Individuals with lower levels of resting beta activity show tendencies towards deliberative motivated action. This, in turn, may facilitate better goal pursuit and more successful goal attainment, because these individuals are more likely to be prepared to move towards some desirable goal or object. Because these individuals are higher in propensity towards planned, goal-directed action, it seems likely that they are more likely to successfully attain desirable goals (Davidson 2004). In general, this tendency could be adaptive in initiating, planning, and maintaining goal pursuit.

In the current study, resting beta activity was related to premeditation and perseverance. These traits are typically associated with traits of *conscientiousness*, which are engaged within an organism during goal-planning and goal pursuit (Cyders and Coskunpinar 2011; Whiteside and Lynam 2001). However, when examining the relationship between resting beta and the emotional traits of impulsivity (positive urgency and negative urgency), there was no significant relationship. These results suggest that resting beta activity is more closely related to thoughtful motor readiness, rather than rash emotional impulsivity (Cyders and Smith 2007).

Regulatory control associated with rBIS is a multi-faceted process. Some have divided control into two different modes: proactive and reactive control (Braver 2012). Proactive control occurs before the onset of goal pursuit and includes planning behaviors using goal-relevant information to efficiently and effectively reach some goal or object. Conversely, reactive control is used as a correction mechanism when some problem or impetus arises that blocks the successful attainment of some goal. The current research found that lower resting beta activity (which occurs before goal pursuit) is associated with greater levels of trait planning. This type of rBIS functioning is more likely related to proactive control. However, in times when reactive control is needed (i.e., unexpectedly inhibiting a motor-action), less beta activity may result in more impulsive behaviors. Using a stop-signal task where participants had to unexpectedly inhibit their motor-action response, Swann et al. (2009) found that beta activation was higher before successfully stopped trials than unsuccessfully stopped trials. In situations requiring reactive control, less beta activity (more motor-action preparation) could make it more difficult to inhibit behavior.

We ran exploratory analyses to examine how much variance in beta power activation was accounted for by gender, as well as if the relations between personality variables and trait beta activation were the same between males and females. Consistent with previous work (Jaušovec and Jaušovec 2010; Nikulin and Brismar 2005), results indicated that females exhibited higher beta power than men. Additionally, the interaction between gender and UPPS-P Total significantly predicted beta activation over the motor cortex. Further probing of this interaction revealed that females had a positive relationship between UPPS-P Total and trait beta activation, while males had a non-significant negative relationship between UPPS-P Total and trait beta activation. Because of the exploratory nature of these analyses, it is difficult to ascertain why there is a difference in the nature of the relationships between UPPS-P Total and trait beta activation. It may be the case that, because females naturally exhibit higher beta power, this elevated beta is more likely to relate positively with UPPS-P Total. Presumably, the change in state beta activity during motor preparation would potentially be greater in females than males, since resting beta activity is naturally higher in females than males.

Understanding the neural mechanisms associated with the approach motivation and control systems contribute to a growing interest in determining stable biomarkers of various personality traits. Indeed, the National Institute of Mental Health's Research Domain Criteria (RDoC) calls for understanding core neural systems that may underlie deviations from normal functioning human behavior, including the positive valence system of approach motivation (Cuthbert and Insel 2013; Sanislow et al. 2010). Decreased resting beta activity may be one neural mechanism underlying the connection between trait approach and control and motor behaviors. The current study suggests that resting beta activity over the motor cortex reflects functioning of motor readiness related to core personality processes.

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