Journal of Personality 83:1, February 2015
DOI: 10.1111/jopy.12084

Left Hemispheric Lateral Preference and High Neuroticism Predict Disinhibition in Two Go/No-Go Experiments

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Abstract

Although disinhibition is widely implicated in impulse-control-related psychopathologies, debate remains regarding the underlying approach and avoidance processes of this construct. In two studies, we simultaneously tested three competing models in which varying levels of extraversion, neuroticism, and hemispheric lateral preference are associated with disinhibition. In both studies (Study 1, $N = 92$; Study 2, $N = 124$), undergraduate students were randomly allocated to one of two versions of the go/no-go task: one where participants were primed through reward to make more "go" responses and another where no such priming occurred. Neuroticism, extraversion, and hemispheric lateral preference measures were also collected. Across both studies, disinhibition was greatest in individuals who reported both a left hemispheric lateral preference and high neuroticism. This pattern was only found for those who were primed through reward to make more "go" responses. There was no association with extraversion. Contrary to previous research, our results suggest that left hemispheric asymmetry and neuroticism and *not* extraversion drive disinhibited approach, following the establishment of a prepotent approach response set. This has salient implications for the theoretical understanding of disinhibited behavior, as well as for the study of continued maladaptive approach behavior.

Individuals high in disinhibition are characterized as being overly focused on rewards (e.g., Avila & Parcet, 2000) and as being insensitive to future consequences (e.g., Vitaro, Brendgen, & Tremblay, 1999). There are currently at least three theories that aim to explain disinhibition. The first, and arguably the most well known, is the response modulation model (RMM; Arnett, Smith, & Newman, 1997; Patterson & Newman, 1993). The second is Robinson, Wilkowski, and Meier's (2008) co-activation model of self-regulation, and the third is Jackson's (2008) biologically based lateral preference model. While there is some congruence across these theories in terms of how disinhibition is defined and displayed behaviorally, there is a lack of agreement about what mechanisms underlie this trait generally, and the roles of extraversion and neuroticism in particular. A large part of the difficulty in advancing our knowledge of disinhibition (and other related traits, such as impulsivity) has been due to discrepancies among these models.

Our aim is to directly compare and test these theories in two experiments. We are the first to make this direct comparison, and we test the validity of these theories under two different conditions: one where participants are conditioned to establish a prepotent response tendency toward approach (which we will label the "approach-primed" group) and one where no such conditioning has occurred (which we will label the "avoidance-primed" group).[1] Testing all three competing theories under these different conditions tests the boundaries of these theories and builds theory by highlighting the potential relevance of establishing prepotent reward.

Models of Disinhibition

Response Modulation Model

According to the RMM, individuals high in disinhibition are those who are overly focused on rewards (Patterson & Newman, 1993). Extraversion is thought to reflect a

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motivational disposition toward reward (Depue & Collins, 1999; Elliot & Thrash, 2002) and as such has been identified in the RMM as a key predictor of disinhibition. These reward processes are thought to be neurobiologically linked to dopamine (DA; Schultz, 2006; Wise, 2004) and the mesocorticolimbic DA system (Depue & Collins, 1999). Given the links between extraversion and genes associated with DA (e.g., DRD2 and DRD4 genes), it appears that individuals high in extraversion (and dopamine) are somewhat hardwired toward approach (e.g., Cohen, Young, Baek, Kessler, & Ranganath, 2005; Wacker, Chavanon, & Stemmler, 2006). Therefore, individuals high in extraversion are likely to have similarly high levels of disinhibition.

Within the RMM there are two competing hypotheses. The first posits that disinhibited approach, in the form of poor response modulation, is the result of high extraversion and *high* neuroticism (Patterson & Newman, 1993), whereas the second views poor response modulation as a result of high extraversion and *low* neuroticism (Arnett et al., 1997). Individuals high in neuroticism are sensitive to threat, pay more attention to negative cues, and respond poorly to environmental stress (Wallace & Newman, 1997). The first hypothesis argues that individuals high in neuroticism are more affected by punishment, which interferes with rational decision making and response modulation. Research by Bachorowski and Newman (1990) indicates that while extraversion is important in determining what type of stimuli participants respond to, neuroticism determines the magnitude of this reaction, such that high neuroticism elicits a strong behavioral response. Findings by Wallace, Bachorowski, and Newman (1991) also indicate that increased levels of neuroticism predispose individuals to heightened arousal levels, so when presented with punishing stimuli, individuals high in trait neuroticism are particularly motivated to quickly resolve the conflict through approach behavior. This hypothesis is in line with previous reports that individuals high in anxiety are likely to attach *more* weight to *less* evidence when making a decision. Thus, in uncertain situations, collecting less information and ending the task as quickly as possible serves to reduce anxiety (Bensi, Giusberti, Nori, & Gambetti, 2010).

In contrast, the second hypothesis, proposed by Arnett and colleagues (1997), views poor response modulation as a result of an individual's low avoidance tendencies in the presence of strong approach tendencies. According to this perspective, individuals low in neuroticism are also low in avoidance drive; therefore, they are unlikely to be sufficiently motivated to disengage from an already conditioned approach response. This position follows Fowles's (1980, 1988) view that impulsive forms of behavior can be attributed to a lack of inhibition and a deficit in passive avoidance due to low anxiety. Individuals who are low in neuroticism are also known to initiate strategies, such as moving rapidly through feedback, which diminish the processing of punished stimuli (Avila, Moltó, Segarra, & Torrubia, 1995). We will test both competing RMM hypotheses:

H1: Disinhibition will be highest for those high in extraversion and high in neuroticism.

H2: Disinhibition will be highest for those high in extraversion and low in neuroticism.

Robinson and Colleagues' (2008) Co-activation Model of Self-Regulation

Robinson and colleagues (2008) provide a similar but broader framework to the RMM where disinhibition is conceptualized as a form of poor self-regulation. Robinson et al. (2008) argue that poor self-regulation is brought about by the co-activation of two strong but opposing internal motivations: one motivation toward approach and one toward avoidance. Therefore, when confronted with conflicting approach-avoidance goals, "good" self-regulation occurs when one internal motivation (either approach *or* avoidance) is dominant over the other and "poor" self-regulation arises when the approach-avoidance motivations are in equilibrium. Poor self-regulation is the result of an individual being equally compelled to both approach and avoid. Although self-regulation failures can result in a range of behaviors, disinhibition is one more frequently observed manifestation.

As per previous research and in line with the RMM, Robinson et al. (2008) align approach tendencies with extraversion and avoidance tendencies with neuroticism. However, where the RMM strictly conceptualizes disinhibition as an approach tendency, Robinson et al. (2008) view disinhibition as poor self-regulation presenting as both active-approach (toward reward) *and* active-avoidance (from punishment). This is a subtle but meaningful difference, as it suggests that the effects of reward and punishment are equally important to disinhibition. Rather than disinhibition being consistently driven by high extraversion (as per the RMM), under Robinson and colleagues' (2008) framework, disinhibition is contingent on both extraversion and neuroticism such that disinhibition can be facilitated by both high extraversion/high neuroticism and low extraversion/low neuroticism combinations.

Testing this theory, Robinson et al. (2008) found that poor self-regulation was significantly predicted by either simultaneously high or simultaneously low levels of extraversion and neuroticism. The interactions between extraversion and neuroticism were associated with an individuals' failure to regulate his or her behavior by recognizing and responding to goal-relevant stimuli. Interestingly, across all four studies, no main effects of neuroticism or extraversion were detected, indicating that in the pursuit of goals, self-regulation is differentially related to the combination of these competing approach and avoidance motives. Although Patterson and Newman's (1993) high neuroticism and high extraversion RMM hypothesis (H1) is somewhat congruent with Robinson and colleagues' (2008) theory, the propositions underlying these hypotheses are functionally different. The former is narrower and more specific to approach tendencies, whereas the latter approach is more concerned with self-regulation in general, either toward efficient approach or avoidance.

H3: Disinhibition will be highest for those who are high in both extraversion and neuroticism or low in both extraversion and neuroticism.

Jackson's (2008) Lateral Preference Model

Jackson's (2008) lateral preference model is somewhat derived from Patterson and Newman's (1993) RMM hypothesis. The model proposes that disinhibition occurs when neurotic people resolve conflict by choosing to approach. High neuroticism is similarly thought to interfere with the logical processing of corrective feedback and is implicated in Jackson's (2008) model as a key predictor of disinhibition. However, rather than conceptualizing disinhibited approach as influenced by extraversion, Jackson (2008) substitutes hemispheric lateral preference for extraversion. This theory is based on the motivational direction model, which views approach-avoidance tendencies as lateralized in the left and right hemispheres of the human brain, respectively (e.g., Davidson, 1995, 1998). The lateral preference model focuses on the approach part of the model and proposes that disinhibition is predicted from high neuroticism in interaction with left hemispheric lateral preference.

Although the motivational direction model is well established (e.g., Harmon-Jones, Sigelman, Bohlig, & Harmon-Jones, 2003; Sutton & Davidson, 1997), it has been challenged by the behavioral activation-behavioral inhibition model of anterior asymmetry (BBMAA; Wacker, Heldmann, & Stemmler, 2003), which clusters all behavioral activation (regardless of direction) to the left anterior region and all goal-conflict–induced inhibition to the right anterior region. These two models differ in the placement of avoidance motivation such that avoidance is identified as a right hemisphere function according to the motivational direction model and a left hemisphere function according to the BBMAA. Although some electroencephalogram (EEG) studies have found increased right frontal lobe (relative to left) to be preferentially involved in withdrawal and avoidance behaviors (e.g., Zuckerman, 2005), others have reported conflicting evidence (e.g., Coan & Allen, 2003; Hagemann, Naumann, Backer, Maier, & Barussek, 1998). With this in mind, and informed by evidence linking the left hemisphere with DA reward pathways (Sobotka, Davidson, & Senulis, 1992; Tucker & Williamson, 1984) and approach tendencies (Coan & Allen, 2003; Harmon-Jones & Allen, 1997), we focus our current research on the connection between approach tendencies and left hemispheric lateral preference.

Hemispheric lateral preference can be measured in a variety of ways (e.g., via EEG). However, research has demonstrated the potential utility of enlisting self-reported paper-and-pencil tests as a cheaper and less invasive measure of contralateral hemispheric activation (see Merckelbach, Muris, Horselenberg, & de Jong, 1997; Merckelbach, Muris, Pool, de Jong, & Schouten, 1996). The lateral preference model focuses more pragmatically on self-reported ear preference, where a self-reported left ear preference is indicative of a habitual right hemispheric lateral preference and a right ear preference is indicative of a habitual left hemispheric lateral preference.

Across eight studies, Jackson (2008) investigated the link between self-reported ear preference and neuroticism in the prediction of a range of goal-oriented approach behaviors (e.g., sales performance, drug and alcohol use). Results across all eight studies demonstrated that disinhibition was highest for individuals who were high in neuroticism and had a right ear preference. Similar findings were also reported by Gullo, Jackson, and Dawe (2010), where participants who were high in neuroticism and had a left ear preference recorded faster reaction times on a reversal learning task measuring disinhibited approach.

Although these results suggest that Jackson's (2005) self-report scale may be an effective indicator of hemispheric activation, we acknowledge that it is not a perfect measure. Perhaps the main issue is that compared with EEG or functional magnetic resonance imaging (fMRI), self-reported ear preference lacks specificity. Rather than being able to map dynamic cortical processes, the self-report scale is a broader, trait-based measure of activation, insensitive to temporal changes and unable to identify what specific regions are activated. However, there is growing evidence that Jackson's (2005) scale, though a broad measure, is a valid measure of hemispheric lateral preference. Research linking right ear/left hemispheric preference with goal-directed approach tendencies (Jackson, 2001, 2003) as well as reports of a small but significant ($r = .14$, $p < .001$) correlation between ear preference and tympanic membrane temperature (Jackson, 2010) support our choice. A final point is that Jackson (2008) uses ear preference in his model of disinhibition, and we can therefore provide a more direct test of his model by using ear preference as opposed to other measures of lateral preference. Our research provides one of the first tests of Jackson's (2008) theory.

H4: Disinhibition will be highest for those who are high in neuroticism and have a left hemispheric lateral preference.

Overview of Studies

Go/No-Go Paradigm

Disinhibition was measured using the go/no-go task (GNGT), which measures the tendency of an individual to deliberately stop or inhibit an already initiated response (e.g., Newman, Widom, & Nathan, 1985). This task requires participants to discriminate between "good" stimuli and "bad" stimuli by making either a "go" response (by pressing with their dominant index finger any button on the keyboard) or a "no-go" response (by withholding the opportunity to press any button on the keyboard).[2] The GNGT has been the main paradigm in seminal studies of disinhibition. Newman and colleagues, for instance, have found commission errors (failure to inhibit a "no-go" response) in the GNGT were committed more frequently by individuals high in psychopathy (Newman, Patterson, Howland, & Nichols, 1990; Newman et al., 1985), high in extraversion (Newman, 1987; Patterson et al., 1987, in their Experiment 1), and high in both extraversion *and* neuroticism (Patterson, Kosson, & Newman, 1987, in their Experiment 2).

Within each study, we randomly assigned participants to one of two versions of the GNGT. One version of the task involved conditioning participants through the provision of reward to favor making a response to GNGT stimuli (i.e., press the button). The effect of this design feature was the establishment of a prepotent response tendency toward approaching GNGT stimuli (rather than inhibition). Participants who were administered this version of the task formed the "approach-primed" group. All three theories (albeit at varying degrees) identify the formation of a prepotent approach tendency as important to disinhibition, and therefore, the approach-primed group is the chief group of interest in the current research.

To test the centrality of establishing a prepotent approach response style to behavioral disinhibition, we created another version of the GNGT. In this alternate version, participants were incentivized through the threat of punishment to inhibit responses to GNGT stimuli. This design feature facilitated a prepotent response tendency to avoid rather than approach stimuli. Participants who were administered this version of the task formed the "avoidance-primed" group. We are the first to test these three competing frameworks in this way and expect that our a priori hypotheses for the three competing theories (e.g., H1–H4) will not find support with the data provided by the avoidance-primed group. That is, if these hypotheses are specific to a prepotent response set (i.e., reward followed by punishment), this group will not engage in disinhibition because its members have not been exposed to the appropriate sequence of reward and punishment.

The number of reward trials differed slightly across the two studies. Study 1 enlisted a more "traditional" version where the number of trials (e.g., 80 trials in the testing block, 10 stimuli), block ordering (e.g., practice block first, mixed-incentive block last), and feedback presentation contingencies (e.g., monetary reward and visual feedback) were comparable to the designs used in previous GNGT studies (e.g., Farmer & Rucklidge, 2006; Newman & Kosson, 1986; Newman & Schmitt, 1998).[3] The rationale behind enlisting this "traditional" design was to try to test the competing frameworks within the scope of an already validated and established paradigm. We altered the contingency of the GNGT paradigm in Study 2 by offering more reward trials as well as more trials overall, with the intention that altering the GNGT parameters would allow constructive replication. Constructive replication provides an opportunity to validate study results as well as extend the generalizability of research by avoiding exact replication through enlisting a new sample and new measures (e.g., Eden, 2002; Lykken, 1968; Schwab, 2005). Increasing the number of reward trials should create conditions to better observe and measure the tendency of an individual to regulate his or her approach-avoidance drive since the increased reward is likely to encourage individuals to approach (and therefore engage in disinhibition) rather than inhibit. Despite the GNGT paradigm being the most appropriate paradigm to study disinhibition, this framework has never been enlisted to simultaneously test these theories in the prediction of disinhibition.

Analysis

Both studies were identically analyzed, with each moderated regression consisting of four steps. Separate regressions were run for the approach-primed and the avoidance-primed groups. We controlled for the effects of sex, total number of omission errors (failure to inhibit a "go" response to "no-go" stimuli), and condition in Step 1.[4] The predictors were extraversion, neuroticism, hemispheric lateral preference (Step 2), and their interactions (Steps 3 and 4). The criterion was disinhibition measured as the total number of GNGT commission errors in Block 4 (the mixed-trial block). Significant interactions were followed up with simple slopes analyses.

Our analysis provides a rigorous comparative test of our hypotheses since we could examine potential interactions between extraversion, neuroticism, and hemispheric lateral preference. Although it would have been statistically efficient to analyze all data across the approach-primed and avoidance-primed groups together and include group type in the analysis, there are at least five reasons why this is unfeasible. First, four-way interaction terms from moderated regression are practically so difficult to find and interpret that they are not widely reported in the literature; second, the reliability of the interaction terms declines as more terms are added; third, the number of independent variables escalates dramatically as all possible interactions are included; fourth, our study is oriented toward testing H1–H4 within just the approach-primed group and does not require us to include the avoidance-primed group to support our results; fifth, our two experimental conditions simply varied by order of reward and punishment. We thought it unlikely that the avoidance-primed group was provided with conditions to potentially display disinhibited behavior, but potentially there may be a recency effect of reward that might interfere with our results. For all these reasons, we decided to analyze our data from the approach- and avoidance-primed groups separately.

STUDY 1

Method

Participants and Procedure. Participants were undergraduate students ($N = 92$, 50 females and 42 males; $M_{age} = 20.41$ years, $SD = 4.90$, range = 17–44) who volunteered to take part in the study in exchange for course credit. Participants were randomly assigned to either the approach-primed group or the avoidance-primed group of the GNGT. After completing the GNGT, participants completed the self-report measures online.

Measures

Go/No-Go Task. Stimuli were 10 randomly generated two-digit numbers where half of the stimuli were designated as "good" and the other half as "bad." Each participant began the task with a simulated amount of $2.00 and was told that the aim of the task was to win as much money as possible. Participants gained a simulated 10¢ for every correct response (i.e., "go" response to a "good" number or "no-go" response to a "bad" number) and lost a simulated 10¢ for an incorrect decision (i.e., "no-go" response to a "good" number or a "go" response to a "bad" number). Each participant was asked to complete 194 trials in total (Block 1: Trials 1–18; Block 2: Trials 19–66; Block 3: Trials 67–114; Block 4: Trials 115–194).

Block 1 was a practice block. In line with traditional versions, this block was weighted toward "go" stimuli (approximately 88% were "go" trials; as a comparison, Farmer and Rucklidge, 2006, offer approximately 67% "go" trials in the practice block), encouraging participants to develop a prepotency to respond and thereby increase the inhibitory effort necessary to successfully withhold responding to go/no-go stimuli. Blocks 2 and 3 were counterbalanced across groups, such that those in the approach-primed group received reward-only feedback in Block 2 and punishment-only feedback in Block 3, and those in the avoidance-primed group received punishment-only feedback in Block 2 and reward-only feedback in Block 3. Block 4 was a mixed-incentive block and is the block of interest. Blocks 1 and 4, respectively, remained positioned as the first and last blocks presented to all participants in both studies. All participants were exposed to approximately 41% of trials where there was an opportunity for reward and 34% of trials where there was an opportunity for punishment; for the remaining 25% of trials, participants were neither rewarded nor punished (these trials involved the provision of nonreward or nonpunishment).

For those in the approach-primed group, the provision of reward (and omission of punishment) in Block 2 (48 trials) should have facilitated the establishment of a prepotent tendency toward approach (i.e., approaching potential "go stimuli). Although the next block (Block 3) involved only punishment (and no provision of reward), the dominant approach response tendency should persevere through until the mixed-block phase in Block 4. In contrast, for those in the avoidance-primed group, the absence of reward and enforcement of punishment should have discouraged a prepotent response style toward approach.

Disinhibition was operationalized as the total number of commission errors made in Block 4 of the GNGT, where more errors indicate higher levels of disinhibition. Number of omission errors was also collected at Block 4 to serve as a check of accuracy.[5]

Eysenck Personality Questionnaire (Revised; EPQ-R). Participants completed the Extraversion and Neuroticism scales of the EPQ-R (Eysenck, Eysenck, & Barrett, 1985). The Extraversion scale consists of 33 items, such as "Do you enjoy meeting new people?" with response *Yes* (1) or *No* (0). The Neuroticism scale consists of 24 items; an example item is "Would being in debt worry you?" Both scales have been repeatedly reported to have high alpha coefficients (e.g., $\alpha \geq .80$; Eysenck & Eysenck, 1991). The alpha for the current sample was acceptable ($\alpha = .83$ for extraversion and $\alpha = .83$ for neuroticism).

Hand, Eye and Ear Preference Questionnaire (HEEP). Hemispheric lateral preference was measured using the HEEP (Jackson, 2005). The HEEP is an adapted version of the Lateral Preference Inventory (Coren, Porac, & Duncan, 1979), which measures preferred attentiveness to left and right modalities in various situations. Coren and colleagues' (1979) measure has demonstrated 92% concordance between self-report and behavioral performance. The complete HEEP was administered to all participants, but given only the seven-item Ear Preference scale is relevant to our current research, only this scale is reported. Participants rate their lateral preference for various acts, such as "Ear used to listen to a low voice." A 5-point scale is used (1 = *Always Left*; 5 = *Always Right*). Hemispheric lateral preference, as measured via ear preference, is a continuous variable where a low score indicates a habitual preference for the left ear (right hemispheric lateral preference) and a high score indicates a habitual preference for the right ear (left hemispheric lateral preference).[6] The HEEP has been used successfully in previous research, and the Ear Preference scale has been found to have high alpha reliabilities (i.e., $\alpha = .70$–$.95$; Gullo et al., 2010; Jackson, 2010). The alpha for the Ear Preference scale for the current sample was acceptable ($\alpha = .84$).[7]

Results and Discussion

Table 1 shows the descriptive statistics for both the approach-primed and avoidance-primed groups. As expected, neuroticism was negatively correlated with extraversion ($r = -.35$, $p = .02$ [approach-primed group]; $r = -.37$, $p = .01$ [avoidance-primed group]). Neuroticism also correlated positively with GNGT commission errors for both groups, indicating that highly neurotic individuals were prone to poor response modulation ($r = .34$, $p = .02$ [approach-primed group]; $r = .38$, $p = .01$ [avoidance-primed group]).

As can be seen in Table 2, the regression results for the approach-primed group revealed a significant Neuroticism × Hemispheric Lateral Preference interaction, $\beta = .55$, $t(36) = 3.47$, $p = .001$, and a significant Extraversion × Hemispheric Lateral Preference interaction, $\beta = .32$, $t(36) = 2.00$,

Table 1 Study 1: Descriptive Statistics for Self-Report and Behavioral Measures

	Approach-Primed Group							Avoidance-Primed Group						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Mean	—	12.76	—	16.49	13.96	23.31	18.07	—	12.87	—	16.22	13.66	23.54	18.85
SD	—	5.77	—	4.77	5.20	6.01	7.33	—	5.13	—	4.36	5.10	4.42	8.34
1. Sex	—	−.03	.07	−.17	−.07	−.10	−.17	—	.10	.08	.03	−.11	−.14	.06
2. Omission errors		—	.05	.15	−.07	.06	−.22		—	−.01	.01	−.10	.01	−.22
3. Condition			—	.21	−.02	.25	−.11			—	−.11	.25	.03	.08
4. Extraversion				—	−.35*	−.09	−.11				—	−.37**	.22	−.16
5. Neuroticism					—	.11	.34*					—	−.20	.38**
6. Hemispheric lateral preference						—	.03						—	−.08
7. Commission errors							—							—

Note. *$p < .05$. **$p < .01$.

Table 2 Standardized Regression Coefficients (β) of Extraversion, Neuroticism, and Hemispheric Lateral Preference as Predictors of Commission Errors

		Approach-Primed Group				Avoidance-Primed Group			
Step	Variable	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4
1	Sex	−.167	−.138	−.126	−.111	.075	.125	.195	.233
	Omission errors	−.218	−.198	−.263	−.239	−.224	−.196	−.254	−.319
	Condition	−.085	−.091	−.009	−.029	.075	−.028	−.104	−.113
2	Neuroticism (N)		.325*	.222	.213		.377*	.469*	.536**
	Extraversion (E)		.026	−.061	−.073		−.033	−.016	−.002
	Hemispheric lateral preference (HLP)		.013	−.141	.047		.024	.019	−.075
3	E × N			.090	.049			.008	−.012
	E × HLP			.321*	−.041			.144	.257
	N × HLP			.549**	.399*			−.153	−.055
4	E × N × HLP				.432				−.253
	R^2	.09	.19	.41	.46	.06	.20	.25	.28
	Model *F*	1.23	1.47	2.77**	2.99**	.88	1.57	1.32	1.37
	R_{ch}^2		.10	.22**	.05		.14	.05	.03
	F_{ch}		1.59	4.56**	3.34		2.19	.86	1.56

Note. *$p < .05$. **$p < .01$.

$p = .05$. The lack of a significant Extraversion × Neuroticism interaction, $\beta = .09$, $t(36) = .56$, $p = .58$, provides evidence to reject H1, H2, and H3. The three-way Neuroticism × Extraversion × Hemispheric Lateral Preference interaction came close but failed to reach statistical significance, $\beta = .43$, $t(35) = 1.83$, $p = .08$.

To further investigate the Neuroticism × Hemispheric Lateral Preference interaction, we conducted slope tests of the regression line estimated at right versus left (one standard deviation below vs. above the mean) hemispheric lateral preference. As seen in Figure 1, for those with a left hemispheric lateral preference, there was a significant association between neuroticism and commission errors, $b = 1.22$, $t(38) = 3.77$, $p < .001$. The most commission errors were committed by participants who reported a left hemispheric lateral preference and who were also high in neuroticism. However, for participants with a right hemispheric lateral preference, neuroticism

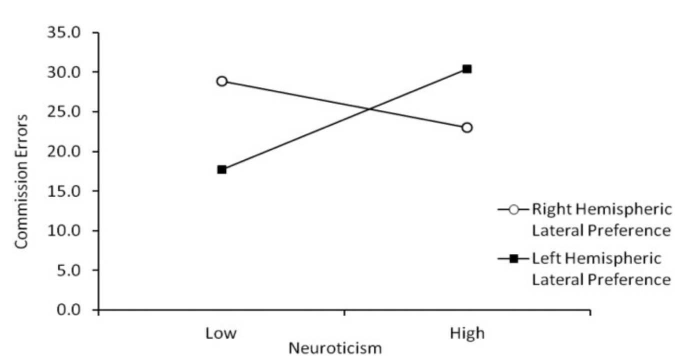

Figure 1 Regression lines for the relationship between neuroticism and total number of commission errors as moderated by hemispheric lateral preference (± 1SD) for those in the approach-primed group.

was not associated with the number of commission errors, $b = -0.56$, $t(38) = -1.59$, $p = .11$. This provides evidence in support of H4.[8]

The simple slopes analysis for the Extraversion × Hemispheric Lateral Preference interaction failed to reveal any significant effect of extraversion on commission errors for those with either a left, $b = .04$, $t(38) = 1.10$, $p = .28$, or right, $b = -0.58$, $t(38) = -1.41$, $p = .17$, hemispheric lateral preference. The lack of a significant Extraversion × Neuroticism interaction (or main effect of extraversion) is an unexpected but not entirely novel finding (e.g., Avila et al., 1995; Newman et al., 1985, their Experiment 2). Although the GNGT contingency enlisted is based on previous research, it is possible that our task did not provide enough reward incentive to encourage individuals high in extraversion to engage in reward-oriented approach behavior. We will more closely examine this possibility in Study 2 by increasing the number of reward trials.

For the avoidance-primed group, there was no significant main effect of extraversion or hemispheric lateral preference. The main effect of neuroticism was significant: Step 2, $\beta = .38$, $t(37) = 2.31$, $p = .03$; Step 3, $\beta = .47$, $t(36) = 2.51$, $p = .02$; Step 4, $\beta = .54$, $t(35) = 2.78$, $p = .01$. This is interesting given that no prepotent approach response style was established in this group. This result suggests that high and not low neuroticism best predicts commission errors and highlights the fundamental role that neuroticism plays in disinhibition. The inclusion of the three two-way interaction terms in Step 3 and the three-way interaction term in Step 4 also failed to improve the fit of the model; therefore, H1, H2, H3, and H4 are rejected.

Jackson's (2008) theoretical approach and results suggest no interaction effect when eye, hand, and overall lateral preference are substituted for ear preference. We also found no significant effects when these other measures of lateral preference were substituted for ear preference.

STUDY 2

Study 2 is a constructive replication of Study 1 and provides an opportunity to test the boundary conditions of our findings with a modified version of the GNGT. Given the failure to find significant effects of extraversion in Study 1, we chose to modify the task contingency in Study 2 to encourage greater approach-oriented behavior by increasing the number of reward trials. Neuroticism and extraversion are known to have differing effects on response modulation, where the former is associated with the facilitation of attention toward threat and negative cues (e.g., Wallace & Newman, 1997) and the latter with an inability to shift attention from positive cues (e.g., Derryberry & Reed, 1994). Therefore, increasing the opportunity to make "go" responses should make it difficult for individuals to inhibit their approach behavior and thereby create conditions most likely to support H1, H2, and H3.

Method

Participants and Procedure. An entirely new sample was enlisted for Study 2, and a new GNGT was used; however, the rest of the procedure remained the same as Study 1. Participants were undergraduate student volunteers ($N = 124$, 98 females and 26 males; $M_{age} = 19.32$ years, $SD = 3.53$, range = 16–45) who participated in exchange for course credit. Participants were randomly assigned to either the approach-primed group or the avoidance-primed group of the new GNGT ($n = 62$ for approach-primed group; $n = 62$ for avoidance-primed group).

Measures

Go/No-Go Task. Compared to the GNGT used in Study 1, the current version had fewer mixed-incentive trials (60 trials), but it had more trials overall, with more practice (Block 1: 30 trials), punishment-only (60 trials), and reward-only trials (60 trials). All participants were exposed to approximately 41% of trials where there was an opportunity for reward and 30% of trials where there was an opportunity for punishment; for the remaining 29% of the trials, participants were neither rewarded nor punished (these trials involved the provision of nonreward or nonpunishment). This version of the task also consisted of four blocks, and all other feedback, incentive contingencies, and collected indices (e.g., commission and omission errors) were the same as in Study 1.

Eysenck Personality Questionnaire (Revised). This measure was identical to Study 1. Alpha for this sample was acceptable ($\alpha = .75$ for extraversion and $\alpha = .70$ for neuroticism).

Hand, Eye and Ear Preference Questionnaire. This measure was identical to Study 1. The internal consistency score for the Ear Preference scale for this sample was acceptable ($\alpha = .82$).

Results and Discussion

Table 3 contains the descriptive statistics for the approach-primed and avoidance-primed groups. Unexpectedly, a small negative correlation between hemispheric lateral preference and omission errors ($r = -.26$, $p = .04$) and a small positive correlation between hemispheric lateral preference and commission errors ($r = .27$, $p = .03$) were found for those in the avoidance-primed condition. Taken together, these results suggest that for this group, those with a stronger right hemispheric lateral preference were less able to inhibit a response and those with a stronger left hemispheric lateral preference were less likely to initiate a response. This finding fits in with Jackson's (2008) conceptualization of right ear preference/left hemispheric lateral preference as a proxy measure of approach tendencies. It is interesting to note that left ear preference/right hemispheric lateral preference appears to be a proxy measure of avoidance tendencies.

Table 3 Study 2: Descriptive Statistics for Self-Report and Behavioral Measures

	Approach-Primed Group							Avoidance-Primed Group						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Mean	—	10.15	—	16.31	13.95	23.92	14.45	—	8.98	—	13.94	13.32	23.08	13.29
SD	—	6.41	—	3.88	3.80	5.61	7.29	—	5.87	—	4.28	4.01	5.79	7.10
1. Sex	—	.03	.16	.19	.23	.10	.16	—	–.12	.11	.22	–.19	–.08	–.08
2. Omission errors		—	.05	–.02	.24	.02	–.25		—	–.01	–.13	.05	–.26*	–.10
3. Condition			—	.20	.02	–.01	–.09			—	.02	.14	.06	–.06
4. Extraversion				—	–.12	–.01	–.12				—	–.14	–.03	–.15
5. Neuroticism					—	–.08	.23					—	–.17	.14
6. Hemispheric lateral preference						—	–.09						—	.27*
7. Commission errors							—							—

Note. $^{*}p < .05$. $^{**}p < .01$.

Table 4 Standardized Regression Coefficients (β) of Extraversion, Neuroticism, and Hemispheric Lateral Preference as Predictors of Commission Errors

		Approach-Primed Group				Avoidance-Primed Group			
Step	Variable	Step 1	Step 2	Step 3	Step 4	Step 1	Step 2	Step 3	Step 4
1	Sex	.179	.190	.224	.226	–.084	.016	.036	–.025
	Omission errors	–.248*	–.271*	–.285*	–.277*	–.115	–.052	.022	.079
	Condition	–.106	–.081	–.177	–.178	–.049	–.100	–.106	–.090
2	Neuroticism (N)		.090	.077	.081		.190	.223	.271
	Extraversion (E)		–.138	–.017	–.011		–.123	–.109	–.088
	Hemispheric lateral preference (HLP)		–.095	–.065	–.069		.297*	.373*	.365*
3	E × N			–.012	–.019			.001	–.072
	E × HLP			–.241	–.213			.174	.045
	N × HLP			.408**	.438**			.118	.176
4	E × N × HLP				–.068				.294
	R^2	.10	.14	.33	.33	.02	.14	.16	.21
	Model *F*	2.13	1.47	2.80**	2.50*	.42	1.44	1.22	1.34
	R_{ch}^2		.04	.19**	.00		.11	.03	.05
	F_{ch}		.83	4.84**	.20		2.43	.56	2.94

Note. $^{*}p < .05$. $^{**}p < .01$.

Table 4 presents the regression results for both the approach-primed group and the avoidance-primed group. Results for the approach-primed group reveal a significant Neuroticism × Hemispheric Lateral Preference interaction, $\beta = .41$, $t(52) = 3.42$, $p = .001$. The Extraversion × Hemispheric Lateral Preference interaction came close but did not reach statistical significance, $\beta = -.24$, $t(52) = -1.96$, $p = .06$.[9] The lack of a significant Extraversion × Neuroticism interaction, $\beta = -.01$, $t(52) = -.08$, $p = .94$, provides evidence in favor of rejecting H1, H2, and H3.

Figure 2 plots the simple slopes for the Neuroticism × Hemispheric Lateral Preference interaction. As per Study 1, simple slopes were plotted at one standard deviation above and one standard deviation below hemispheric lateral preference; we label these "left hemispheric lateral preference" and "right hemispheric lateral preference," respectively. For those with a left hemispheric lateral preference, there was a significant association between neuroticism and commission

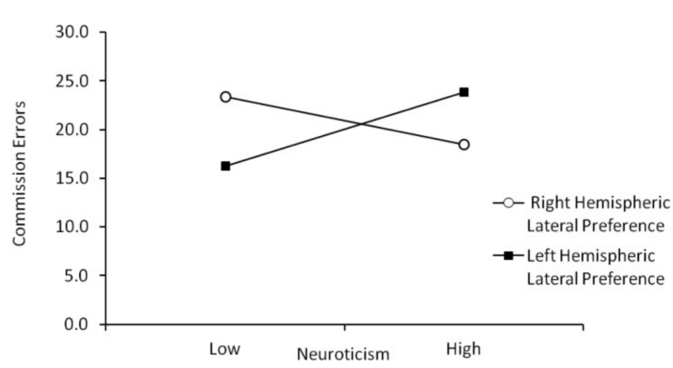

Figure 2 Regression lines for the relationship between neuroticism and total number of commission errors as moderated by hemispheric lateral preference (± 1SD) for those in the approach-primed group.

errors, $b = .95$, $t(55) = 2.49$, $p = .016$, where more commission errors were committed by participants who reported a left hemispheric lateral preference and who were also high in neuroticism. For participants with a right hemispheric lateral preference, neuroticism was not associated with the number of commission errors, $b = -.62$, $t(55) = -1.65$, $p = .104$. This provides evidence in support for H4.[10]

For the avoidance-primed group, there was no significant main effect of extraversion or neuroticism. However, there was a significant main effect of hemispheric lateral preference: Step 2, $\beta = .30$, $t(37) = 2.21$, $p = .03$; Step 3, $\beta = .37$, $t(36) = 2.37$, $p = .02$; Step 4, $\beta = .37$, $t(35) = 2.35$, $p = .02$.[11] This result supports Jackson's (2008) conceptualization of right ear/left hemispheric lateral preference as being aligned with approach. The inclusion of the three two-way interaction terms in Step 3 and the three-way interaction term in Step 4 failed to improve the fit of the model. The lack of a significant interaction for the avoidance-primed group indicates that for any of the three competing models to hold, a prepotent response tendency toward approach must be established.

GENERAL DISCUSSION

In two independent samples using two different versions of the GNGT measuring disinhibition, the current research compared and contrasted the RMM (H1: Patterson & Newman, 1993; H2: Arnett et al., 1997), Robinson and colleagues' (2008) co-activation model of self-regulation (H3), and Jackson's (2008) lateral preference model (H4). The results of Study 1 are largely replicated in Study 2. Results for the approach-primed group showed that participants who were high in neuroticism but who also had a left hemispheric lateral preference committed the most commission errors. That is, disinhibited approach was highest for those who were high in neuroticism and who had greater left than right hemispheric preference.

Jackson's (2008) Lateral Preference Model

H4 was supported in both studies. Taken together, our results are congruent with Jackson's (2008) lateral preference model. These results suggest that neurotic individuals engage in disinhibition as a way to resolve conflict, and, as added by Jackson's (2008) model, we would argue that this is moderated by a biological predisposition toward approach (left hemispheric activation).

Right hemispheric lateral preference is thought to be linked to *inhibition* rather than disinhibited approach (Sutton & Davidson, 1997; Wacker, Chavanon, Leue, & Stemmler, 2010) such that it is concerned with the inhibition of approach behavior rather than the execution of such behavior. Thus, we did not explicitly predict a priori a relationship between avoidance tendencies as measured by right hemispheric lateral preference (left ear/ increased right hemisphere activation) and disinhibition. Nevertheless, the significant negative correlation between omission errors and hemispheric lateral preference and positive correlation between commission errors and hemispheric lateral preference for those in the avoidance-primed group in Study 2 suggests that there may be some correspondence between these constructs. Given the conflicting evidence provided by both the motivational direction model (Davidson, 1995) and the BBMAA (Wacker et al., 2003) with respect to the function of the right hemispheric preference in particular, we were hopeful that a result of low disinhibition and right hemispheric lateral preference (either as a main effect or in interaction with extraversion or neuroticism) may have shed some light on the debate. We acknowledge that since the scope of our research was limited to *dis*inhibition rather than inhibition, we cannot make any strong conclusions as to the implications of our work on the inhibition component of either model. However, we can interpret our results to suggest that left hemispheric lateral preference is more aligned to approach motivation than avoidance motivation, and that conflict resolution via disinhibited approach is not associated with right hemisphere activation.

Our research makes an important contribution to the existing body of work by highlighting discrepancies in the avoidance component of the motivational direction model (e.g., Harmon-Jones & Allen, 1997; Hewig, Hagemann, Seifert, Naumann, & Bartussek, 2004, 2005). While the lack of a robust association between right hemispheric lateral preference and disinhibition does not detract from our overall findings, it does indicate the need for further clarification regarding the relationship between right hemisphere activation and avoidance tendencies. More specifically, we think further research is required to determine whether disinhibition is the same as *poor* inhibition and how disinhibition and inhibition present under different reward-punishment contingencies.

Future efforts should also be directed at exploring the unexpected but interesting Extraversion × Hemispheric Lateral Preference interaction found in Study 1. Although simple slopes analysis indicated that the effect of extraversion on commission errors did not vary according to hemispheric lateral preference, it is worthy of further investigation, particularly given the importance of reward sensitivity and our emerging research linking disinhibition to left hemispheric lateral preference. If one sees hemispheric lateral preference as a proxy measure of approach-avoidance motivation, then it is plausible that the multiplicative effects of extraversion would only heighten disinhibition. Jackson (2008) reported similar findings in the prediction of decision-making speed on a conflict task as well as alcohol intake among university students, but we are the first to find this result using the GNGT, and notably, this result is only found for those in the approach-primed group.

Our research also demonstrates that increased levels of neuroticism actually promote rather than inhibit disinhibited approach. We think the goal formation tendencies of individuals with a left hemispheric lateral preference encourage action-goal formation tendencies such that individuals attempt to quickly resolve conflict rather than delaying or avoiding conflict resolution. Under these competing reward-punishment circumstances, highly neurotic individuals appear to fail to take into account the necessary feedback to modify their behavior. In line with Patterson and Newman (1993), our pattern of results indicates that high rather than low neuroticism underscores disinhibition (e.g., Gomez, 2003).

Patterson and Newman's (1993) and Arnett and Colleagues' (1997) Response Modulation Model

In both Study 1 and Study 2, and across the approach-primed group and avoidance-primed group, extraversion, either as a main effect or as part of a two-way interaction with neuroticism, did not predict disinhibition. Thus, H1 and H2 are rejected. The lack of the effect of extraversion is a new and unexpected finding primarily because there has been an ongoing assumption in the previous GNGT literature that high extraversion underlies disinhibition. Illustrative of this is the inclusion of high extraversion in three of the four disinhibition frameworks tested in the current research (e.g., H1: Patterson & Newman, 1993; H2: Arnett et al., 1997; H3: Robinson et al., 2008). Further, while not explicitly implicated in Jackson's (2008) lateral preference framework (H4), even Jackson's (2008) studies revealed some significant main effects of extraversion or extraversion in interaction with neuroticism. In light of the evidence linking extraversion to reward and DA reward pathways (Depue & Collins, 1999; Wacker et al., 2006), we expected extraversion to have a significant influence on disinhibition.

While we could interpret the nonsignificant result of extraversion as a possible consequence of methodological inconsistencies between our current research and previous research, this seems an unlikely explanation given that we modeled the design on seminal GNGT research (e.g., Newman & Kosson, 1986; Newman et al., 1985).[12] Closer examination of the literature suggests that a number of other GNGT studies have also reported nonsignificant main effects of extraversion (e.g., Robinson et al., 2008, Experiment 4). Therefore, perhaps a more likely interpretation is that the influence of extraversion on disinhibition is only noticeable under specific situational conditions, such as when impulsivity might also be a predictor of the approach tendencies being studied. This is an important contribution, as it brings the role of extraversion under the spotlight to indicate that it may not be as fundamental to disinhibition as previously thought. Thus, future research should be aimed at studying how different measures of disinhibition might be differentially predicted by extraversion and how this is affected (if at all) by task characteristics such as provision and strength of reward contingencies.

Our finding of high and not low neuroticism as underlying disinhibition does not support Arnett and colleagues' (1997) alternative interpretation of the RMM; therefore H2 is rejected. In line with the RMM, Arnett et al. (1997) argue that the weak avoidance motivation of individuals low in neuroticism fails to alert and disengage the individual from his or her already conditioned approach response set. However, contrary to Arnett and colleagues' hypothesis, our study finds no evidence that low neuroticism is related to disinhibition. Therefore, we consider it unlikely that disinhibition manifests from a lack of avoidance motivation or a weakened avoidance drive; rather, our results suggest that disinhibition is underscored by *strong* avoidance tendencies. More specifically, we view disinhibition as a form of maladaptive active avoidance in which high neuroticism is a central driving factor. Our results provide at least some support for Patterson and Newman's (1993) interpretation of the RMM (H1), implicating high and not low neuroticism as a factor underlying disinhibition.

Robinson and Colleagues' (2008) Co-activation Model of Self-Regulation

Robinson and colleagues' (2008) co-activation framework (H3) also implicates high neuroticism (when combined with high approach drive) in poor self-regulation. Although H3 is rejected given the lack of findings for the concomitant effects of extraversion and neuroticism, we contend that the broad concept of competing approach-avoidance drive is still highly relevant to disinhibition. However, rather than identifying extraversion as the mechanism of approach tendencies, we draw on converging neurobiological evidence (e.g., Cohen et al., 2005; Depue & Collins, 1999; Schultz, 2006; Wise, 2004) to suggest that left hemispheric lateral preference is a better marker for DA (and corresponding reward drive) than self-reported extraversion and that high neuroticism is also required for the display of disinhibition. Tentatively, we can speculate that if left hemispheric lateral preference is a suitable substitute for the approach aspect of extraversion, then the broad theoretical propositions of Robinson and colleagues' (2008) framework is supported by our current findings. We believe that an important area of future research is closer investigation of approach tendencies associated with extraversion with those associated with left hemispheric lateral preference.

LIMITATIONS

The main limitations of our research studies are the size and composition of our samples. Using a small (Study 1: $N = 92$; Study 2: $N = 124$) and largely female (Study 1: 54% female; Study 2: 79% female) undergraduate student sample to test our main hypotheses restricts the generalizability of our findings. Power is a common issue in research enlisting hierarchical moderated multiple regression and is also a limitation for the current research. Nevertheless, consistent replication across multiple studies suggests that the reportable findings are reasonably robust.

CONCLUSION

Our studies make several important new contributions to the disinhibition, self-regulation, and personality literature: (a) Using two controlled studies, we directly compare seminal behavioral theories of disinhibition with more recent socio-cognitive and sociobiological theories to identify the utility of using hemispheric lateral preference rather than extraversion in the prediction of disinhibition; (b) we build theory by clarifying the role of neuroticism and extraversion in competing models of disinhibition; and (c) we highlight the important role of reward contingencies in shaping disinhibited behavior.

Notes

1. We use the term *prepotent response tendency* to describe a habitual, dominant, and overriding presence for one course of action over another.
2. Participants were shown a fixation screen for 1500 milliseconds, and then stimuli were presented for 1000 milliseconds (however, if the participant responded, then the presentation time stopped immediately). The inter-trial interval was 1000 milliseconds.
3. Although key features of the GNGT in the current research are in line with previous studies as noted, there are some features that are different. The key difference is our decision not to include nonreward or nonpunishment in the mixed-incentive block. For this block, all responses attracted either punishment (e.g., incorrect positive, incorrect negative) or reward (e.g., correct positive, correct negative).
4. Study 1 and Study 2 are part of two larger studies investigating self-regulation and personality. In addition to the measures administered in the current study, participants were also asked to complete a Stop Signal Task, Iowa Gambling Task, and Bisecting Lines Task. The order of presentation of each of these four tasks (including the GNGT) was randomized, resulting in participants being assigned to one of eight possible conditions. We include condition as a control variable in the current analysis to control for any potential effects of task presentation. The current study focuses on only the GNGT, and these are the first data from these larger studies to be published.
5. As one reviewer notes, omission errors may also be an index of approach tendency (or tendency to make a " 'go" response). While we elect to include omission errors in our model, we acknowledge that inclusion or exclusion of this variable does not make a substantive difference to the results of either Study 1 or Study 2.
6. We chose to use only ear preference because we think it is the best and least contaminated measure of lateral preference. In comparison with ear preference, handedness is more strongly influenced by cultural norms (e.g., Perelle & Ehrman, 1994), contaminated by other modalities (e.g., Bourassa, McManus, & Bryden, 1996), and dependent on attached limb movement (e.g., Gabbard & Hart, 1996).
7. Alpha for the HEEP scale was .91. Alphas for the Hand and Eye subscales were .91 and .90, respectively.
8. A regression analysis with the omission of the nonsignificant extraversion main effects and interaction terms revealed the same Neuroticism × Hemispheric Lateral Preference interaction, $\beta = .40$, $t(39) = 2.79$, $p = .008$, and pattern of simple slopes.
9. We plotted the simple slopes for the nonsignificant Extraversion × Hemispheric Lateral Preference interaction for Study 2. Similar to the results found in Study 1, both simple slopes were nonsignificant, indicating that extraversion did not appear to have any significant effect on commission errors regardless of hemispheric lateral preference.
10. A regression analysis with the omission of the nonsignificant extraversion main effects and interaction terms revealed the same Neuroticism × Hemispheric Lateral Preference interaction, $\beta = .40$, $t(55) = 3.38$, $p = .001$, and pattern of simple slopes.
11. Alpha for the HEEP scale was .89. Alphas for the Hand and Eye subscales were .91 and .89, respectively. We ran alternative regression analyses with the Hand subscale, Eye subscale, and scale total in replacement of ear preference in our model for both the approach-primed and avoidance-primed group. Results failed to reveal any significant effects, reinforcing our decision to focus on ear preference. It is also worth noting that we did not get the same pattern of results with the HEEP for Study 2 as we did in Study 1. Results of an interaction effect for the Ear subscale but not hand, eye, and overall lateral preferences are in accordance with Jackson's (2008) theory and results.
12. The contingency design of the GNGT for the approach-primed group in Study 2 was exploratory. Initially, we designed the feedback contingency to include more reward incentives to encourage approach behavior. However, the results showing the similarity of the average percentage of total commission errors (Study 1's 20% compared with Study 2's 21%) and omission errors (Study 1's 14% compared with Study 2's 13%) between the two studies indicate that our manipulation was not successful. Although this does not at all detract from our results, it does suggest that Study 2 should be thought of as a constructive replication rather than an entirely new and separate study.

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