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BRIEF REPORT

Cognitive Control in Generalized Anxiety Disorder: Relation of Inhibition Impairments to Worry and Anxiety Severity

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Abstract Cognitive models of generalized anxiety disorder (GAD) propose that cognitive control, broadly construed, and inhibition specifically, play a role in the maintenance of GAD symptoms. However, few studies have explicitly investigated inhibition, and in particular "cold" (non-emotional) inhibition, and its relation to worry and anxiety severity in GAD. Adults with GAD ($n=35$) and healthy controls ($n=21$) completed computerized Stroop and Go/NoGo tasks, two widely-used tests of inhibition. GAD status predicted significantly worse (slower and less accurate) performance on the Stroop but not the Go/NoGo task. Clinician-rated anxiety severity predicted slower and less accurate Stroop performance over and above the effect of GAD diagnosis but did not predict Go/NoGo performance. Trait worry did not incrementally predict performance on either task. These findings provide qualified support for theoretical models of inhibition impairments in GAD and suggest that inhibition could be a promising target for novel neurocognitive interventions.

Keywords Generalized anxiety disorder · Inhibition · Inhibitory control · Cognitive control · Worry · Anxiety

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Introduction

Current cognitive models of generalized anxiety disorder (GAD) and closely-related disorders (e.g., major depressive disorder; MDD) have converged on *cognitive control* as a potential mechanism of psychopathology (Hirsch and Mathews 2012; Joormann 2006; Joormann et al. 2009). Cognitive control (also labeled executive control or attentional control) is an umbrella term for a collection of related yet distinct processes that are collectively responsible for guiding attention and facilitating goal-directed activity (Miyake et al. 2000). According to one leading model (Miyake et al. 2000), cognitive control is comprised of three related but dissociable components: *working memory*, the ability to maintain and update information at the forefront of one's mind, *shifting* or *switching*, the ability to shift between task sets, and *inhibition*, the ability to override a prepotent or dominant response in favor of a less dominant but task-appropriate response.

Within the clinical literature, theoretical interest in cognitive control derives in part from the observation that GAD and several other emotional disorders are characterized by unwanted thought and impaired concentration. These cognitive symptoms are associated with considerable impairment. For example, uncontrollability (difficulty of dismissal) of worry is associated with increased disorder severity, comorbidity, and other negative outcomes, even after controlling for other symptoms of GAD (Hallion and Ruscio 2013). In MDD, which is also characterized by difficulty concentrating and uncontrollable thought in the form of rumination (Nolen-Hoeksema et al. 2008), cognitive control deficits have been linked to increased rumination severity (Joormann and Gotlib 2010) and poorer prognosis (Stange et al. 2016). However, little is known about the role that cognitive control might play in GAD,

including the specific facets of cognitive control that might be impaired, or how those impairments might relate to symptom severity.

To date, much of the research on cognitive control in the context of anxiety and depression has focused on inhibition of emotional ("hot") stimuli (e.g., De Lissnyder et al. 2010). Fewer studies have investigated the role of "cold" inhibition deficits; i.e., inhibition deficits that are present at baseline in anxious populations, in the absence of any emotional stimuli. This is a significant gap in the literature, particularly because a number of theoretical models of worry and anxiety propose a major role for "cold" inhibition impairments. For example, attentional control theory (Eysenck et al. 2007) proposes that anxiety impairs the efficiency but not effectiveness of cognitive control, reflected in intact accuracy but slower response times on cognitive control tasks. The effect of anxiety on cognitive control is proposed to be mediated at least in part by worry, which competes for attentional resources, and is proposed to be larger for threat-related compared to neutral stimuli. However, support for the model has also been found on "cold" cognitive control tasks (see Eysenck and Derakshan 2011 for a review).

In an alternative framework, Hirsch and Mathews (2012) propose that GAD is characterized by "cold" cognitive control impairments that interact with "hot" bottom-up influences (e.g., attentional biases toward threat) to allow threatening information into consciousness. This interaction is proposed to lead to the development of a worry episode and concomitant anxiety. Support for this theory comes from a series of experimental and self-report findings that link poorer "cold" cognitive control to anxiety symptoms, particularly in healthy or unselected populations. For example, individuals with high trait anxiety who report having good attentional control are able to disengage more rapidly from threat compared to similarly anxious individuals who report poor attentional control (Derryberry and Reed 2002; Peers and Lawrence 2009). Similarly, individuals with high trait worry show more impairment on cold cognitive control tasks when worrying than when thinking about a positive topic (Hayes et al. 2008; Leigh and Hirsch 2011). Additionally, performance on other cold cognitive control tasks is more impaired when individuals attempt to control worry as compared to neutral thought (Hallion et al. 2014), consistent with a role for cold cognitive control in the regulation of worry and anxiety. The Hirsch and Mathews model of GAD has a number of strengths, including its ability to account for experimental research linking various cognitive impairments to anxiety pathology (e.g., Eysenck et al. 2007). However, a limitation of the model is that it does not specify which facets of cognitive control are proposed to maintain GAD. Different facets of cognitive control (e.g., inhibition; working memory) are assessed and experimentally manipulated using different tasks and paradigms. Within the context of cognitive training, improvements are generally specific to the process being trained, with limited or no transfer to untrained processes (Owen et al. 2010). Thus, to identify cognitive mechanisms of GAD that could serve as potential intervention targets, it becomes important to specify which components of cognitive control are related most directly to GAD symptoms.

Inhibition has been identified across several studies as a potentially relevant cognitive control facet in GAD. Price and Mohlman (2007) frame their discussion of inhibition within the avoidance theory of worry and GAD (Borkovec et al. 2004; Borkovec and Inz 1990), which proposes that individuals with GAD engage in verbal-linguistic worry in order to inhibit the processing of more emotionally evocative imagery (Borkovec and Inz 1990). In this model, pathological worry relies on intact and perhaps even enhanced inhibition. This hypothesis is supported in part by Price and Mohlman's finding of a positive association between inhibition performance and worry severity in a group of older adults with GAD. However, GAD status was not independently associated with inhibition impairments or enhancements relative to an age-matched group of healthy controls in that study.

A competing hypothesis is that GAD is associated with inhibition impairments. Surprisingly little is known about the neuropsychology of GAD (Tempesta et al. 2013). However, several models of anxiety propose that worry is a dominant or automatic response for anxious individuals or high trait worriers; once activated, worry must be inhibited in order to facilitate task-appropriate cognition (Beck and Clark 1997; Mathews 1990; McNally 1995). An extension of these models is that GAD may be associated with inhibition impairments that contribute to uncontrollable worry and impaired concentration (e.g., Hallion et al. 2014). Consistent with this prediction, inhibition deficits have been observed in closely related disorders characterized by unwanted thought, including MDD (Joormann 2010; Joormann and Gotlib 2010) and obsessive–compulsive disorder (OCD; Enright and Beech 1993, although see Abramovitch et al. 2013). Experimental research has linked worry to impaired, rather than enhanced, inhibition performance (Eysenck et al. 2007; Hallion et al. 2014) and performance on closely related cognitive control tasks (e.g., working memory; Hayes et al. 2008).

These models and their corresponding findings largely converge on cognitive control and inhibition in particular as relevant to GAD, anxiety, and worry, but they differ in the role that inhibition is proposed to play. Further complicating the interpretation of these findings, the samples included in the existing studies (e.g., unselected undergraduates; older adults with GAD) may not be representative of the larger population of adults with GAD. Finally,

these studies typically do not distinguish between different subtypes of inhibition. Theoretical and empirical accounts have subdivided the relatively broad *inhibition* construct in several ways (Friedman and Miyake 2004; Nigg 2000). Although the precise delineations differ by account, these taxonomies generally distinguish between inhibition of prepotent motor responses and cognitive inhibition of interference from dominant but irrelevant information. For these reasons, existing research does not clearly establish whether GAD is associated with impairments or enhancements in inhibition, nor whether inhibition may be a cognitive mechanism of GAD pathology.

The present study assessed inhibition in a sample of treatment-seeking individuals with GAD and a comparison sample of healthy controls. Participants completed computerized variants of two widely-used and well-validated measures of inhibition: the Go/NoGo tasks (Riccio et al. 2001), which is primarily a motor inhibition task, and the Stroop task (Stroop 1935), which also features a cognitive inhibition component. In keeping with cognitive models of GAD that propose a role for cognitive control impairments in the disorder (e.g., Hirsch and Mathews 2012), we hypothesized that GAD would be associated with inhibition deficits, and in particular cognitive inhibition deficits. We further hypothesized that inhibition impairments would be positively associated with worry severity, anxiety severity, or both, in keeping with cognitive models of inhibition as a potential mechanism of GAD pathology.

Method

Participants

Descriptive data are presented in Table 1. Participants were adults with primary (most severe) or co-primary GAD ($n=35$; 77% female) who were recruited as part of either a neuroimaging or a treatment study and a comparison sample of healthy controls with no history of mental health treatment or mental disorders ($n=21$; 74% female). GAD participants were required to have at least moderate anxiety severity as evidenced by a score ≥18 on the Hamilton Anxiety Rating Scale (Shear et al. 2001) and at least moderate global clinical severity as evidenced by a score ≥4 on the Clinical Global Impression scale (Guy 1976).

Approximately two-thirds (62%) of GAD participants met criteria for another DSM-IV diagnosis as assessed by the MINI. The most common comorbidities were MDD (32%) and another anxiety disorder (38%), most often social anxiety disorder (SAD; 27%). To reduce the likelihood that observed deficits could be explained by depression while simultaneously maintaining ecological validity, participants with moderate or severe depression (Hamilton Depression Rating Scale score ≥18; Williams 1988) were excluded. This decision was considered important for interpretability because MDD has been independently associated with neuropsychological deficits, with some studies finding these impairments to be more pronounced at severe levels (Snyder 2013). Three potentially eligible participants were excluded for depression of moderate or greater severity. Psychotropic medication was permitted provided that dosage was stable for the previous 3 months. Two-thirds (66%) of GAD participants were taking one or more psychotropic medications, primarily for mood or anxiety symptoms. Other exclusion criteria included acute suicidality, recent (past 6 months) history of head trauma or loss of consciousness >5 min, recent substance use disorder, history of severe mental illness, pervasive developmental disorder, posttraumatic stress disorder, or obsessive–compulsive disorder, current psychotherapy, and contraindications for MRI (related to the larger study).

Measures

Clinical Measures

Diagnostic Status Diagnostic status for both clinical and healthy control participants was determined by a Master's-level diagnostician or licensed clinical psychologist via Mini International Neuropsychiatric Interview (MINI;

Table 1 Demographic and clinical characteristics

	GAD *M* (*SD*) ($n=35$)	Healthy control *M* (*SD*) ($n=21$)	*t*	*p*
Age, years	43.12 (14.05) Range 21–64	40.43 (16.90) Range 22–71	$t(53)=-0.64$	.526
Nonverbal IQ (normalized)	99.90 (14.65) Range 46.60–118.60	99.05 (18.02) Range 52.30–118.00	$t(53)=-0.19$	.849
Hamilton anxiety rating scale	22.06 (4.68) Range 18–35	0.52 (0.87) Range 0–3	$t(36.64)=-26.12$	<.001
Penn state worry questionnaire	66.76 (8.58) Range 45–80	35.20 (9.74) Range 24–59	$t(52)=-12.41$	<.001

GAD generalized anxiety disorder, *Nonverbal IQ* NeuroTrax matrix reasoning score

Lecrubier et al. 1997), a widely-used and well-validated semi-structured diagnostic interview (Sheehan et al. 1997). Prior to administering the MINI independently, the Master's-level diagnostician observed the MINI and provided co-ratings twice, and was then observed conducting the MINI by the licensed psychologist until diagnoses were reliable. In a separate study, GAD inter rater reliability for these two raters was good ($\kappa = 0.71$). Diagnostic severity was established via Clinical Severity Rating (CSR; Brown et al.2001). Overall clinical severity of moderate or greater was established via Clinical Global Impression (CGI; Guy 1976).

Anxiety Severity Anxiety severity was assessed via the Structured Interview Guide for the Hamilton Anxiety Rating Scale (SIGH-A; Shear et al. 2001), a widely-used 14-item clinician-administered measure of anxiety symptoms with strong interrater and test-retest reliability and convergent validity in clinical samples (Shear et al. 2001). Cronbach's $\alpha = 0.91$ in the present sample.

Trait Worry Trait worry was assessed via the Penn State Worry Questionnaire (PSWQ; Meyer et al. 1990), a 16-item self-report measure of worry severity in daily life that displays strong psychometric properties in clinical samples (Brown et al. 1992). Cronbach's $\alpha = 0.97$ in the present sample.

Depression Severity To minimize potential confounds due to depression, depression severity was assessed via the Structured Interview Guide for the Hamilton Depression scale (SIGH-D; Williams 1988), a widely-used and well-established 17-item clinician-administered measure of depression symptoms with generally strong psychometric properties in clinical samples (López-Pina et al. 2009). Cronbach's $\alpha = 0.88$ in the present sample.

Neuropsychological Measures

Participants completed the NeuroTrax Comprehensive Testing Suite during a single testing session (NeuroTrax; e.g., Abramovitch et al. 2015; Dwolatzky et al. 2003). The full battery included 10 tasks in total, including tests of motor skills, verbal memory, and processing speed; however, only the three tasks that pertained directly to the study hypotheses (two assessing inhibition and one assessing nonverbal IQ) were analyzed for the present study. In keeping with the validated NeuroTrax administration protocol, the tasks were administered in a standardized order. Participants completed the test battery in a private, sound-attenuated room using a Dell OptiPlex 755 computer with a 17-inch display. Total administration time was approximately 45 min. Results are normalized according to age- and education-specific data from cognitively healthy participants and presented as standardized scores ($M = 100$, SD 15).

Stroop Task Participants completed the Stroop task (e.g., Stroop 1935), a well-established, widely-used measure with several variations. In this variant, which was adapted for computer administration, participants were presented with color words (e.g., red) presented in an alternative letter color (e.g., green). Participants were instructed to ignore the meaning of the word and instead respond via button press to indicate the letter color of the presented word. Participants completed 45 trials total, including 25 color-only or word-only trials (not analyzed) and 15 interference trials as described above. Performance on interference trials is assessed in terms of accuracy and reaction time (RT) and computed as an age- and education-normed standardized score, independent from performance on color-only and word-only trials. In a validation study (Doniger 2011), NeuroTrax Stroop performance showed acceptable convergent validity with the classic paper administration of the Stroop Color-Word Test ($r = 0.52$, $p < .01$), which is comparable to or greater than the convergent validity typically observed between computerized and paper administrations of the Stroop (Kindt et al. 1996).

Go/NoGo Task Participants completed the Go/NoGo continuous performance task (e.g., Riccio et al. 2001), a widely-used and well-established computerized assessment of inhibition with good convergent validity ($r = 0.87$ with the Conners CPT-II; Schweiger et al. 2007) and alternate forms test–retest reliability (Doniger 2011). In this task, participants viewed colored squares (white, blue, green, or red) that were presented sequentially. Participants were instructed to respond via button press as quickly as possible to all squares except for the red square, which occurred less frequently (40% of trials). Participants were instructed to not press any button (i.e., withhold their dominant motor response) if the square was red. Participants completed 30 trials total, including 12 NoGo trials. Performance is assessed in terms of accuracy and RT.

Nonverbal IQ Estimate To evaluate whether observed differences in inhibition could be accounted for by general intelligence, participants completed a matrix reasoning task incorporated into the computerized battery (Doniger et al. 2008) that is similar to and shows good convergent validity with Raven's Progressive Matrices ($r = 0.60$; Raven et al. 2003). Participants were presented with a series of matrices with increasing difficulty. For each matrix, participants were instructed to select one of six shapes to complete the pattern.

Results

Preliminary Analyses

The data were screened for outliers. One participant (GAD) was excluded because his pattern of neuropsychological

performance was inconsistent with test psychometrics (Hegedish et al. 2012), indicating poor effort. Data were missing for less than 5% of observations. Little's Missing Completely at Random (MCAR; Little 1988) was nonsignificant (χ^2 (17) = 11.61, $p = .819$), consistent with data being missing completely at random. Missing data were therefore addressed using pairwise deletion.

The GAD and healthy control groups did not differ on age, gender, or nonverbal IQ (see Table 1). GAD participants who were excluded for moderate or more severe depression did not differ from included participants on age, gender, overall clinical severity, or trait worry (all $p \geq .219$). GAD participants with comorbid MDD did not differ in performance from those without comorbid MDD on any outcome measure (all $p \geq .286$). GAD participants taking psychotropic medication did not differ from GAD participants not taking medication on any measure except Go/NoGo accuracy, wherein participants taking medication were less accurate ($p = .041$). GAD participants in the treatment study did not differ from those in the neuroimaging study on any demographic or outcome variable except that clinician-rated anxiety severity was higher in treatment study participants ($p = .011$). Results did not differ when estimated nonverbal IQ (matrix reasoning task) or depression severity (SIGH-D) were statistically controlled, when the four participants with a co-primary disorder ($n = 2$ MDD; $n = 2$ SAD) were excluded, or when GAD participants from the neuroimaging study were excluded. We therefore present results from the full sample and do not consider these variables further.

Regression Results

We conducted a multiple regression analysis for each of the primary outcomes (see Table 2). Diagnostic status (GAD or healthy control) was included on the first step to evaluate potential group differences in inhibition. PSWQ and SIGH-A were included on the second step to assess potential incremental effects of trait worry and anxiety over and above diagnostic status.

GAD participants performed more slowly ($\beta = 1.03$, $p = .014$) and less accurately ($\beta = -0.93$, $p = .024$) than healthy controls on the Stroop task. Trait anxiety explained additional variance to Stroop performance for both accuracy ($\beta = -1.38$, $p = .001$) and reaction time ($\beta = -1.59$, $p < .001$). Trait worry did not significantly predict Stroop performance above GAD status ($\beta \leq 0.25$, $p \geq .374$). Diagnostic status did not significantly predict Go/NoGo accuracy ($\beta = -0.15$, $p = .940$) or reaction time ($\beta = -0.13$, $p = .466$), nor did trait worry ($\beta \leq 0.03$, $p \geq .357$) or anxiety severity ($\beta \leq -0.45$, $p \geq .326$) account for significant variance in either model. Standardized scores for performance on the Stroop and Go/NoGo are presented in Table 3.

Discussion

The present study investigated inhibition performance and its association to GAD status, worry, and anxiety severity. Relative to healthy controls, GAD status predicted moderate deficits on the Stroop task but did not predict performance on the Go/NoGo task. Trait anxiety but not trait worry predicted Stroop performance over and above diagnostic status, while neither trait anxiety nor trait worry incrementally predicted Go/NoGo performance.

Taken together, these findings provide qualified support for cognitive models of GAD that propose a role for impairments in cognitive control, broadly construed, and inhibition specifically. In keeping with the model proposed by Hirsch and Mathews (2012), we found that GAD status predicted impaired "cold" inhibition and, debatably, impaired cognitive inhibition specifically, with additional variance explained by trait anxiety, although not by trait worry. These findings also provide mixed support for attentional control theory (Eysenck et al. 2007), which proposes that anxiety impairs cognitive efficiency by requiring greater effort (reflected partly in slower response times) to maintain adequate overall performance (reflected in task accuracy), and that this increased effort is attributable in part to the presence of worry, which competes for attentional resources. In keeping with this model, we found that trait anxiety was associated with impaired inhibition as assessed by the Stroop task, over and above the effects of GAD diagnosis. However, we found evidence of impairments in both efficiency (reaction time) and effectiveness (accuracy), which does not follow directly from the attentional control theory model. We also did not find the expected effect of trait worry on inhibition performance as would be predicted by attentional control theory. However, this null finding does not rule out the possibility that state worry adversely influenced inhibition performance. Experimental research using worry inductions (e.g., Hallion et al. 2014; Hayes et al. 2008) or thought sampling would provide valuable insights into the precise relationships between anxiety, worry, and inhibition performance.

Notably, these findings do not align with those of Price and Mohlman (2007), who found intact inhibition in older adults with GAD and a positive association between inhibition performance and worry severity. The differences between these two studies may be due in part to differences in the populations (older adults versus our mixed-age sample). Aging is independently associated with various forms of neurocognitive decline (West 1996) and changes in mood and anxiety symptoms (Jorm 2000). Thus, it is possible that relationship between cognitive control and GAD symptoms may be different in older versus early and middle adulthood.

Table 2 Incremental validity of GAD status, trait worry, and trait anxiety for predicting inhibition performance

Model and predictor variables	*B*	*SE* (*B*)	β	*p*	R^2	ΔR^2
Stroop accuracy						
Model 1				.046	.08	.08
GAD status	−9.52	4.66	−0.28	.046		
Model 2				.004	.27	.19
GAD status	31.68	13.57	0.93	.024		
PSWQ score	0.09	0.26	0.10	.717		
SIGH-A score	−2.02	0.60	−1.38	.001		
Stroop reaction time						
Model 1				.071	.07	.07
GAD status	−11.11	6.03	−0.26	.071		
Model 2				.002	.30	.23
GAD status	44.49*	17.48	1.03	.014		
PSWQ score	0.29	0.32	0.25	.374		
SIGH-A score	−3.00	0.78	−1.59	.000		
Go/NoGo accuracy						
Model 1				.288	.02	.02
GAD status	−2.67	2.49	−0.15	.288		
Model 2				.515	.05	.03
GAD status	0.59	7.72	0.003	.940		
PSWQ score	0.14	0.15	0.028	.357		
SIGH-A score	−0.35	0.35	−0.45	.326		
Go/NoGo reaction time						
Model 1				.314	.02	.02
GAD status	−3.14	3.26	−0.13	.314		
Model 2				.546	.04	.02
GAD status	7.44	10.13	0.32	.466		
PSWQ score	−0.04	0.19	−0.06	.845		
SIGH-A score	−0.43	0.46	−0.42	.354		

GAD generalized anxiety disorder, *PSWQ* penn state worry questionnaire, *SIGH-A* structured interview for the Hamilton anxiety scale

Table 3 Inhibition performance

	GAD *M* (*SD*)	Healthy control *M* (*SD*)	*t*	*p*	*d*
Stroop performance					
Stroop accuracy	95.68 (20.39)	104.59 (3.43)	$t(33.63) = 2.42$	.021	0.61
Stroop reaction time	93.62 (25.50)	104.00 (9.11)	$t(40.23) = 2.08$	.044	−0.54
Go/NoGo performance					
Go/NoGo accuracy	102.30 (11.62)	104.36 (10.70)	$t(53) = 0.75$	.460	0.18
Go/NoGo reaction time	101.62 (12.33)	104.84 (9.36)	$t(53) = 1.02$	.311	0.29

GAD generalized anxiety disorder. Results are presented as standardized scores (M = 100) derived from the Stroop and Go/NoGo subtests of the NeuroTrax comprehensive testing suite

The present findings raise the question of why performance was impaired and related to symptom severity for one inhibition task (Stroop) but not the other (Go/NoGo). These findings may be attributable in part to subtle differences in the demands of the tasks and their underlying neural circuitry. Whereas the Go/NoGo Task only requires participants to inhibit motor responses, the Stroop task also includes an element of cognitive inhibition (i.e., participants must inhibit their dominant tendency to read the word and instead attend to the letter color) that must occur before the motor response is executed. Meta-analytic findings from neuroimaging studies (Nee et al. 2007) support

the assertion that the tasks are overlapping but distinct: Go/NoGo performance is associated primarily with activation in right dorsolateral prefrontal cortex (dlPFC), which is implicated in response selection, and to a lesser extent with activation in left dlPFC, anterior cingulate cortex (ACC), and right posterior parietal cortex (PPC), while Stroop activation is primarily left-lateralized, focused on the left dlPFC, insula, and medial prefrontal cortex, including the ACC, which are heavily implicated in selective attention (Nee et al. 2007). Theoretical models and latent variable studies have begun to confirm the existence of different subfacets of inhibition, including a cognitive inhibition subfacet (Friedman and Miyake 2004; Nigg 2000). Although the Stroop cannot be considered a pure measure of cognitive inhibition due to its clear motor demands, the dissociation between Stroop and Go/NoGo performance suggests that cognitive inhibition specifically may be a fruitful target for future mechanism and treatment development research.

The present findings should be interpreted in light of several limitations. First, preliminary analyses revealed that GAD participants taking psychiatric medication performed more poorly on one facet of the Go/NoGo task compared to unmedicated GAD participants. However, medicated and unmedicated GAD participants did not differ on Stroop performance. Therefore, we are reasonably confident that the primary findings are not driven or influenced by any adverse (or positive) effects of medication on task performance. Second, the tasks were administered in a fixed order, raising the possibility that fatigue or other order effects could have contributed to the results. However, this administration procedure is in keeping with standard, validated NeuroTrax procedures, and the validation studies suggest that this approach does not compromise the validity of tests administered later versus earlier in the battery (Doniger 2011). Third, the present study did not assess working memory, shifting, or other forms of cognitive control that may also play a role in GAD, worry, and anxiety. Future research should aim to use a wider battery of cognitive control tasks, including more reliable measures of cognitive inhibition such as the antisaccade task (e.g., Roberts et al. 1994), to compare the specific contribution of different facets of cognitive control to the maintenance of GAD. Nevertheless, the finding of intact performance on the Go/NoGo task helps to rule out the possibility that our results are due to nonspecific factors such as general slowing or poorer sustained attention in the GAD group .

An additional factor that should be considered is the decision to assess inhibition outside the context of a worry or anxiety induction. The Hirsch and Mathews (2012) model of GAD proposes that cognitive control impairments interact with "bottom-up," affect-related processes to produce GAD symptoms. Although our study provides support for the first part of the model (i.e., cognitive control impairments), we are unable to evaluate the second part (interaction with affective processes). Additionally, there is some evidence that inhibition of emotional material is impaired in GAD (Mogg and Bradley 2005) and MDD (Joormann and Gotlib 2010). However, it was not clear whether inhibition deficits emerge only in the context of emotional material, or whether they are present at baseline. The present findings provide some support for the presence of baseline, non-emotional deficits. Future research would benefit from assessing inhibition in both emotional and non-emotional contexts, using both emotional and non-emotional stimuli, to further clarify the impairments that are most relevant to GAD symptoms.

Finally, the models described in this paper propose a causal role for cognitive control deficits in the maintenance of GAD. The cross-sectional nature of the present study precludes a direct evaluation of this causal hypothesis. Although a substantial number of studies have experimentally manipulated anxiety and observed its effect on cognitive functioning (e.g., Eysenck et al. 2007), far less research has tested the alternate causal pathway (i.e., manipulating cognitive control and observing its effect on anxiety). Subsequent research might aim to either enhance or disrupt inhibition, perhaps through cognitive training or via neurostimulation such as repetitive transcranial magnetic stimulation (rTMS). Such studies would not only inform our mechanistic understanding of cognitive control as it relates to GAD, but could easily form the basis of novel interventions that directly target the cognitive mechanisms that maintain GAD.

Taken together, the present findings suggest that GAD is characterized by impairments in inhibition, and potentially cognitive inhibition specifically. Clinician-rated anxiety severity was further associated with inhibition impairments even after diagnostic status was statistically controlled, suggesting a specific relationship between anxiety and inhibition that is independent of a GAD diagnosis. Subsequent research would be valuable to establish the extent to which inhibition can be improved (e.g., via cognitive training), and whether such interventions could form the basis of a novel, efficacious approach to treating GAD and anxiety.

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Compliance with Ethical Standards

Conflict of Interest Lauren S. Hallion declares no conflict of interest. David F. Tolin declares no conflict of interest. John Goethe declares no conflict of interest. Gretchen J. Diefenbach receives material support from Neuronetics for research.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964

Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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