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Restlessness in Generalized Anxiety Disorder: Using Actigraphy to Measure Physiological Reactions to Threat

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Generalized anxiety disorder (GAD) is characterized by excessive, uncontrollable worry accompanied by symptoms of physiological arousal. Although individuals with GAD report greater subjective arousal than healthy individuals, they show equivalent or even attenuated physiological reactions to threat. This may result from using physiological measures better suited to fear than anxiety. To test this possibility, 102 adults with and without GAD were assessed for restlessness, a core physiological symptom of GAD. They were exposed to an *in vivo* threat task designed to elicit anxiety in the laboratory. Throughout the task, restlessness was measured physiologically with actigraphy sensors on both ankles and both wrists, and subjectively with self-report ratings. The GAD group reported higher subjective restlessness than the no-GAD group, and in the subset of cases who had restlessness as a clinically significant symptom, actigraphy scores were reliably elevated as well. However, although actigraphy scores increased with proximity to the threat, the increases did not differ by group. These findings provide initial validation for actigraphy as a novel measure of motor restlessness in GAD. In addition, they underscore the value of measuring restlessness using multiple assessment methods. These methods suggest that, in GAD, restlessness reflects a chronic state of arousal rather than a heightened physiological reaction to threat.

Keywords: generalized anxiety disorder; actigraphy; restlessness; psychomotor; threat

GENERALIZED ANXIETY DISORDER (GAD) affects about 3.7% of the population worldwide (Ruscio et al., 2017) and is one of the most common anxiety disorders (Bandelow & Michaelis, 2015). Despite this, GAD remains the least successfully treated anxiety disorder (Newman et al., 2013). A better understanding of the clinical features of GAD is necessary to improve treatment precision and efficacy.

GAD symptoms are typically assessed by self-report, but self-report has yielded perplexing findings. Although diagnosed individuals report hyperarousal, physiological measures tell a different story (Fisher et al., 2010). Individuals with GAD report higher heart rate and greater sweating than nonanxious controls, yet show mixed evidence of heightened autonomic arousal at rest (Chalmers et al., 2014; Hoehn-Saric & McLeod, 2000) and show equivalent or even *less* change on autonomic measures in reaction to laboratory stressors (Lang et al., 2007; Marin et al., 2017). This reactivity paradox suggests a discrepancy between self-reported (subjective) and physiologically assessed (objective) responding in GAD.

There are, however, several plausible alternative explanations for these paradoxical findings. One possibility is that greater sensitivity to, or misinterpretation of, arousal in individuals with GAD may amplify self-reports without associated physiological changes. A different possibility, though, is that

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physiological changes do occur but are missed by standard measures. Prior studies have typically assessed physiological reactivity using measures of autonomic nervous system functioning, such as changes in heart rate and vagal tone (e.g., Friedman, 2007), respiration (e.g., Van Diest et al., 2006; Wilhelm et al., 2001), and skin conductance (e.g., Bradley et al., 2001; Marin et al., 2017). However, while autonomic measures may be well suited for disorders in which fear and alterations in the fear response play a central role (Grillon et al., 2009), they may be a poorer match for disorders marked by worry and "anxious expectation" (Andrews et al., 2010). Given the overall inhibition of sympathetic nervous system activity (Hoehn-Saric et al., 1989) and chronic suppression of the parasympathetic system (Lyonfields et al., 1995) in GAD, it is perhaps not surprising that blunted autonomic responding has been observed in this disorder. It is possible that the reactivity paradox, rather than reflecting a true divergence in responding, reflects a failure of autonomic measures to capture changes in arousal in GAD.

A measure of central nervous system arousal may provide a more powerful test of reactivity in GAD than measures of autonomic arousal. Supporting this idea, individuals with chronic anxiety have been shown to exhibit increased muscle tension—a nonautonomic measure of hyperalertness—rather than sympathetic hyperarousal (Hoehn-Saric & McLeod, 2000). Of particular relevance to GAD, which is defined centrally by worry, anxious individuals show greater corticospinal motor responses during worry periods than during neutral cognitive tasks (Oathes, Bruce, & Nitschke, 2008), suggesting motor activation and preparedness as a relevant physiological correlate of worry. A measure of motor activation would specifically target the physiological concomitants of worry that may be present during anticipation of and exposure to threat. Notably, motor restlessness is a key symptom of GAD (American Psychiatric Association, 2013). It is one of the few physiological symptoms that were retained when symptoms of autonomic arousal were removed from the GAD diagnostic criteria in the fourth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (*DSM-IV*; American Psychiatric Association, 1994), in recognition of the specific association of anticipatory anxiety with motor tension and vigilance (Brown et al., 1995). At the same time, restlessness is found in other mental disorders as well, hinting that a measure of motor restlessness could have applications beyond GAD. Such a measure would be especially timely given growing awareness of the prevalence and importance of motor disturbances in different forms of psychopathology, as reflected in the recent addition of a sensorimotor domain to the National Institute of Mental Health's Research Domain Criteria (Walther et al., 2019).

Actigraphy is a prime candidate for a measure of motor restlessness. It is a measure of acceleration and ambulatory movement in the forward, lateral, and vertical directions (X, Y, and Z axis in the three-dimensional space) intended to capture continuous, general movement (Grap et al., 2011). Actigraphy has gained the most traction in the sleep literature as a measure of restless wakening and circadian rhythm disruption, and in the literature on attention-deficit/hyperactivity disorder (ADHD) as a measure of hyperactivity (De Crescenzo et al., 2016). Although actigraphy has seldom been used to study movement in emotional disorders, there is preliminary evidence for its utility as a measure of physiological experiences and locomotor activity in anxious individuals. Clark et al. (1990) found that participants with panic disorder and low phobic avoidance exhibited greater daily motor activity, measured with ambulatory sensors, than participants with high phobic avoidance and healthy controls. Notably, movement intensity data were collapsed across one sleep and awake period and may not have been sensitive to the subtle movements characteristic of restlessness. However, when a similar study was conducted with continuous activity monitoring, individuals with panic disorder low in phobic avoidance still displayed greater movement than individuals without panic (Sakamoto et al., 2008). To our knowledge, no study has assessed motor restlessness in the laboratory, where movement confounds seen in daily life can be minimized and restlessness can be isolated reliably from general activity. Furthermore, no study has investigated motor restlessness in GAD. As the only anxiety disorder for which restlessness is a symptom, GAD is a natural focus for this research.

The aim of the present study was to evaluate actigraphy as a novel measure of motor restlessness in GAD, and to use actigraphy to probe the reactivity paradox in this disorder. Given our particular interest in motor restlessness, our operationalization of restlessness focused on its physical manifestation rather than on internal states of agitation or unease. Participants completed an *in vivo* threat task in which they anticipated, performed, and recovered from a speech and mental arithmetic task delivered in front of a committee of judges. As anxiety is concerned with preparation for possible, upcoming threats (Craske et al., 2009), we judged a task involving an

approaching, personally relevant stressor to be more likely to evoke threat responding in GAD than a fear task involving immediate, sensory stimuli such as electric shock or aversive images (Dugas et al., 1998). We hypothesized that both self-reported restlessness and actigraphy scores would increase with rising threat and decrease with declining threat across phases of the task. We also hypothesized that self-reported restlessness and actigraphy scores would be higher in persons with GAD than in those without GAD, given that restlessness is a symptom of the disorder (Criterion C1). Finally, we hypothesized that increases in restlessness in response to the threat would be larger among persons with GAD than those without GAD. Notably, although restlessness is a symptom of GAD, it is not found in all cases, as only three of the six Criterion C symptoms are required for a diagnosis. To capture the heterogeneity of GAD with respect to experiences of restlessness, we supplemented the measure of GAD diagnostic status with a measure of clinician-rated restlessness severity.

Method

PARTICIPANTS

One hundred and two community-dwelling adults with GAD (n = 71) or no lifetime psychopathology (n = 31) were recruited from the Philadelphia area through electronic and print media. The two groups did not differ in age, sex, or race-ethnicity (Table 1). Exclusion criteria for the no-GAD group were current or lifetime psychopathology or a Penn State Worry Questionnaire (Meyer et al., 1990) score of 56 or higher. Exclusion criteria for the GAD group were current substance-related disorder (other than tobacco), active psychosis, and active suicidal intent. Other current comorbid disorders were permitted; the most common were major depressive disorder (43.1%), social anxiety disorder (40.2%), persistent depressive disorder (22.5%), and posttraumatic stress disorder (17.6%). Notably, of the few participants who volunteered symptoms of ADHD, none met the *DSM-5* criteria for ADHD on further assessment. To reduce the possibility that restlessness was influenced by the effects of medication or drugs, we applied *DSM-5* Criterion E for GAD, which prohibits the diagnosis when the disturbance is attributable to the physiological effects of a substance, and instructed all participants to refrain from using caffeine or tobacco within 1.5 hours of their experimental session. Seven participants reported taking either an anxiolytic or stimulant medication, as prescribed, prior to the experimental session; the analyses were performed with and without these participants and the results did not change, so we report results for the full sample.

MEASURES

Clinical Assessment

Psychopathology was assessed using the *Anxiety and Related Disorders Interview Schedule for DSM-5–Lifetime Version* (ADIS-5; Brown & Barlow, 2014a). Interviewers were trained to high interrater agreement with each other and the supervising licensed clinical psychologist. Interrater reliability for GAD diagnoses (K = 1.00) and clinical severity ratings (ICC = 0.97) was excellent among the laboratory interviewers. In addition to

Table 1
Participant Characteristics for the Generalized Anxiety Disorder (GAD) Group, the No-GAD Group, and the Total Sample

	GAD (n = 71)	No-GAD (n = 31)	Total sample (N = 102)
Demographic characteristics			
Age	32.28 (10.88)	31.65 (13.31)	32.09 (11.61)
Sex (% female)	62.0	58.1	60.8
Race			
Caucasian	63.4	54.8	60.8
African-American	25.4	22.6	24.5
Asian	1.4	16.1	5.9
Other	7.2	6.5	6.9
Education			
High school or lower	16.9	6.5	13.7
Some college	26.8	25.8	26.5
College degree or higher	56.3	67.7	59.8
Clinical characteristic			
GAD severity	5.35 (0.78)	0.73 (0.73)	3.94 (2.08)

Note. Generalized anxiety disorder (GAD) severity refers to the clinical severity rating (0-8) for GAD from the *Anxiety and Related Disorders Interview Schedule for DSM-5*. *M (SD)* are presented for dimensional variables; all other values represent percentages.

assigning GAD diagnoses, we extracted responses to the question from the ADIS-5 GAD module assessing the extent to which participants felt "restless, keyed up or on edge" in the past 6 months. Interviewers rated the severity of this symptom on a Likert-type scale (0 *absent* – 8 *very severely disturbing*; a rating ≥ 4 denotes a clinically significant severity level; Brown & Barlow, 2014b).

Self-Reported Restlessness Ratings

During the threat task, participants were prompted by the question, "*How is your body feeling now?*" to rate their current physical state on 0–100 scales. Two items were rated at the end of the baseline phase, after being informed of the performance task, immediately before the performance, and shortly after the performance. One of these items was anchored with 0 (*settled*) and 100 (*restless*); the other item was anchored with 0 (*loose*) and 100 (*keyed up or on edge*). Both were written for the present study to represent the restlessness symptom of GAD. The two items were highly correlated at each phase of the task (r = .69–.86) and, when combined, had a high Cronbach's alpha at each phase (α = .81–.93). Consequently, they were standardized and averaged to create a composite self-reported restlessness score for each phase.

Actigraphy

To capture movement in any limb, actigraphy sensors were worn on both wrists and ankles—a total of four devices—during the entire experimental procedure. We used ActiGraph wGT3X-BT devices (Pensacola, Florida) for which good reliability has been demonstrated during sleep (e.g., Cellini et al., 2013) and physical activity (e.g., Trost et al., 1998). The devices were originally calibrated by ActiGraph and recalibrated before each participant run via device initialization in ActiLife v. 6.9.5 software. Data were recorded continuously from each device at a sampling rate of 30 Hz (frequency cutoff 0.1 Hz) in 1-second epochs. After the experiment, raw actigraphy values were extracted and vector magnitude ($\sqrt{X^2 + Y^2 + Z^2}$) was calculated offline using ActiLife for each 1-sec epoch. Data correlated highly across the four limbs (α = .75–.87 per phase) and therefore were averaged across limbs to yield one actigraphy value per second. Average actigraphy scores were then calculated for each phase and for the total task.

PROCEDURE

The protocol was approved by the University of Pennsylvania's Institutional Review Board. Participants made two visits to the laboratory. During the first visit, they gave informed consent and were administered the ADIS-5. Eligible participants returned to complete the Trier Social Stress Test (TSST; Kirschbaum et al., 1993), a widely used task involving a potent, personally relevant threat. The TSST reliably evokes a robust, acute stress response in healthy individuals and in a wide range of clinical populations (Allen et al., 2017; Dickerson & Kemeny, 2004). We employed a version of the task incorporating elements that are known to heighten reactivity, including multiple forms of evaluation (the speech was both videotaped and performed in front of an audience) and elements of uncontrollability (time constraints on preparation; unresponsive audience; speech followed by a surprise mental arithmetic task; see Dickerson & Kemeny, 2004).

The task began with a 5-minute baseline during which participants were asked to focus their attention on their breathing (Baseline). Next, participants were informed that they would be giving a 5-minute videotaped speech in front of a panel of judges who would evaluate their performance. After meeting the judges, participants completed another 5-minute focused breathing period (Early Anticipation). Participants were then told their speech topic and given 3 minutes to prepare the speech, during which a timer prominently counted down the time (Immediate Anticipation). Speech topics were personalized based on participants' earlier responses regarding their future educational or occupational goals. Participants gave their videotaped speech, followed by a surprise mental arithmetic task, before a mixed-sex panel of two judges who were instructed to respond only minimally to the participant (Performance). Immediately after the performance, the judges left—ostensibly to rate the performance and prepare feedback—and participants completed another 5-minute focused breathing period (Recovery). During the last phase, all participants received noncontingent positive feedback from the judges consisting of social praise tailored to their performance, denoting a clear end to the threat, then completed a final focused breathing period (Feedback). Importantly, experimenters and judges were blind to diagnostic group.

STATISTICAL ANALYSES

Separate mixed-model ANOVAs were performed for self-reported restlessness ratings and average actigraphy scores. Each ANOVA included group (GAD, no-GAD) as a between-subjects factor and task phase (baseline, early anticipation, immediate anticipation, performance, recovery, and feedback) as a within-subjects factor. A significant within-subjects effect was followed up with planned

contrasts comparing the performance phase with the phases immediately before and after it, when the largest changes in restlessness were expected. As restlessness is the clinical phenomenon of interest and is not required for a GAD diagnosis, we repeated the analyses using groups defined by the presence (interviewer rating ≥ 4; high restlessness) or absence (interviewer rating < 4; low restlessness) of clinically significant restlessness, irrespective of diagnostic status.

Results

MANIPULATION CHECK

To check whether participants perceived the task to be threatening, we examined their self-reported nervousness and anxiety during the task, rated on a 1 (*not at all*) to 7 (*extremely*) scale. In the total sample, average ratings immediately before the speech fell between *moderately* and *quite a bit* on this scale ($M = 4.51$, $SD = 1.56$) and were substantially higher than at baseline ($M = 3.02$, $SD = 1.56$) or recovery ($M = 3.38$, $SD = 1.78$), $F(2, 192) = 39.70$, $p < .001$. As a further check, we asked participants, during a debriefing interview at the end of the study, to rate how stressful they found the task. Using the same 1–7 scale, participants indicated that they found the task *moderately* to *quite a bit* stressful on average ($M = 4.87$, $SD = 2.06$).

SELF-REPORTED RESTLESSNESS RATINGS

Mean Differences Between Groups Defined by GAD Diagnosis

Analysis of *in vivo* restlessness ratings revealed a significant main effect of group, $F(1, 98) = 23.41$, $p < .001$, $\eta_p^2 = .19$. Mean levels of self-reported restlessness, shown here on the original 0–100 scale for ease of interpretation, were moderate to high in the GAD group (42.34 at baseline, 62.39 at early anticipation, 64.54 at performance, and 58.66 at recovery) and low to moderate in the no-GAD group (22.82 at baseline, 42.98 at early anticipation, 42.40 at performance, and 36.60 at recovery). By contrast, the main effect of time was not significant: Participants' reports of restlessness were fairly consistent across the task, $F(3, 294) = 0.01$, $p = .999$, $\eta_p^2 < .01$. Moreover, there was no interaction of group by time, indicating that individuals with GAD were no more reactive to the threat than individuals without GAD, $F(3, 294) = 0.03$ $p = .994$, $\eta_p^2 < .01$.

Mean Differences Between Groups Defined by Clinical Restlessness

Restlessness severity, assessed by the ADIS, varied widely among individuals with GAD (Range: 0–8, $M = 5.45$, $SD = 1.55$) and also showed some variation among controls (Range: 0–4, $M = 1.39$, $SD = 1.26$), although the average rating was much higher for the GAD than the no-GAD group, $t(97) = 12.35$, $p < .001$, $d = 2.88$. In the total sample, 67 individuals met our operational definition of high restlessness and 32 individuals fell below this threshold (3 participants were eligible for the study based on GAD status, but were missing restlessness ratings and were therefore excluded from subsequent analyses). Notably, all but one participant in the high restlessness group also had GAD, suggesting that this group essentially consisted of GAD cases with clinically significant restlessness. In the low restlessness group, only five individuals had GAD. The high and low restlessness groups did not differ significantly on any of the demographic characteristics listed in Table 1.

Consistent with the analyses for GAD, individuals in the high restlessness group rated themselves as significantly more restless during the task than individuals in the low restlessness group, $F(1, 95) = 17.59$, $p < .001$, $\eta_p^2 = .16$. Mean *in vivo* restlessness levels in the high (42.14 to 64.22) and low (24.95 to 46.31) restlessness groups were nearly identical in magnitude and pattern across phases to the mean levels reported by the GAD and no-GAD groups. Once again, there was no main effect of time: Restlessness levels did not differ reliably across the phases of the task, $F(3, 285) = 0.04$, $p = .989$, $\eta_p^2 < .01$. The interaction of group by phase was also not significant, indicating that the high and low restlessness groups did not differ in their reactivity to the threat, $F(3, 285) = 0.42$, $p = .736$, $\eta_p^2 < .01$.

ACTIGRAPHY

Mean Differences Between Groups Defined by GAD Diagnosis

Although actigraphy values for the GAD group fell above those for the no-GAD group at each phase, the main effect of group was not significant, $F(1, 96) = 1.91$, $p = .170$, $\eta_p^2 = .02$ (Figure 1). By contrast, there was a significant main effect of time, $F(5, 480) = 17.59$, $p < .001$, $\eta_p^2 = .16$, with actigraphy values higher during the performance than during the phase before (immediate anticipation; $t = 7.20$, $p < .001$) or after (recovery; $t = 4.19$, $p < .001$). The interaction of group by time was not significant, $F(5, 480) = 0.64$, $p = .672$, $\eta_p^2 < .01$. Group differences were small at most phases (Cohen's $d = .28$–$.38$; overall task $d = .31$), with the largest differences observed during recovery ($d = .31$) and feedback ($d = .38$). Given the novelty of the actigraphy measure, we examined differences in variance as well as differences in means across groups. Levene's test was nonsignificant at all phases ($.071 < p < .220$), indicating that the variance of the actigraphy variable was equal across groups.

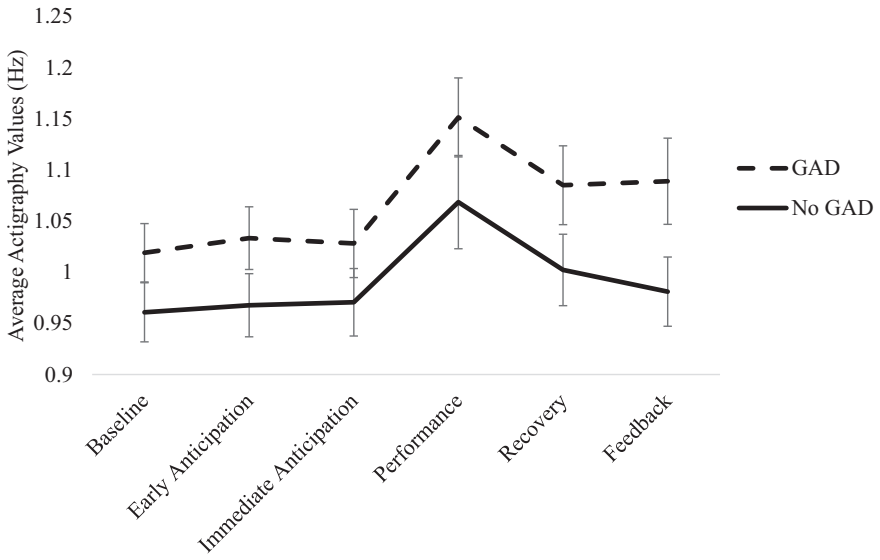

FIGURE 1 GAD = generalized anxiety disorder. Mean actigraphy values across experimental phases by group. Error bars represent standard errors.

Mean Differences Between Groups Defined by Clinical Restlessness

In contrast to the results of the GAD analyses, the mixed-model ANOVA for the relationship between restlessness group and actigraphy revealed a significant main effect of group, $F(1, 93) = 4.43$, $p = .038$, $\eta_p^2 = .05$. Participants who reported higher restlessness on the ADIS had persistently elevated actigraphy scores throughout the task (Figure 2). As in the earlier analyses, there was a main effect of time, $F(5, 465) = 16.37$, $p < .001$, $\eta_p^2 = .15$, but no interaction of group by time: The high restlessness group had consistently higher actigraphy values across the task than the low restlessness group, $F(5, 465) = 0.72$, $p = .612$, $\eta_p^2 < .01$. The group differences in actigraphy values were moderate in magnitude at each phase ($d = .42$–$.49$) and for the task overall ($d = .48$). These results provide support for actigraphy as a measure of motor restlessness and suggest that, even for individuals whose clinical presentation prominently features restlessness, there is no evidence for heightened threat reactivity on this physiological measure.

Variability Differences

The use of mean-level data in determining group differences in actigraphy may have obscured differences in variability that better differentiate

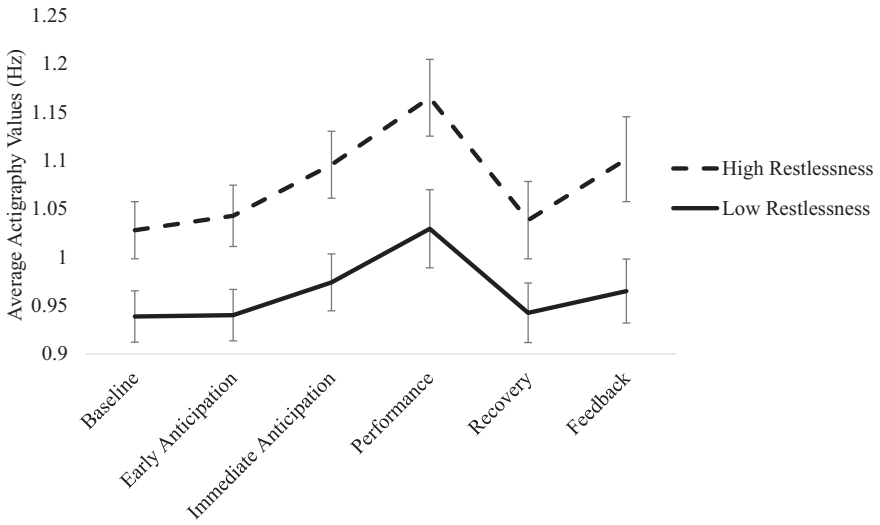

FIGURE 2 Mean actigraphy values across experimental phases by level of restlessness reported on the *Anxiety and Related Disorders Interview Schedule for DSM-5*. Error bars represent standard errors.

anxious from nonanxious individuals. Given limited understanding of how restlessness unfolds across time during threat responding in GAD, the mean square successive difference (MSSD; Jahng et al., 2008) was used to explore the pattern of movement in individuals with GAD relative to individuals without GAD. The MSSD, a measure of variability in a times series, is the average of the squared differences between consecutive observations. Examining the mean alone may be misleading if there are differences in temporal fluctuations across time. For example, stable actigraphy values second-to-second would indicate a very different pattern of restlessness than responding characterized by significant changes between observations.

We focused on phases of the task during which group differences in reactivity were theorized to be especially likely: early anticipation (when participants first learned they would be giving a speech), immediate anticipation (directly before the speech), and recovery (directly after the speech). The anticipation phases were selected to capture restlessness experienced in preparation for a threat, given the centrality of anticipatory anxiety and apprehensive expectation in GAD. The recovery phase was selected to explore the possibility that anxious individuals experience prolonged arousal, while healthy individuals recover quickly, after a threat has been removed. Independent samples t tests revealed no difference in the pattern of movement between the GAD and no-GAD groups during any of the three target phases, all $p > .668$, corroborating the prior mean-level analyses.

Relationship between self-reported restlessness and actigraphy

Differences in the pattern of results for self-reported and actigraphy-assessed restlessness during the task raised the question of how closely these measures were related. To examine this directly, we correlated *in vivo* restlessness ratings with average actigraphy scores from corresponding phases of the task. All four analyses revealed very small positive correlations that were not statistically significant, $r = .02–.07$, all $p > .527$.

Discussion

The present study was the first to use actigraphy, a measure of acceleration and motor activity, to study restlessness in GAD. Actigraphy scores were elevated in individuals with high clinician-rated restlessness and were sensitive to changes in threat level across a task involving exposure to an impending, personally relevant threat. However, even using a physiological measure well suited to the symptoms of GAD, individuals with GAD were not more reactive to the threat than those without the disorder, thereby replicating the reactivity paradox. Instead, restlessness was chronically elevated in persons who reported restlessness as a significant clinical symptom, with no exaggerated boost in restlessness when anticipating or experiencing threat.

Actigraphy as a promising measure of motor restlessness

Although restlessness is a core feature of GAD, no study has tested a physiological index of this behavior. Our findings provide initial evidence for actigraphy as a valid measure of motor restlessness in this disorder. Restlessness reported in a clinician-administered interview was associated with actigraphy values recorded during the threat task. Additionally, for participants who reported restlessness as a symptom, actigraphy values were higher at baseline, in anticipation of, during, and in recovery from the threat relative to those who did not endorse restlessness. These findings extend prior research that has shown actigraphy to be sensitive to motor activity disturbances in ADHD (De Crescenzo et al., 2016) and sleep disorders (Sadeh, 2011). Collectively, these studies point to actigraphy as a promising physiological measure of motor abnormalities in psychopathology. However, as motor disturbances may differ in magnitude, form, or eliciting conditions in different disorders, research is needed to determine whether these findings generalize to other disorders.

We found that differences in actigraphy scores emerged between groups defined by clinician-rated restlessness rather than by GAD diagnosis. This implies that actigraphy is a marker of restlessness specifically, rather than a marker of GAD more generally. The heterogeneous nature of the GAD diagnosis, which requires three of the six Criterion C symptoms (of which restlessness is only one), means that the diagnosis pools together individuals who experience restlessness with those who do not. Similar concerns about phenotypic heterogeneity in other disorders, where constituent symptoms have been shown to differ in their etiology and response to treatment, have led some to suggest that investigation of syndromes be supplemented, or even replaced, with investigation of more homogenous symptom dimensions (e.g., Hyman, 2007; Skodol et al., 2002; Watson, 2009). Studying restlessness in its own right, perhaps in conjunction with related motor phenomena traditionally associated with other disorders (e.g., psychomotor agitation in major depression), may accelerate advances in understanding this often-overlooked symptom.

NEW INSIGHTS INTO THE REACTIVITY PARADOX

Although tempered by the novel use of actigraphy to measure restlessness and by the fact that restlessness is not reported by all individuals with GAD, our findings are highly consistent with patterns of arousal observed during laboratory stressors in other anxiety disorders (e.g., Garfinkel et al., 2015). Those patterns reveal marked divergence between subjective and objective measures of arousal, which is usually interpreted as evidence of low interoceptive accuracy in anxious individuals. Importantly, divergence between self-report and physiological assessment is not unique to anxiety; it is a well-established finding in the emotion literature. In studies investigating the components of an emotional response, associations between self-report and physiological components are routinely found to be weak (e.g., Mauss et al., 2005) or nonexistent (e.g., Mauss et al., 2004). The lack of association has led some theorists to question whether expecting these systems to be coherent is unfounded and, in fact, whether the systems are better understood as independent (Barrett, 2006; Lang, 1988). The near-zero correlations observed here between the subjective experience of restlessness and its overt manifestations add further fuel to these questions, and suggest that efforts to better understand the divergence should focus on emotion in general rather than on anxiety (or GAD) specifically.

Regardless of the reasons for the divergence, the discrepant findings caution against an exclusive clinical reliance on self-reports for assessing arousal symptoms in GAD, perhaps especially when assessing an inherently physiological symptom like restlessness. Self-report measures provide critical information about perceived experience, yet self-reports alone appear to yield an incomplete picture of motor disturbance in this disorder. Physiological measures offer a unique window into patients' bodily states that is complementary, though by no means superior, to self-reports. Instead, both sources provide valuable information, and both are needed to arrive at a full understanding of the restlessness experience of the individual. In keeping with the tradition of behavior therapy, using multiple assessment modalities may be important for a comprehensive description of a patient's clinical presentation. To that end, there may be value in harnessing ambulatory technology to supplement traditional assessment methods with physiological data. Actigraphy sensors, in particular, are found in many mobile technologies, including patients' smartphones as well as personal fitness devices such as Fitbits, and may be a potential avenue for synthesizing across diverse methods to arrive at a broader clinical picture.

While the present results argue against a robust physiological response to threat in GAD, the reasons for the lack of response are unclear and merit further study. It is possible that the entire experimental procedure was perceived as more threatening by the individuals with GAD, including the baseline and post-performance phases, given heightened intolerance of uncertainty in this disorder (Dugas et al., 2005). This could account for persistently elevated self-reported restlessness across the task, rather than selectively elevated restlessness in the presence of threat provocation. Relatedly, perhaps baseline activation is closer to ceiling in individuals with GAD, leaving less room for arousal to increase in response to threat. Although we did not observe heightened baseline arousal in the GAD group on our actigraphy measure, some studies have shown attenuated baseline heart rate variability in GAD (as well as in other anxiety disorders; Pittig et al., 2013), underscoring the value of examining basal arousal along with threat reactivity to disentangle their respective contributions to the reactivity paradox.

It is possible that differences in reactivity were not observed due to other, concurrent processes. For example, there is evidence that cognitive processes characteristic of GAD, such as worry, have a dampening effect on arousal at rest (e.g., Delgado et al., 2014). A competing possibility is that chronic worry leads to sustained physiological activation, so that GAD worriers are already activated—and thereby avoid large increases in arousal—when negative events occur (Llera & Newman, 2014). While not measured explicitly in the present study, it seems reasonable to infer that individuals with GAD were worrying in anticipation of the performance and in the recovery period, which may explain why elevated reactivity, relative to the no-GAD group, was not observed. Research that directly manipulates and measures worry is needed to adjudicate between potential dampening vs. activating effects of worry on restlessness.

LIMITATIONS AND FUTURE DIRECTIONS

Our study had several limitations. It is possible that participants' movements were constrained by the laboratory environment (e.g., the small testing room; other simultaneous physiological recording) or by demand characteristics (e.g., instructions to remain seated discouraged large movements such as pacing). Conversely, it is possible that movements were magnified by gesturing during the speech, although the fact that group differences emerged at phases other than the performance suggests that

gesturing alone does not account for the findings. Our ability to detect differences in movement also depended on the sensitivity of our sensors, which captured movement over the target threshold but may have missed minute motor activity, such as trembling, finger tapping, or toe scrunching. Although restlessness is recognized as a symptom of GAD, how this restlessness manifests is poorly understood. Restlessness in GAD may include subtler movements in anticipation of or recovery from threat. Furthermore, it is possible that restlessness, as captured by clinical interviews such as the ADIS, reflects general feelings of uneasiness or whole-body sensations of hyperarousal rather than a specific motor phenomenon. Rich clinical descriptions of the nature of restlessness in GAD would aid in designing future studies to maximize sensitivity to this symptom. Nevertheless, our finding that actigraphy values were greater in the high restlessness group than the low restlessness group suggests that the experimental setup permitted a range of movement and was sensitive to individual differences in restlessness.

Given that the investigation of restlessness in GAD is a new area of study, we sought to maximize sensitivity to potential effects and therefore did not correct for multiple comparisons. Moreover, given our primary interest in probing the reactivity paradox, we analyzed the actigraphy and self-report variables separately rather than combining them in a multivariate analysis. To hold down the family-wise error rate, we constructed a single, reliable composite for actigraphy and for self-reported restlessness, respectively, then examined change in each composite across phases of the task. A further limitation was the small size of our control group, which raised concerns about statistical power and the possibility that we may have missed a difference between groups had one existed. Given the large number of tests, the unequal group sizes, and the novel use of actigraphy for measuring motor restlessness in this population, these results should be interpreted with caution and subjected to replication with larger samples. Sample characteristics should also be considered when interpreting these results. Like most GAD samples (Bruce et al., 2001; Ruscio et al., 2017), ours had high rates of comorbid disorders; the potential influence of those disorders on the findings—perhaps especially social anxiety disorder, given our use of a performance task—requires further exploration. Additionally, although our sample was fairly diverse, most participants identified as Caucasian and all were recruited from a single U.S. metropolitan area. It will be important to replicate these results in other, especially non-Western, samples to evaluate generalizability.

If replicated, these results may have implications for treating patients who struggle with significant restlessness as part of their GAD. Understanding how and in what contexts restlessness occurs is important for designing effective interventions to address it. Our finding of persistently elevated restlessness, regardless of the proximity to a salient threat, suggests that restlessness-focused interventions should target chronic hyperarousal rather than threat responding per se. Although consistent with the *DSM-5* conceptualization of GAD as a chronic disorder, this finding goes beyond the requirement that restlessness be present "more days than not for the past 6 months" to show how restlessness presents under conditions that are ecologically valid for this disorder. Another implication of our results is that treatment may need to target maladaptive perceptions of arousal as well as, or in some cases instead of, attempting to reduce objective levels of arousal. To further inform treatment planning, there is a need for extensions to other measures of arousal relevant for GAD (e.g., muscle tension) and to settings outside the laboratory that allow a broader range of movement and a wider range of stressors. With a clearer understanding of physiological responses to ecologically valid threat in GAD, future studies can incorporate other processes, such as cognitive responses, that may help resolve the reactivity paradox in anxiety.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest.

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