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Examining the Relationship Between Worry and Sleep: A Daily Process Approach

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There is growing evidence suggesting that worry and sleep are intimately linked. However, the relationship between these two phenomena over the course of a day remains largely unstudied. It is possible that (a) worry predicts sleep disturbance that night, (b) sleep disturbance predicts worry the following day, or (c) there is a bidirectional relationship between worry and sleep disturbance. The present study examined the daily relationship between worry (both during the day and immediately prior to sleep onset) and sleep in 50 high trait worriers who were randomly assigned to one of two interventions aimed at reducing worry as part of a larger study. A daily process approach was utilized wherein participants completed daily reports of sleep and worry during a 7-day baseline period followed by a 14-day intervention period. Results of repeated measures multilevel modeling analyses indicated that worry experienced on a particular day predicted increased sleep disturbance that night during both the baseline and intervention weeks. However, there was no evidence of a bidirectional relationship as sleep characteristics did not predict worry the following day. Additionally, the type of intervention that participants engaged in did not affect the daily relationship between worry and sleep. Results of the present study are consistent with the cognitive model of insomnia (Harvey, 2002) and highlight the importance of addressing and treating worry among individuals with high trait worry and sleep disturbance.

Keywords: worry; anxiety; sleep; insomnia; daily process approach

WORRY AND SLEEP SHARE a close relationship. Worry is a common occurrence in individuals suffering from insomnia (Morin, 1993), and insomnia likely plays a role in exacerbating symptoms of psychopathology (Ford & Kamerow, 1989), including chronic and severe worry. Several forms of psychopathology that involve chronic worry are also associated with sleep difficulties. One reason for this relationship is that sleep disturbance is a symptom or clinical feature of several psychological disorders in the *Diagnostic and Statistical Manual of Mental Disorders*, 5th ed. (DSM-5; American Psychiatric Association, 2013) and is particularly associated with anxiety disorders. For example, Ohayon, Caulet, and Lemoine (1998) found that 41.6% of individuals with insomnia were diagnosed with an anxiety disorder, and difficulty with sleep onset is a feature of many anxiety disorders (Morin, 1993). Furthermore, generalized anxiety disorder (GAD), which is characterized by chronic worry, is the most prevalent anxiety disorder diagnosis among individuals with sleep disturbance (Ohayon et al., 1998). Among those with severe sleep disturbance, 13% report symptoms of GAD (Mellinger, Balter, & Uhlenhuth, 1985).

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Additionally, it is estimated that 50–70% of individuals with GAD have insomnia (Anderson, Noyes, & Crowe, 1984). Given that the diagnostic criteria for GAD includes sleep disturbance, it is not surprising that individuals with GAD often complain of difficulty engaging in sleep due to excessive and uncontrollable worry (Monti & Monti, 2000).

Despite strong evidence indicating a general association between worry and sleep disturbance, little research has examined how they might affect each other on a daily basis. There are three possible ways in which worry and sleep disturbance are related: it is possible that (a) worry contributes to sleep disturbance; (b) sleep disturbance contributes to worry; or (c) there is a bidirectional relationship between worry and sleep disturbance. An important step in understanding the relationship between these two phenomena is to examine the degree to which they predict each other over the course of a day. Understanding the relationship between worry and sleep disturbance has the potential to elucidate key processes involved in these phenomena and may aid in the development and implementation of interventions.

The Effect of Worry on Sleep Disturbance

According to the cognitive model of insomnia (Harvey, 2002), worry contributes to poor sleep quality, thus maintaining and exacerbating insomnia. Generally, individuals with insomnia experience intrusive thoughts and excessive and uncontrollable worry while trying to fall asleep (Borkovec, 1979, 1982; Morin, 1993) that exacerbate insomnia symptoms. Additionally, during the day these individuals have distorted beliefs about the previous night's sleep and the perceived consequences of a poor night's sleep (Bonnet, 1990; Morin, Stone, Trinkle, Mercer, & Remsberg, 1993). These beliefs lead them to engage in counterproductive safety behaviors (e.g., drinking before bedtime, limiting physical activities during the day; Wooley & Simon, 2006). Together, experiencing catastrophizing worries that result in increases in anxiety and distress (Harvey & Greenall, 2003) and engaging in counterproductive behaviors create conditions that impede successful sleep onset (Espie, 2002). As individuals become trapped in this cyclical cognitive process, the escalation of anxiety and emotional distress can lead to an actual deficit in sleep, which subsequently reinforces and strengthens their concerns. Thus, the cognitive model of insomnia suggests that a relationship exists between worry, examination of threat cues, beliefs about sleep, and counterproductive safety behaviors that ultimately maintain and strengthen insomnia.

Although the content of worry discussed in the cognitive model of insomnia is specifically related to sleep concerns, it is also possible that increased general worry (not specific to sleep) leads to the development of insomnia. For example, Gross and Borkovec (1982) manipulated participants' likelihood of engaging in cognitive mentation prior to sleep onset by informing one group of good sleepers that they would have to give a speech immediately following a nap. Participants who were informed about the speech took significantly longer to fall asleep than did participants who were not asked to give a speech upon awakening. This finding suggests that participants had difficulty falling asleep as a result of the cognitive intrusions (i.e., worry) related to giving a speech. Additionally, Hall, Buysee, Reynolds, Kupfer, and Baum (1996) manipulated presleep stress in female good sleepers and found a positive relationship between subjective stress-related intrusive thoughts and objective sleep onset latency. Finally, in addition to cognitive consequences, worry has also been demonstrated to have physiological effects that subsequently disrupt sleep (Brosschot, Van Dijk, & Thayer, 2007).

The Effect of Sleep Disturbance on Worry

It is also possible that sleep disturbance leads to the emergence and exacerbation of worry. Compared with individuals without insomnia, those with insomnia report higher trait worry symptoms during the day (Means, Lichstein, Epperson, & Johnson, 2000), and individuals who sleep less tend to worry more even after controlling for sleep disturbance attributed to worry, suggesting that reduced sleep length continues to be associated with worry beyond the negative effects of presleep cognitive activity (Kelly, 2002). Research has also shown that individuals who sleep for fewer than 6 hours per night report more anxiety than do individuals who sleep 9 or more hours per night (Kumar & Vaidya, 1984). Bonnet and Arand (1992) induced objective (i.e., increased sleep onset latency, decreased total sleep time) and subjective (i.e., perceived sleep quality, number of awakenings) sleep disturbance in good sleepers over the course of a week and found that participants reported significant increases in anxiety, dysphoria, and tension, suggesting that insomnia leads to psychological distress.

Although insomnia is often conceptualized as an epiphenomenon of various physical and psychological conditions (Spielman & Glovinsky, 1997), a growing body of literature suggests that insomnia may predate the onset of these disorders and contribute to their development (Ford & Kamerow, 1989; Vollrath, Wicki, & Angst, 1989; see Harvey, 2001, for a review). The National Institute of Mental Health Epidemiologic Catchment Area

Study surveyed 7954 community residents about their sleep and psychopathology at two time points separated by 1 year (Ford & Kamerow, 1989). Results indicated that individuals who had insomnia at Time 1 and not at Time 2 were at 1.6 times the risk of developing any psychiatric disorder (and 1.5 times the risk of developing an anxiety disorder) over that year. Individuals who had insomnia at both time points were at 4.0 times the risk of developing any psychiatric disorder (and 6.3 times the risk of developing an anxiety disorder) over that year. Additionally, a longitudinal study by Vollrath et al. (1989) indicated that compared with individuals who did not endorse sleep disturbance (22%), 42–48% of individuals who experienced occasional or brief periods of insomnia suffered from anxiety or depressive disorders during the subsequent year.

Furthermore, in addition to other psychological constructs, worry may be a mediating factor in the relationship between sleep disturbance and psychopathology. Specifically, it is possible that sleep disturbance exacerbates psychological domains (e.g., worry, neuroticism, negative affect) that increase risk for psychopathology. Indeed, individuals with insomnia demonstrate more anxious worrying behavior and neuroticism (Coursey, Buchsbaum, & Frankel, 1975). Chronic insomnia leads to psychological symptoms such as irritability, tension, and dysphoria in the absence of a diagnosed psychiatric disorder (Ford & Kamerow, 1989).

The Bidirectional Effects of Worry and Sleep Disturbance

Given that there is research to support the notion that worry contributes to sleep disturbance *and* that sleep disturbance contributes to worry, it is also possible that a bidirectional relationship exists wherein worry and sleep disturbance affect and exacerbate each other. Specifically, increases in worry may lead to increases in sleep difficulties, which in turn might exacerbate worry such that a cyclical relationship develops. This point is supported by evidence that the relationship between worry and insomnia likely becomes stronger over time (Jansson & Linton, 2006a). Indeed, some researchers have suggested a bidirectional relationship between insomnia and anxiety/worry (Baglioni, Spiegelhalder, Lombardo & Riemann, 2010; Jansson & Lindblom, 2008; Jansson & Linton, 2006a, 2006b). However, support for this assertion is limited by the fact that many of the sources that suggest such a bidirectional relationship are theoretical or cross-sectional and thus cannot adequately test theories of bidirectionality. Additionally, those studies employing a longitudinal design have examined these processes over extended and broad assessments, and find that insomnia is associated with new cases of anxiety disorders and that anxiety disorders are associated with new cases of insomnia (Jansson & Lindblom, 2008; Jansson & Linton, 2006a, 2006b). To our knowledge, no studies have examined a bidirectional relationship between worry and sleep disturbance on a daily basis, and few studies have utilized an analytic approach that allows for the examination of a temporal relationship. If a bidirectional relationship between worry and insomnia exists, this would suggest that the experience of either phenomenon might begin a negative spiral wherein each state leads to the experience of the other state. Additionally, this would suggest that intervening at any point in the cycle could lead to improvements in both phenomena.

Several investigations have also explored the relationship between worry and sleep disturbance by examining whether treating one phenomenon leads to improvements in the other. For example, Bélanger, Morin, Langlois, and Ladouceur (2004) found that cognitive-behavioral therapy (CBT) for GAD was associated with significant decreases in insomnia symptoms at posttreatment. Other investigations (Blais, Mimeault, & Morin, 2000; Vallieres, Bastien, Ouellet, & Morin, 2000) have found that CBT for insomnia has ameliorating effects on anxiety. Although these studies provide support for the strong relationship between worry and insomnia, and suggest that treating one phenomenon results in reductions in the other, they did not examine how treatment might affect the daily relationship between the two phenomena. Such an investigation might help to answer questions regarding whether these temporal relationships are static, or whether they might change as symptoms reduce and/or function as a type of treatment.

The Present Study

The aims of this investigation were to examine the nature of the relationship between worry and sleep disturbance among high trait worriers, with attention to how these phenomena potentially predict each other on a daily basis. Specifically, the primary aim was to examine whether worry experienced during the day and prior to sleep onset predicts characteristics of sleep that night, and/or whether characteristics of nighttime sleep predict worry the following day. Evidence of both predictive relationships would suggest a bidirectional relationship. A secondary aim was to examine whether these temporal relationships are static, or whether they change as symptoms change. We utilized data

from a larger investigation of the efficacy of stimulus control training for worry (McGowan & Behar, 2013). In that investigation, participants assigned to a stimulus control training condition evidenced larger reductions in both worry and insomnia symptoms relative to participants assigned to a control condition. If the temporal relationship between worry and sleep disturbance is static, then the temporal nature of that relationship should be the same whether symptoms are ameliorating to a greater or lesser degree; on the other hand, if the temporal relationship between these two phenomena depends on severity, then the temporal nature of that relationship should differ as a result of successful treatment.

Given that no known studies have examined the daily relationship between worry and sleep disturbance using a daily process approach, this investigation provides an important first step in identifying the potential predictive relationship between these two phenomena. We utilized a daily process approach (Affleck, Zautra, Tennen, & Armeli, 1999) in which we included repeated measurements of variables that are thought to change in meaningful ways each day. This approach (a) allows for the examination of fluctuations in the relationship among variables as they change over time, (b) reduces biases due to retrospective reporting by minimizing the time between an event and emotional responding, and (c) allows for the examination of a temporal relationship among variables (Laurenceau, Hayes, & Feldman, 2007; Tennen & Affleck, 1996). Finally, this approach allows investigators to examine more sophisticated questions about the process of symptom change than can be addressed using outcome data.

Method

PARTICIPANTS

Fifty-three introductory psychology students from a large Midwestern university were included in this investigation. Three participants' data were excluded from analyses because they dropped out of the study for personal reasons prior to being randomly assigned to an intervention (n = 2) or no longer met the inclusionary criteria at the baseline assessment (n = 1), leaving a total of 50 participants in the investigation. Participants were administered the Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990) as part of a group screening process. Those with a score of 67 or higher were invited to take part in the study, as this score has been shown to distinguish individuals with GAD from nonanxious individuals (Molina & Borkovec, 1994). On the day of the laboratory baseline assessment, participants completed the PSWQ a second time and were retained in the study if they scored 53 or higher on the PSWQ at the baseline assessment (shown to be 1 standard deviation above the mean for normal individuals; Gillis, Haaga, & Ford, 1995). On average, participants' scores on the PSWQ decreased from the group screening administration to the baseline assessment (M_{diff} = −4.11, SD_{diff} = 6.53); however, participants still evidenced elevated PSWQ scores at the baseline assessment (M = 68.00, SD = 5.84). Although participants in this study were selected on the basis of their high trait worry, they were not formally diagnosed with GAD or with insomnia.

Participants were predominantly female (82.0%), with a mean age of 19.72 years (SD = 3.7 years). Our sample was ethnically diverse and comprised 42% Caucasian, 10% African American, 20% Asian, 14% Latino, and 14% other participants. Participants included in the analyses did not differ from excluded participants with respect to age, $t(50) = -0.27$, $p = .786$; gender, $\chi^2(1) = 0.43$, $p = .509$; ethnicity, $\chi^2(1) = .50$, $p = .482$; or race, $\chi^2(7) = 6.93$, $p = .436$. In addition, age, $t(48) = -1.91$, $p = .062$; gender, $\chi^2(1) = 2.92$, $p = .087$; ethnicity, $\chi^2(1) = 0.32$, $p = .571$; and race, $\chi^2(7) = 4.65$, $p = .702$ were equivalent across the two intervention groups. Because there was a trend for age being different across the two intervention groups, we examined the analyses that included between-groups effects (i.e., differences between intervention groups on baseline Insomnia Severity Index [ISI] and PSWQ scores) with age added as a covariate; results were identical and thus, age was not included as a covariate.

SYMPTOM MEASURES

Penn State Worry Questionnaire

The PSWQ (Meyer et al., 1990) is a 16-item self-report questionnaire that assesses the frequency and intensity of worry. The PSWQ has demonstrated favorable reliability and validity for both clinical and nonclinical populations (Brown, Antony, & Barlow, 1992). It has good sensitivity (.75) and specificity (.86) in distinguishing GAD samples from nonanxious controls and from other anxiety groups (Behar, Alcaine, Zuellig, & Borkovec, 2003; see also Brown et al., 1992). In this study, the PSWQ had acceptable internal consistency (α = .72).

Insomnia Severity Index

The ISI (Bastien, Vallieres, & Morin, 2001) is a seven-item self-report questionnaire that assesses sleep problems, impairment of functioning due to inadequate sleep, and perceptions of severity of insomnia. The ISI has adequate internal consistency,

as well as adequate convergent validity with clinician report, sleep diary, and polysomnography measures (Bastien et al., 2001). In this study, the ISI had good internal consistency (α = .82).

DAILY DIARIES

Daily diaries were administered on personal digital assistants (PDAs) that were provided to each participant. The Experience Sampling Program (ESP; Barrett & Barrett, 2000) was downloaded onto PDAs and allowed participants to complete daily diaries at their instructed times. One advantage of using experience sampling over self-report questionnaires is that it reduces memory bias and tracks participant compliance with study procedures (Barrett & Barrett, 2001). For this investigation, we asked participants to complete their diaries as close to an experience as possible such that it would reduce retrospective reporting, but not artificially increase or change the natural experience as it was occurring. Thus, participants were instructed to complete a morning diary upon awakening and an evening diary as the last activity of the day.

Morning Diary

Participants were asked to complete a morning diary immediately upon awakening each morning. The morning diary comprised (a) a sleep diary and (b) an assessment of worry prior to falling asleep. Sleep diaries are an essential component of studies examining sleep and insomnia symptoms (Buysse, Ancoli-Israel, Edinger, Lichstein, & Morin, 2006). As recommended by Buysse et al. (2006), sleep was assessed by having participants estimate the time they attempted to fall asleep, the amount of time they spent trying to fall asleep (sleep onset latency), an estimate of the number of hours slept, the number of nocturnal awakenings, and the time of awakening in the morning. Standard sleep continuity measures were extracted from the sleep diaries, including sleep onset latency, total sleep time, number of awakenings, and sleep efficiency (Buysse et al., 2006). Sleep efficiency ([total sleep time]/[time in bed]*100) was calculated as one index of sleep quality (Spielman, Sasky, & Thorpy, 1987). Additionally, participants provided a rating of the extent to which they felt worried prior to falling asleep on a scale of 1 (*not at all worried*) to 5 (*extremely worried*). This 1–5 rating was previously used by Åkerstedt, Kecklund, and Axelsson (2007) in showing that worry at bedtime is associated with sleep disturbance.

Evening Diary

Participants were asked to rate the percentage of the day (0–100%) that they worried, which has been shown to distinguish among individuals with GAD, individuals with subthreshold anxiety, and nonclinical control participants (Montorio, Nuevo, Márquez, Izal, & Losada, 2003). Participants were asked to complete evening diaries as their last activity of the day.

PROCEDURE

The purpose and hypotheses of the study were masked throughout the experiment (as detailed below). Participants were randomly assigned to one of two interventions aimed at reducing worry: stimulus control (n = 26) or focused worry (n = 24). Participants received course credit as compensation for their participation.

Baseline Laboratory Session

Following informed consent procedures, participants were asked to complete the PSWQ and the ISI. They were then given instructions on how to complete the morning diaries during the baseline week.

Baseline Week

Participants completed a morning diary each day for 7 days using the online survey tool SurveyMonkey. During this week, participants were instructed to complete daily morning diaries immediately upon awakening.

Intervention Laboratory Session

After the baseline week, participants returned to the laboratory to receive training in the intervention to which they had been randomly assigned. The experimenter met with each participant individually to explain the intervention and provide instructions. All instructions were scripted in order to ensure consistency of information across participants and to reduce the risk of experimenter bias. Participants were also provided with written materials that reiterated the rationale for the intervention and all instructions that had been delivered by the experimenter. Neither intervention included any information regarding psychoeducation about sleep or any sleep-related treatment principles. (See McGowan & Behar, 2013, for a more detailed description of the two interventions.)

The *stimulus control* intervention entailed teaching participants to identify worrisome thoughts and identify a specific and consistent 30-min worry period and location where they would focus on their worries each day. This worry period occurred at least 3 hours prior to participants' usual bedtimes in order to reduce the risk of study procedures unintentionally impacting the association between worry and sleep, particularly given that recording worrisome thoughts immediately prior to bedtime has been shown to reduce sleep

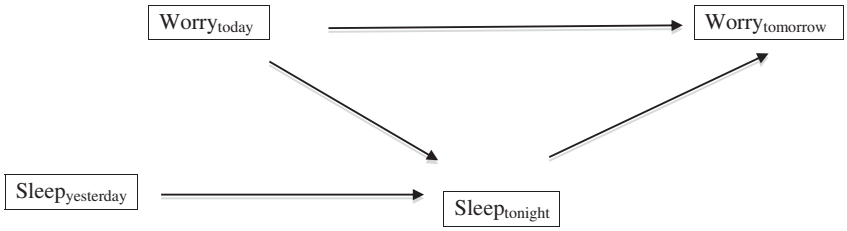

FIGURE 1 Representation of complex models estimated using multilevel repeated measures analysis.

onset latency (Harvey & Farrell, 2003). Participants were instructed to use the 30-min worry period to worry as they normally do, to make this worry as intense as possible, and to keep the focus of their attention on the worry process. They were also instructed that when they noticed spontaneous worry occurring during the day outside of the prescribed worry period, they were to postpone that worry until the worry period and to instead focus on the present moment. Finally, they were instructed to use the worry period to problem solve when appropriate.

The *focused worry* intervention entailed providing participants with a rationale that would encourage them to engage in worry as they normally do, and to expect that this practice would lead to a reduction in worry and its associated emotions. They were told that avoiding the occurrence of worry paradoxically leads to increased levels of worry, and that allowing worry to naturally occur would decrease the frequency and intensity of those paradoxical increases. Participants were instructed to worry as they normally do whenever they noticed such thoughts occurring, to make this worry as intense as possible, and to keep the focus of their attention on the worry process.

Intervention Weeks

Participants engaged in their assigned intervention each day during the 14-day intervention period. Participants were instructed to complete morning diaries immediately upon awakening and evening diaries as their last activity of the day. Given that participants were undergraduate students, special consideration was given to the timing of the study vis-à-vis the academic calendar; participants engaged in all study procedures during the school year and never during school breaks or during final exams in order to reduce the effects of environmental changes and stressors.

DAILY DIARY COMPLIANCE

Participants were instructed to complete one diary entry per day during the baseline week (morning diary) and two diary entries per day during each of the two intervention weeks (morning diary and evening diary). Of the 1750 total diaries requested from the final sample (N = 50), 1551 (88.6%) were completed. Specifically, during the baseline week, participants completed 93.14% of the requested morning diaries. During the intervention weeks, participants completed 94.3% of the requested morning diaries and 88.0% of the requested evening diaries. There were no differences in diary completion between the two intervention groups during the intervention weeks, $t(48) = 1.44$, $p = .157$. In the multilevel models, only participants with complete data on all relevant variables were included.

APPROACH TO MULTILEVEL ANALYSES

The present study utilized a repeated measures multilevel modeling approach using Mplus (Muthén & Muthén, 1999–2012). Data for the main analyses were nested (i.e., observations nested within individuals). In multilevel modeling, two sources of variance are partitioned in the dataset: differences between persons on the average levels of daily variables and differences within persons on their daily reporting of variables over time. Level 1 variables represent the within-person observations that are being measured over time, which in the present study included sleep onset latency, total sleep time, number of awakenings, sleep efficiency, worry before bed, and percentage of daily worry. Level 2 variables are between-person variables, which in the present study was intervention (stimulus control vs. focused worry).

A multilevel repeated measures path analysis was used to examine the lagged within-persons relationship between Level 1 variables. We examined two directional pathways: (a) whether worry during the day and prior to sleep onset predicted sleep disturbance that night, controlling for the previous day's sleep disturbance; and (b) whether nighttime sleep disturbance predicted worry the following day, controlling for the previous day's worry (see Fig. 1). Separate analyses were conducted for data collected during the baseline week and during the intervention weeks, and analyses for data collected during the intervention weeks also

Table 1
Means (*SD*s) and Ranges for Baseline Symptom Measures and Sleep Measures

Variable	Mean (*SD*)	Range
Baseline Symptom Measures		
PSWQ	68.00 (5.84)	56–80
ISI	13.35 (5.60)	4–27
Baseline Sleep Diary Variables*		
Sleep onset latency (mins)	38.58 (33.28)	5.71–203.86
Total sleep time (hours)	6.72 (0.99)	4.17–8.13
Number of awakenings	2.69 (0.91)	1.29–4.86
Worry before bed	2.63 (0.81)	1–5
Sleep efficiency (%)	84.74 (8.95)	60.13–97.05

Note. *SD* = standard deviation; PSWQ = Penn State Worry Questionnaire; ISI = Insomnia Severity Index.
* Averaged across 7 baseline days.

examined whether the Level 2 variable intervention (stimulus control vs. focused worry) moderated the association between sleep and worry. One of the advantages of multilevel path modeling is that both pathways (i.e., worry predicting sleep and sleep predicting worry) can be estimated within the same model. However, such a simultaneous analysis was possible only for the intervention weeks because half as much data were available for the baseline week.

The multilevel path models were estimated using maximum likelihood. Covariance matrices for all models are provided as supplemental material (Tables S1–S2). All Level 1 slopes were modeled as fixed because of convergence problems associated with models including random slopes. For all analyses, dependent variables were left in their original metric. Independent predictor variables were person centered in order to eliminate any between-persons variation and produce a regression model that is solely based on within-persons variation (Enders & Tofighi, 2007). The goodness of fit of the path models for the intervention weeks

Table 2
Repeated Measures Multilevel Regression Results During Baseline Week

Model	Effect	*B*	β	*t*	*p*
	Worry ➔ Sleep Analyses				
B1	**Sleep efficiency**				
	$\text{Sleep efficiency}_{\text{yesterday}}$ ➔ $\text{Sleep efficiency}_{\text{tonight}}$	0.23	0.29	3.88	.001
	$\text{Worry before bed}_{\text{today}}$ ➔ $\text{Sleep efficiency}_{\text{tonight}}$	−5.26	−0.29	−4.81	<.001
B2	**Sleep onset latency**				
	$\text{Sleep onset latency}_{\text{yesterday}}$ ➔ $\text{Sleep onset latency}_{\text{tonight}}$	0.42	0.46	5.69	<.001
	$\text{Worry before bed}_{\text{today}}$ ➔ $\text{Sleep onset latency}_{\text{tonight}}$	12.52	0.25	2.93	.003
B3	**Total sleep time**				
	$\text{Total sleep time}_{\text{yesterday}}$ ➔ $\text{Total sleep time}_{\text{tonight}}$	−0.12	−0.10	−2.03	.043
	$\text{Worry before bed}_{\text{today}}$ ➔ $\text{Total sleep time}_{\text{tonight}}$	−0.34	−0.17	−3.11	.002
B4	**No. of awakenings**				
	$\text{No. of awakenings}_{\text{yesterday}}$ ➔ $\text{No. of awakenings}_{\text{tonight}}$	0.38	0.38	5.03	<.001
	$\text{Worry before bed}_{\text{today}}$ ➔ $\text{No. of awakenings}_{\text{tonight}}$	0.14	0.08	0.99	0.323

	Effect	*B*	β	*t*	*p*
	Sleep ➔ Worry Analyses				
B5	**Sleep efficiency**				
	$\text{Worry before bed}_{\text{today}}$ ➔ $\text{Worry before bed}_{\text{tomorrow}}$	−0.06	−0.04	−0.78	0.434
	$\text{Sleep efficiency}_{\text{today}}$ ➔ $\text{Worry before bed}_{\text{tomorrow}}$	0.01	0.07	1.01	0.311
B6	**Sleep onset latency**				
	$\text{Worry before bed}_{\text{today}}$ ➔ $\text{Worry before bed}_{\text{tomorrow}}$	−0.09	−0.07	−1.31	0.189
	$\text{Sleep onset latency}_{\text{today}}$ ➔ $\text{Worry before bed}_{\text{tomorrow}}$	<.01	0.064	1.31	0.189
B7	**Total sleep time**				
	$\text{Worry before bed}_{\text{today}}$ ➔ $\text{Worry before bed}_{\text{tomorrow}}$	−0.08	−0.06	−1.15	0.252
	$\text{Total sleep time}_{\text{today}}$ ➔ $\text{Worry before bed}_{\text{tomorrow}}$	<.001	<.001	<.001	1.000
B8	**No. of awakenings**				
	$\text{Worry before bed}_{\text{today}}$ ➔ $\text{Worry before bed}_{\text{tomorrow}}$	−0.09	−0.06	−1.27	0.205
	$\text{No. of awakenings}_{\text{today}}$ ➔ $\text{Worry before bed}_{\text{tomorrow}}$	0.04	0.05	0.52	0.602

Note. *B* = unstandardized coefficient; β = standardized coefficient; *t* and *p* values refer to the unstandardized coefficients.

Table 3
Repeated Measures Multilevel Regression Results During Intervention Weeks

Effect		Worry before bed					Percentage of daily worry			
		B	β	*t*	*p*		*B*	β	*t*	*p*
	Model					Model				
Sleep efficiency	**1**					**5**				
Sleep efficiency$_{yesterday}$ ➔ Sleep efficiency$_{tonight}$		−0.05	−0.05	−1.28	.199		−0.03	−0.03	−0.74	.458
Worry$_{today}$ ➔ Sleep efficiency$_{tonight}$		−2.36	−0.28	−5.03	<.001		−0.02	−0.07	−2.62	.009
Worry$_{today}$ ➔ Worry$_{tomorrow}$		0.12	0.13	1.67	.094		0.10	0.18	3.30	.001
Sleep efficiency$_{today}$ ➔ Worry$_{tomorrow}$		<.01	−0.02	−0.41	.680		0.17	0.08	1.47	.143
	Model					Model				
Sleep onset latency	**2**					**6**				
Sleep onset latency$_{yesterday}$ ➔ Sleep onset latency$_{tonight}$		−0.05	−0.05	−0.48	.628		−0.03	−0.03	−0.29	.772
Worry$_{today}$ ➔ Sleep onset latency$_{tonight}$		7.71	0.28	5.67	<.001		0.08	0.05	1.11	.269
Worry$_{today}$ ➔ Worry$_{tomorrow}$		0.13	0.14	1.69	.091		0.25	0.27	4.27	<.001
Sleep onset latency$_{today}$ ➔ Worry$_{tomorrow}$		<.01	−0.01	−0.16	.870		−0.06	−0.10	−1.16	.248
	Model					Model				
Total sleep time	**3**					**7**				
Total sleep time$_{yesterday}$ ➔ Total sleep time$_{tonight}$		−0.04	−0.04	−0.63	.529		−0.02	−0.02	−0.36	.717
Worry$_{today}$ ➔ Total sleep time$_{tonight}$		−0.29	−0.16	−3.46	.001		−0.02	−0.16	−3.75	<.001
Worry$_{today}$ ➔ Worry$_{tomorrow}$		0.14	0.14	1.95	.052		0.25	0.27	4.37	<.001
Total sleep time$_{today}$ ➔ Worry$_{tomorrow}$		0.03	0.05	1.43	.152		0.46	0.05	1.02	.310
	Model					Model				
No. of awakenings	**4**					**8**				
No. of awakenings$_{yesterday}$ ➔ No. of awakenings$_{tonight}$		0.08	0.08	1.60	.109		0.10	0.10	1.64	.102
Worry$_{today}$ ➔ No. of awakenings$_{tonight}$		0.45	0.40	5.67	<.001		<.01	0.04	1.21	.228
Worry$_{today}$ ➔ Worry$_{tomorrow}$		0.13	0.13	1.71	.088		0.24	0.26	4.25	<.001
No. of awakenings$_{today}$ ➔ Worry$_{tomorrow}$		0.02	0.02	0.40	.686		−0.65	−0.04	−1.05	.296

Note. *B* = unstandardized coefficient; β = standardized coefficient; *t* and *p* values refer to the unstandardized coefficients.

was generally acceptable (see Table S3) except for the fit of Model 3 (association between worry before sleep and total hours of sleep). Model 3 should therefore be interpreted with caution.

Results

DESCRIPTIVE STATISTICS OF BASELINE MEASURES AND SLEEP DIARY VARIABLES

Table 1 presents descriptive statistics for baseline symptom measures and baseline sleep diary variables. One participant was an outlier (> 4 *SD*s above the mean) with respect to his or her reports of sleep onset latency. Results were identical when this participant was excluded from analyses; therefore, we retained this participant in all analyses. Mean baseline PSWQ and ISI scores were in the clinical range. Baseline scores on the PSWQ, $t(48) = -.82$, $p = .415$; and ISI, $t(48) = -1.54$, $p = .130$, were equivalent across the two interventions. As per ISI cutoff recommendations established by Morin (1993), 14% of the sample was within the "no clinical insomnia" range, 46% was within the "subthreshold insomnia" range, 34% was within the "clinical insomnia—moderate severity" range, and 6% was within the "clinical insomnia—severe" range.

BASELINE WEEK: LAGGED WITHIN-PERSON ANALYSES

Results indicated that greater *worry before bed* predicted decreased total sleep time, decreased sleep efficiency, and greater sleep onset latency during the baseline week (see Table 2, Models B1–B3). A comparison of the βs indicated that worry before bed had the strongest association with decreased sleep efficiency, although worry before bed also had a strong association with increased sleep onset latency. Worry before bed had a significant, but weaker, association with total sleep time. However, worry before bed was not associated with number of awakenings. Results indicated that none of the sleep variables (sleep onset latency, total sleep time, number of awakenings, or sleep efficiency) significantly predicted worry before bed the following day (see Table 2, Models B5–B8). In other words, worry before bed significantly predicted several measures of sleep characteristics; however, no sleep characteristics predicted worry before bed.

INTERVENTION WEEKS: LAGGED WITHIN-PERSON ANALYSES

Similar to the baseline week analyses, greater *worry before bed* during the intervention weeks predicted

decreased total sleep time, decreased sleep efficiency, increased sleep onset latency, and increased number of awakenings (see Table 3, Models 1–4). A comparison of the βs indicates that worry before bed had the strongest relationship with total number of awakenings, although worry before bed also had a strong association with decreased sleep efficiency and increased sleep onset latency. Worry before bed had a significant, yet weaker, association with total sleep time. Consistent with baseline week results, none of the sleep variables (sleep onset latency, total sleep time, number of awakenings, or sleep efficiency) significantly predicted worry before bed.

Results indicated that greater *percentage of daily worry* predicted decreased total sleep time and decreased sleep efficiency (see Table 3, Models 5 and 7). However, percentage of daily worry did not predict sleep onset latency or number of awakenings (see Table 3, Models 6 and 8). A comparison of the βs indicates that percentage of daily worry had a stronger association with total sleep time than with sleep efficiency, although both associations were relatively weak. None of the four sleep variables significantly predicted percentage of daily worry.

The Level 2 variable of intervention did not moderate the within-person associations for any independent worry–sleep relationship and thus was not included in the final models (all *p*s > .30). In summary, both worry variables predicted several measures of sleep characteristics; however, no sleep characteristics predicted either worry variable.[1] This relationship existed regardless of the type intervention that participants engaged in.

Discussion

The present study utilized a daily process approach to examine the relationship between worry and sleep in a sample of high trait worriers. Results indicated that worry occurring throughout the day and prior to bed predicted several sleep variables. Specifically, during the baseline and intervention weeks, worry before bed predicted decreased total sleep time and sleep efficiency, as well as increased sleep onset latency. During the intervention weeks, worry before bed additionally predicted increased number of awakenings. Furthermore, the percentage of worry that participants experienced during the day predicted decreased total sleep time and decreased sleep efficiency during the intervention weeks.

Our finding that worry occurring before bed negatively predicts sleep characteristics is consistent with the cognitive model of insomnia (Harvey, 2002), which posits that worry before bed causes increased autonomic arousal and emotional distress that interferes with sleep onset. Extant literature supports the claim that excessive worry—especially worry occurring before bed—contributes to sleep disturbance (Borkovec, 1979, 1982; Harvey, 2002; Morin, 1993). Harvey (2002) posits that presleep worry accounts for problems with sleep onset latency as well as sleep maintenance (i.e., sleep efficiency). Consistent with this model, worry before bed evidenced strong associations with increased sleep onset latency and decreased sleep efficiency. Furthermore, the present study supports and potentially extends the cognitive model of insomnia by demonstrating that worry occurring throughout the day also predicts sleep disturbance. Harvey (2002) theorized that worrisome thinking occurring during the day contributes to and maintains insomnia. Consistent with this hypothesis, we found that worry on a particular day predicted sleep characteristics that night. It is possible that sleep disturbance is not only affected by worrying while attempting to fall asleep, but that worry also has lasting effects such that its occurrence throughout the day continues to have negative effects that contribute to sleep disturbance.

Although daily worry predicted reduced sleep efficiency and total sleep time, it did not predict sleep onset latency, which is often assumed to be the result of cognitive intrusions before bed (Harvey, 2002; Monti & Monti, 2000). Interestingly, worry before bed was associated with all aspects of sleep disturbance (trouble falling asleep and staying asleep; see also Åkerstedt et al., 2007), whereas daily worry seemed to be associated only with characteristics of sleep maintenance (sleep efficiency and total sleep time). One possible reason for this finding is that the accumulation of worry experienced throughout the day does not have a direct impact on the time it takes one to fall asleep, but rather has other lasting effects that interfere with sleep maintenance. Brosschot et al. (2007) found that prolonged worry was associated with higher heart rate and lower heart rate variability not only during waking but also during sleep periods, suggesting that worry's maladaptive physiological effects might interfere with the sleep process. This finding could also explain why the strongest relationship existed between worry before bed and number of awakenings. Thus, it is likely that worry has both cognitive and physiological

[1] In additional analyses, we included baseline levels of ISI and PSWQ as Level 2 covariates. Neither variable was significantly associated with any sleep or worry variables measured on Level 1, nor did including these variables as covariates change the Level 1 path coefficients substantively (see Tables S4–S6). We therefore report the models without these covariates.

consequences that interfere with sleep. These findings provide further support for the cognitive model of insomnia and suggest that there are multiple pathways through which worry might negatively impact sleep.

Our two measures of worry captured two different elements of this construct. Specifically, our daytime worry variable assessed the *frequency* of daytime worry, whereas our nighttime worry variable assessed the *degree* of worry before sleep. Although frequency and severity feature prominently in clinical measures of worry (e.g., Meyer et al., 1990), the difference offers a rival hypothesis to explain why the results of these two analyses differed. It may be that trouble initiating and maintaining sleep is predicted by either (a) worry before bed and/or (b) worry severity; likewise, it may be that trouble with sleep maintenance is predicted by either (a) daytime worry and/or (b) worry frequency. Future investigations should examine whether different elements of worry (e.g., frequency, severity, duration, content) differentially predict and affect sleep.

Given these relationships between worry and sleep, addressing worry may be vital to impacting change in sleep disturbance. CBT for insomnia (CBT-I; Edinger, Wohlgemuth, Radtke, Marsh, & Quillian, 2001; Morin et al., 1999; Morin & Espie, 2003) is one of the leading treatments for insomnia, and the inclusion of cognitive therapy components in this approach is based on evidence that addressing cognitive maintaining factors of disorders increases the short- and long-term efficacy of treatments (Harvey, 2005; Salkovskis, 2002). Although behavioral interventions for insomnia are efficacious on their own when compared with wait-list or no-treatment conditions (Edinger et al., 2001; Espie, Lindsay, Brooks, Hood, & Turvey, 1989; Lichstein, Riedel, Wilson, Lester, & Aguillard, 2001), CBT-I additionally addresses the maladaptive cognitions and worries associated with sleep disturbance. Results from the present study suggest that addressing worry and negative cognitive activity may be crucial to creating significant changes in sleep disturbance, especially for individuals who experience high trait worry. Additionally, it may be important to address and reduce worry experienced throughout the day in addition to worry prior to bedtime in order to reduce the effects of worry on sleep. We previously demonstrated that participants from this study evidenced significant reductions in insomnia symptoms after undergoing an intervention targeted at reducing worry (McGowan & Behar, 2013). Additionally, Bélanger et al. (2004) found that CBT for worry also significantly reduced insomnia symptoms. Thus, there is preliminary evidence to suggest that reducing worry might be efficacious as a stand-alone treatment for improving sleep disturbance for high trait worriers. However, a dismantling study comparing treatment for worry, treatment for insomnia, and their combination is needed to determine which elements of these interventions are necessary and sufficient.

Importantly, our results did not find evidence of a bidirectional relationship between worry and sleep in that sleep characteristics did not predict worry. Although several studies suggest that insomnia and reduced sleep length are associated with and possibly contribute to worry and anxiety (e.g., Kelly, 2002; Kumar & Vaidya, 1984; Means et al., 2000), many of these studies employ methodological designs that examine the relationship between anxiety and sleep more broadly, and none have utilized a daily process approach to examine the directionality of the relationship. Specifically, several studies have demonstrated that the development of insomnia predates the development of anxiety and mood disorders, and have suggested that insomnia might contribute to the onset of these disorders (Ford & Kamerow, 1989; Vollrath et al., 1989; see Harvey, 2001, for a review). These studies suggest that insomnia represents a risk factor for the later development of psychiatric disorders (Roth, 2007). One interpretation of these findings is that sleep disturbance leads to symptoms of anxiety, irritability, and worry, which later develop into anxiety and mood disorders. Another interpretation is that symptoms of worry, anxiety, and tension initially contribute to the development of insomnia and later contribute to the development of mood and anxiety disorders. Results of the present study are more consistent with the latter interpretation. In other words, for some individuals, the emergence of insomnia may be a prodrome to the development of other psychological disorders. Indeed, several investigations have demonstrated that insomnia is a prodromal feature of mood and anxiety disorders (Eaton, Badawi, & Melton, 1995; Neckelmann, Mykletun, & Dahl, 2007; see Gillin, 1998, for a review). Although these investigations suggest that insomnia symptoms also contribute to the development of psychological disorders, our results suggest that sleep disturbance does not affect worry on a daily basis.

The daily relationship between worry and sleep was not influenced by the type of intervention that participants underwent to reduce their worry. Although both worry and sleep disturbance decreased significantly more as a result of the stimulus control intervention relative to the focused worry intervention (McGowan & Behar, 2013), the daily relationship between both phenomena were not differentially affected. In other words, worry continues to predict sleep characteristics regardless

of the type of intervention participants engaged in. Thus, the temporal relationships examined in this investigation seem to be static, and do not change as a result of a reduction in worry or insomnia symptoms.

LIMITATIONS

The present study had several limitations. First, it is possible that we failed to find that sleep predicted worry the next day due to a methodological detail of our investigation. Specifically, greater time periods between the measurement of two phenomena decreases their ability to predict each other. For example, Stone, Neale, and Shiffman (1993) demonstrated that lagged or next-day effects of stressors on mood are rarely found in the literature. This is because the ability of an experience to affect subsequent mood decreases with time. Thus, because more time elapsed between the measurement of sleep and the subsequent measures of worry relative to the amount of time that elapsed between the measurement of worry and the subsequent measure of sleep, there may have been a decreased likelihood of detecting the lasting effects of sleep on subsequent worry. Another possibility is that the small sample size in this study limited the statistical power to detect sleep's potential effect on worry; however, an examination of the standardized effect sizes from these analyses demonstrated that these effects were very small.

Second, we did not include a measure of sleep quality. According to the cognitive model of insomnia, an individual's perception of the quality of his or her sleep might have a stronger influence on his or her propensity to worry the following day.

Third, participants retrospectively reported both worry before bed and sleep variables the following morning, introducing the risk of a mood–memory effect (i.e., participants who slept poorly might have inaccurately recalled more presleep worry activity). However, it is unlikely that this limitation can account for the finding that percentage of daily worry predicted sleep characteristics, as these variables were not measured simultaneously. Future research utilizing sleep diaries should seek to measure worry and sleep characteristics at different time points by asking participants to complete measures of worry prior to bed and measures of sleep upon awakening.

Fourth, our results may not generalize to nonanxious populations. Anxious individuals' sleep characteristics differ from those of nonanxious individuals (Rosa, Bonnet, & Kramer, 1983), and state anxiety is significantly correlated with sleep onset latency among insomniacs but not among normal sleepers (Chambers & Kim, 1993). Given that we examined the relationship between worry and sleep among high trait worriers, it is quite possible that the relationship between these variables is different for individuals who do not experience high levels of worry. Related to this, our sample was not diagnosed with insomnia, but participants did report moderate insomnia symptoms both at the baseline assessment and during the baseline week. It is possible that our results might not generalize to individuals with insomnia or to those with no sleep disturbance.

Fifth, this investigation did not use objective measures of sleep disturbance (e.g., polysomnography, actigraphy). Although sleep diaries have been found to have acceptable agreement with polysomnography (Rogers, Caruso, & Aldrich, 1993), the current findings are limited to participants' perception of their worry and sleep difficulties, which could be overestimated in individuals who are more prone to worry (Tang & Harvey, 2004).

Sixth, we did not ask participants about the use of medications or sleep aids that could have influenced sleep. The use of drugs that alter sleep (either positively or negatively) may alter the nature of the relationships examined in this investigation.

Finally, it is important to note that our design allows for the elucidation of predictive relationships, but we cannot infer causality from these results. Thus, although we consistently found that worry predicts sleep disturbance, we cannot assume that worry causes those disturbances. Future experimental work should address such questions of causality in the question to understand the impact of worry on sleep from day to day.

Conclusion

In spite of these limitations, our investigation has several strengths. First, this study is among the first to examine the relationship between worry and sleep using a daily process approach and multilevel modeling techniques. Second, ecological momentary assessment was used to assess worry and sleep measures in the moment. This approach reduces the time elapsed between an experience and an account of that experience, potentially yielding more accurate measures of individuals' experiences. Taken together, these strengths are noteworthy refinements over prior research. In conclusion, we demonstrated that in a sample of individuals with high trait worry who experienced moderate sleep disturbance, worry predicts sleep characteristics that night, but sleep does not predict worry symptoms the following day. Additionally, engaging in an intervention to reduce worry did not change the relationship between worry and sleep. Results from this study underscore the importance

of identifying and treating worry in individuals with comorbid worry and sleep difficulties.

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.beth.2015.12.003.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest.

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