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Time of day effects on the relationship between daily sleep and anxiety: An ecological momentary assessment approach

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ABSTRACT

Previous research has linked sleep disturbance to anxiety. However, evidence for this relation has been inconsistent, largely limited to retrospective reports that do not account for daily variability, and silent on when the association is most pronounced. Thus, the present study utilized ecological momentary assessment (EMA) to examine the effects of daily deviations in total sleep time (TST) and person-average TST on anxiety and whether these effects varied as a function of time of day in a sample of unselected adults ($N = 138$). Results indicate that the amount of TST on a given night, relative to personal average TST, negatively predicted anxiety, and this relation was significant in the morning and afternoon, but not evening. In contrast, person-average TST was unrelated to average anxiety. Relations between TST and anxiety did not differ across objective (e.g., actigraphy) and subjective (e.g., sleep diary) measures. Furthermore, the pattern of results remained the same when controlling for previous day's anxiety and were not bidirectional. These findings suggest that getting less sleep than is typical for the individual predicts subsequent anxiety, and this effect is particularly strong in the morning. Average sleep duration may be less important to the experience of anxiety than deviations from that average. These findings highlight the importance of EMA to examine how and when variability in sleep confers vulnerability for anxiety symptoms.

Recent attention has been given to the role of sleep disturbance in psychopathology, with accumulating evidence for the presence of sleep disturbance across the majority of disorders (Baglioni et al., 2017). In addition to general psychopathology, sleep disturbance has also been specifically linked to the experience of anxiety. Findings from prospective studies indicate sleep disturbance predicts symptoms of anxiety, including repetitive negative thinking (Cox, Cole, Kramer, & Olatunji, 2018) and general anxiety (Doane, Gress-Smith, & Breitenstein, 2015). Further, results from experimental studies indicate that both total sleep deprivation and partial sleep restriction result in increased anxiety (Babson, Trainor, Feldner, & Blumenthal, 2010; Reddy, Palmer, Jackson, Farris, & Alfano, 2017), suggesting a causal relation between acute sleep loss and elevated anxiety. Finally, sleep disturbance is evident in the majority of anxiety-related disorders (Cox & Olatunji, 2016) and predicts the development of an anxiety disorder (Batterham, Glozier, & Christensen, 2012).

Although some findings in the literature suggest a causal link between sleep disturbance and anxiety, evidence for this relation has not been wholly consistent. Indeed, in contrast to prospective evidence that sleep disturbance predicts anxiety, other studies have found a unidirectional relation between anxiety-related disorders and subsequent insomnia symptoms, though these findings are limited to adolescent samples (Alvaro, Roberts, Harris, & Bruni, 2017; Johnson, Roth, & Breslau, 2006). Similarly, although considerable research has found sleep-related deficits among those with anxiety disorders compared to controls, several studies have also found no such differences (see Cox & Olatunji, 2016 for a review). One possible source of these discrepancies relates to measurement. That is, the majority of extant research on sleep and anxiety has utilized retrospective measures that are vulnerable to recall bias (Shiffman, Stone, & Hufford, 2008). Further, previous research utilizing daily monitoring methods (i.e., sleep diaries, actigraphy) has generally aggregated these measures to yield average levels of sleep parameters. Such aggregation may mask the prospective impact of daily sleep variability on subsequent experiences of anxiety.

Many of these discrepant findings in the literature may be addressed with ecological momentary assessment (EMA) that enables researchers to sample sleep and anxiety as they occur in the participant's natural environment, both reducing recall bias and enhancing ecological validity. Such EMA data can be analyzed with multilevel modeling, which allows for the examination of person-average, daily-average, and within-day variability of variables of interest. Indeed, recent findings utilizing these methods have yielded a more consistent link between

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sleep disturbance and anxiety-related outcomes. For example, decreased subjective daily sleep quality predicts next day stress and anxiety in unselected samples (Kalmbach, Arnedt, Swanson, Rapier, & Ciesla, 2017; Lee, Crain, McHale, Almeida, & Buxton, 2017). Similarly, decreased subjective daily sleep quality predicts next day worry among those with generalized anxiety disorder (GAD; Thielsch et al., 2015), and decreased subjective daily sleep quality and sleep efficiency predict next day posttraumatic stress disorder (PTSD) symptoms among those with PTSD (Short, Allan, & Schmidt, 2017). Although more recent research has employed EMA to demonstrate a link between daily fluctuations in sleep and subsequent anxiety, these findings are limited by lack of objective sleep measurement. Given previous evidence for discrepancies between objective and subjective sleep measures (Lauderdale, Knutson, Yan, Liu, & Rathouz, 2008), studies relying only on subjective sleep assessment may lack precision in characterizing the effect of sleep disturbance on anxiety.

An additional strength of EMA is the ability to examine time of day effects, allowing for more detailed characterization of how dynamic processes, such as anxiety, vary between morning, afternoon, and evening. Research on the diurnal course of anxiety is limited; however, extant findings indicate anxiety-related processes may peak at certain times of day. Among those with OCD, obsessions are most frequent in the afternoon (Nota, Gibb, & Coles, 2014). Similarly, among those with panic attacks, general anxiety and panic symptoms are highest in the afternoon; however, sense of threat is highest in the morning (Kenardy, Fried, Kraemer, & Taylor, 1992). To date, however, no study has tested whether the relation between daily sleep disturbance and anxiety may vary as a function of time of day. Evidence for time of day effects on this relation could highlight when therapeutic intervention might be most effective or implicate processes that peak at similar times as potential underlying mechanisms. Previous research suggests conflicting possibilities for the direction of a time of day effect. For example, a recovery model would suggest that anxiety would diminish over time following a stressor such as sleep loss (Verkuil, Brosschot, & Thayer, 2014), thus anxiety may be highest in the morning and lowest in the evening. In contrast, homeostatic sleep pressure increases with sustained wakefulness (Borbely, Daan, Wirz-Justice, & Deboer, 2016), and this accumulation process may interact with poor sleep to produce highest anxiety in the evening when sleep pressure is highest.

The aim of the present study was to address an important gap in the literature by utilizing both subjective and objective sleep measures and EMA to examine the link between daily sleep and anxiety in a sample of unselected adults. Total sleep time (TST) was chosen as the index of sleep, as this parameter has the most consistency with polysomnography when measured by actigraphy (Ancoli-Israel et al., 2003). For reasons given above, we hypothesized that decreased subjective and objective daily and average TST and increased average insomnia symptoms (i.e., difficulties with sleep initiation and/or maintenance) would predict increased anxiety. We then conducted exploratory analyses to examine whether time of day moderated the effect of TST on anxiety. Given previous evidence for bidirectional links between sleep and anxiety, we also tested an alternate model of bidirectional relations between daily TST and daily anxiety.

1. Methods

1.1. Participants

The sample consisted of unselected undergraduate students and community adults ($N = 151$). Undergraduate students were recruited from psychology courses and were compensated with course credit. Community adults were recruited from flyers and ResearchMatch, a national health volunteer registry created by several academic institutions and supported by the U.S. National Institutes of Health as part of the Clinical Translational Science Award (CTSA) program, and were compensated with $25. Thirteen participants withdrew from the study for a final sample of 138 (75.5% female). Due to equipment availability, actigraphy data was collected on a subset of participants ($n = 100$).[1] Three participants failed to complete sleep diaries. Due to a programming error, eight participants did not complete the Morningness-Eveningness Questionnaire. Thus, the final samples for the objective and subjective TST models included 98 and 130 participants, respectively.

The mean age of the sample was 22.48 ($SD = 9.24$), ranging from 18 to 64. The majority of the sample was college age (18–22; $n = 117$; 84.2%). The age distribution of the remainder of the sample was as follows: 23–29 ($n = 8$; 5.8%), 30–39 ($n = 4$; 2.9%), 40–49 ($n = 3$; 2.2%), 50–59 ($n = 2$; 1.4%), 60–64 ($n = 3$; 2.2%). The ethnicity composition was as follows: Caucasian ($n = 80$; 57.6%), African American ($n = 17$; 12.2%), Asian ($n = 33$; 23.9%), Hispanic/Latino ($n = 7$; 5.1%), Other ($n = 1$; 0.7%). 33% of the sample met criteria for a major form of psychopathology, 12% met criteria for a mood disorder, and 24% met criteria for an anxiety disorder as determined by the MINI International Neuropsychiatric Interview. 8% screened positive for clinical insomnia as determined by the Insomnia Severity Index.

1.2. Measures and materials

Actigraphy. Actigraphy is an objective sleep measure that estimates sleep and wake from motion (Ancoli-Israel et al., 2003). The present study utilized ActiGraph wGT3X-BT activity monitors (ActiGraph, Pensacola, FL). Previous research indicates that actigraphy is highly accurate when compared to polysomnography (Marino et al., 2013) and that the ActiGraph wGT3X-BT is reliable and valid for estimating sleep (Cellini, Buman, McDevitt, Ricker, & Mednick, 2013). Objective TST was calculated with the Sadeh algorithm (Sadeh, Sharkey, & Carskadon, 1994).

Consensus Sleep Diary (CSD; Carney et al., 2012). The CSD is a 9-item sleep diary that asks participants about their last night of sleep. The CSD was developed by a panel of sleep experts to create a standard sleep diary for the assessment of daily sleep. Subjective TST was calculated as the difference between the time the participant began trying to sleep and the time of final awakening, minus sleep onset latency and wake after sleep onset.

Insomnia Severity Index (ISI; Bastien, Vallieres, & Morin, 2001). The ISI is a 7-item self-report measure of insomnia symptoms. Items include assessment of difficulties with sleep initiation and maintenance (e.g., "Difficulty falling asleep") and subjective impairment (e.g., "How satisfied/dissatisfied are you with your current sleep pattern?"). Items are rated on a Likert scale from 1 (*none*) to 4 (*very severe*), and higher scores indicate increased insomnia symptoms. A score of 15 or higher indicates clinical insomnia (Bastien et al., 2001). The ISI demonstrated adequate internal consistency at time 1 ($\alpha = 0.86$) in the present sample.

Mini International Neuropsychiatric Interview (MINI; Sheehan et al., 1998). The MINI is a structured diagnostic interview that assesses 17 DSM disorders. The MINI was administered by bachelor- and master-level students trained and supervised by a licensed clinical psychologist.

Morningness-Eveningness Questionnaire (MEQ; Horne & Ostberg, 1976). The MEQ is a 19-item self-report measure of chronotype and is thought to reflect the individual's circadian rhythms. Items on the MEQ are rated on a Likert scale ranging from 1 to 6 with answer options varying by item content. Higher scores indicate increased morningness. The MEQ demonstrated adequate internal consistency ($\alpha = 0.84$) in the present sample.

Momentary anxiety. Momentary anxiety was measured with a single item ("How anxious do you feel right now?") on a scale from 0 ("not anxious at all") to 100 ("most anxious you could ever imagine feeling").

[1] There was no difference on other sleep measures between participants who received an actigraph and those who did not.