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## Differential associations between chronotype, anxiety, and negative affect: A structural equation modeling approach

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### Abstract

**Background:** Increasing evidence implicates circadian rhythms, including chronotype, in anxiety symptoms and disorders. However, it remains unclear whether this relation is accounted for by sleep disturbance. Likewise, given overlap between anxiety and negative affect, a unique link between chronotype and anxiety remains to be established. The present study addressed these questions using a multimethod approach to determine whether there is a unique relation between chronotype and anxiety symptoms, controlling for sleep disturbance.

**Methods:** Indicators of chronotype, sleep disturbance, anxiety, and negative affect were collected in a sample of adults ( $N=151$ ) using a combination of subjective and behavioral measures both within and outside the laboratory over a 9-day period. Structural equation modeling was used to examine associations between latent constructs.

**Results:** Results revealed significant associations between sleep disturbance and both anxiety and negative affect. A significant association was found between chronotype and anxiety, over and above the effect of sleep disturbance. In contrast, the relation between chronotype and negative affect was nonsignificant after controlling for sleep disturbance.

**Limitations:** Unselected sample, lack of experimental manipulation, cross-sectional design.

**Conclusions:** These findings suggest a unique role of chronotype in anxiety and point to circadian disruption as a potential biological mechanism in anxiety-related disorders.

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#### Contributions

Ms. Cox designed the study, collected the data, performed the statistical analysis, and wrote drafts of the manuscript. Dr. Olatunji contributed to study design, oversaw data collection, and assisted with statistical analysis and manuscript preparation. All authors contributed to and have approved of the final manuscript.

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#### Compliance with ethical standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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#### Conflict of Interest

The authors declare that they have no conflict of interest.

## Keywords

chronotype; eveningness; sleep; anxiety; negative affect

Circadian rhythms have received increasing attention within the context of psychopathology, with circadian disruption posited as a contributing factor in multiple psychiatric conditions, including anxiety disorders (e.g., Wulff, Gatti, Wettstein, & Foster, 2010; McClung, 2013). Circadian rhythms are autonomous 24-hours cycles in processes ranging from gene expression to behavior that occur independent of environmental input, and misalignment in these rhythms may result in pathology (Roenneberg & Merrow, 2016). Indeed, multiple single nucleotide polymorphisms of circadian genes have been linked to anxiety disorders (Sipila et al., 2010). Likewise, there is considerable evidence for disruption in circadian and circadian-related processes among individuals with anxiety disorders. Alterations in diurnal cortisol secretion have been linked to both anxiety symptoms (Greaves-Lord et al., 2007) and disorders (Kallen et al., 2008; Vreeburg et al., 2013), and decreased melatonin has been implicated in affective disorders, including anxiety disorders, more broadly (Carpenter et al., 2017; Naismith et al., 2012). Similarly, delayed sleep timing has been linked to anxiety disorders generally (Robillard et al., 2015) and obsessive-compulsive disorder (OCD), specifically (Nota, Sharkey, & Coles, 2015). Individuals with delayed sleep phase disorder are also at an increased risk for anxiety and mood disorders (Reid et al., 2012). Finally, individuals with anxiety disorders also exhibit increased variability in daily activity rhythms (Luik et al., 2015).

Despite these findings, research on circadian disruption in anxiety disorders is hindered by the cost and burden of gold-standard chronobiology methods, as preferred methods such as sampling dim light melatonin onset or employing a constant routine procedure can be burdensome and difficult to implement in the large samples needed for behavioral research (Roenneberg, 2012). In contrast, chronotype, a measure of individual differences in circadian preference/phase of entrainment can be sampled through self-report measures and is an indicator of underlying circadian rhythms (Duffy, Rimmer, & Czeisler, 2001). Chronotype represents a spectrum from morningness to eveningness, such that individuals who trend towards eveningness have a later sleep-wake schedule and later peaks in circadian processes such as cortisol, core body temperature, and subjective alertness and vice versa (Bailey & Heitkemper, 2001; Kerkhof & Van Dongen, 1996). Importantly, eveningness may be indicative of desynchrony in circadian rhythms and environmental demands (Duffy et al. 2001). Consistent with evidence for circadian disruption in anxiety disorders, accumulating evidence links eveningness to anxiety symptoms in healthy samples (Alvaro, Roberts, & Harris, 2014; Park et al., 2015) and anxiety-disorder status in clinical populations (Lemoine, Zawieja, & Ohayon, 2013), though findings have been inconsistent on a unique link to anxiety disorders (Antypa, Vogelzangs, Meesters, Schoevres, & Penninx, 2016). However, chronotype has also been implicated in specific anxiety-related disorders, such that eveningness longitudinally predicts increased OCD symptoms (Cox, Tuck, & Olatunji, 2018) and is associated with increased posttraumatic stress disorder (PTSD) symptoms in military veterans (Hasler, Insana, James, & Germain, 2013).

Although existing research suggests that chronotype may indicate links between circadian rhythms and anxiety pathology (i.e., Cox et al., 2018), research has also implicated sleep disturbance in anxiety symptoms and disorders. For example, daily variability in sleep is linked to next day anxiety in both unselected (Cox, Sterba, Cole, Upender, & Olatunji, 2018) and anxiety-disordered samples (Short, Allan, & Schmidt, 2017; Thielsch et al., 2015). Likewise, sleep disturbance is evident in the majority of anxiety disorders (Cox & Olatunji, 2016), with particularly robust evidence for decreased sleep continuity (Baglioni et al., 2017). Sleep and circadian rhythms are closely linked. Sleep is regulated by both the homeostatic drive for sleep and the circadian arousal rhythm (Borbely, Daan, Wirz-Justice, & Deboer, 2016), and alterations in sleep produce variability in circadian processes (e.g., Eckel et al., 2015). It is perhaps unsurprising then that sleep is also linked to chronotype, with evidence for increased sleep disturbances associated with eveningness (Fernandez-Mendoza et al., 2010). Further, chronotype is associated with increased anxiety among individuals with insomnia (Passos et al., 2017). Given overlap between sleep and circadian processes, including chronotype, observed links between anxiety and chronotype may be better explained by concurrent sleep disturbance. However, the few studies that have examined this question have yielded mixed findings. Indeed, one recent study found that sleep disturbance mediates the relation between eveningness and anxiety symptoms in a sample of university students, but not among non-university young adults (Dickinson, Wolkow, Rajaratnam, & Drummond, 2018), and another study found that sleep disturbance partially mediated the relation between eveningness and OCD symptoms (Cox et al., 2018). Thus, it is unclear whether sleep disturbance fully accounts for the link between chronotype and anxiety. Notably, both of these studies are limited by utilizing single-measures of constructs of interest, and discrepant findings may be due to measurement error. Therefore, examination of the relations between chronotype, sleep disturbance, and anxiety using a multimethod approach is needed.

Chronotype has also been linked to negative affect and mood symptoms. Recent studies of large unselected samples indicate correlations between eveningness and general depression symptoms (Dickinson et al., 2018), as well as cognitive reactivity, a vulnerability factor for depression (Antypa et al., 2017). Similarly, evening chronotype is associated with increased odds for major depressive disorder (MDD) (Antypa et al., 2016; Merikanto et al., 2013), and increased eveningness is associated with depression symptom severity among those with MDD (Fares et al., 2015). Interestingly, recent findings suggest that the relation between evening chronotype and negative affect may be explained by sleep disturbances (Simor, Zavecz, Palosi, Torok, & Koteles, 2015; Tavernier & Willoughby, 2014). Given considerable conceptual and diagnostic overlap between anxiety and mood pathology (Clark & Watson, 1991; Moffitt et al., 2007), it is unclear whether chronotype is uniquely associated with anxiety, or rather is associated with affective symptoms more broadly. Evidence for specificity may point to circadian disruption as a biological vulnerability that distinguishes mood from anxiety disorders. An additional limitation of the extant literature in this area is reliance on single indicators of the constructs of interest, which are prone to measurement error. Alternatively, structural equation modeling (SEM) affords the opportunity to extract the underlying construct of interest from multiple indicators. This method reduces measurement error by utilizing the theoretically error-free latent factor (e.g., chronotype)

common to multiple, error-prone measures (e.g., Morningness-Eveningness Questionnaire, mean mid-sleep) (Cole & Maxwell, 2003; Loehlin & Beaujean, 2017). Thus, the present study employed SEM to elucidate the relations between chronotype, sleep disturbance, anxiety, and negative affect. It was hypothesized that chronotype, specifically eveningness, would be associated with increased anxiety and negative affect, after controlling for sleep disturbance.

## Methods

### Participants

The sample consisted of unselected undergraduate students and community adults ( $N = 151$ ; 74.7% female). 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. Participants age 18–65 were recruited. Due to equipment availability, actigraphy data was collected on a subset of participants ( $n = 100$ )<sup>1</sup>.

The mean age of the sample was 22.48 ( $SD = 9.21$ ), ranging from 18 to 64. The ethnicity composition was as follows: Caucasian ( $n = 88$ ; 58.7%), African American ( $n = 17$ ; 11.3%), Asian ( $n = 34$ ; 22.7%), Hispanic/Latino ( $n = 8$ ; 5.3%), Other ( $n = 3$ ; 2.0%). Within those recruited from undergraduate courses ( $n = 121$ ; 75% female), the mean age was 19.35 ( $SD = 1.21$ ), ranging from 18 to 23. The ethnicity composition of the undergraduate student sample was as follows: Caucasian ( $n = 66$ ; 55.0%), African American ( $n = 11$ ; 9.2%), Asian ( $n = 33$ ; 27.5%), Hispanic/Latino ( $n = 8$ ; 6.7%), Other ( $n = 2$ ; 1.7%). Within those recruited from the community ( $n = 30$ ; 73.3% female), the mean age was 35.13 ( $SD = 15.13$ ), ranging from 18 to 64. The ethnicity composition of the community sample was as follows: Caucasian ( $n = 22$ ; 73.3%), African American ( $n = 6$ ; 20.0%), Asian ( $n = 1$ ; 3.3%), Other ( $n = 1$ ; 3.3%).

### Measures and Materials

#### Chronotype and sleep measures

**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 exhibits high agreement with polysomnography (Marino et al., 2013), and actigraph estimates of total sleep time, sleep efficiency, and wake after sleep onset are highly correlated with PSG estimates, though estimates of sleep onset latency are modestly correlated (Slater et al., 2015). Further, the ActiGraph wGT3X-BT is reliable and valid for estimating sleep (Cellini, Buman, McDevitt, Ricker, & Mednick, 2013). Sleep efficiency was selected to indicate sleep disturbance, as it represents multiple aspects of poor sleep (i.e., decreased total sleep time, increased sleep onset latency, etc; Khan & Woodward,

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<sup>1</sup>There was no difference on other sleep measures between participants who received an actigraph and those who did not.

2018). Objective sleep efficiency 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 the previous night's sleep for 1 week. The CSD was developed by a panel of sleep experts to create a standard sleep diary for the assessment of daily sleep. Mid-sleep was calculated as the midpoint between time of sleep onset (calculated as time the participant began trying to sleep minus sleep onset latency) and time of final awakening (Roenneberg et al., 2007) for each day. Recent evidence suggests that a weekly average mid-sleep more closely approximates intrinsic circadian phase (Kantermann & Burgess, 2017) than mid-sleep on free days (Roenneberg et al., 2007); therefore, mean mid-sleep for the week was calculated. Mean mid-sleep was selected to indicate chronotype, as mid-sleep is recommended for subjective chronotype assessment (Roenneberg et al., 2007). Subjective sleep efficiency was calculated as the ratio of total sleep time to time in bed and was included as an indicator of sleep disturbance, as objective and subjective measures of sleep often differ (Ancoli-Israel et al., 2003).

**Insomnia Severity Index (ISI; Bastien, Vallieres, & Morin, 2001).** The ISI is a 7-item self-report measure of insomnia symptoms over the past 2 weeks. 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 ( $\alpha = .86$ ) in the present sample. The ISI was selected to indicate sleep disturbance given its utility in measuring subjective insomnia symptoms (Bastien et al., 2001).

**Morningness-Eveningness Questionnaire (MEQ; Horne and 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 reflect morningness, and lower scores reflect eveningness. The MEQ demonstrated adequate internal consistency ( $\alpha = .84$ ) in the present sample. The MEQ was selected to indicate chronotype, as previous research has shown MEQ scores to correlate with mid-sleep, the recommended chronotype indicator (Roenneberg et al., 2007).

**Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989).** The PSQI is a 19-item self-report measure of sleep quality and sleep disturbance over the past month. Items include reporting sleep variables such as typical number of hours slept each night and typical bedtime, as well as rating sleep problems on a Likert scale from 0 (*not during the past month*) to 3 (*three or more times a week*). The PSQI has 7 component scores (subjective sleep quality, sleep onset latency, total sleep time, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction) that are summed to calculate a total score, and higher scores indicate more severe sleep problems. The PSQI demonstrated borderline internal consistency ( $\alpha = .68$ ) in the present sample. The PSQI was selected to indicate sleep disturbance, as this measure and the ISI are the two self-report

measures recommended for assessing sleep disturbance (Buysse, Ancoli-Israel, Edinger, Lichstein, & Morin, 2006).

**Stanford Sleepiness Scale (SSS; Hoddes, Dement, & Zarcone, 1972).** The SSS is a 1-item self-report measure of current level of sleepiness. Answer choices range from 1 (*Feeling active and vital; alert; wide awake*) to 7 (*No longer fighting sleep, sleep onset soon; having dream-like thoughts*), with higher scores indicating increased sleepiness. Time of peak sleepiness was calculated as the mode of time of day (i.e., morning, afternoon, or evening) of highest SSS score across the EMA period. Time of peak sleepiness was selected to indicate chronotype based on the observation that subjective sleepiness peaks later in evening chronotypes compared to morning chronotypes (Taillard, Philip, Coste, Sagaspe, & Bioulac, 2003).

### **Anxiety and negative affect measures**

**Anxiety Sensitivity Index (ASI; Reiss, Peterson, Gursky, & McNally, 1986).** The ASI is a 16-item self-report measure of the fear of the sensations and behaviors associated with the experience of anxiety. Items on the ASI are rated on a Likert scale from 0 (*very little*) to 4 (*very much*), and higher scores indicate higher anxiety sensitivity. The ASI demonstrated adequate internal consistency ( $\alpha = .87$ ) in the present sample. The ASI was selected to indicate anxiety given considerable evidence for elevated anxiety sensitivity in anxiety-related disorders (Olatunji & Wolitzky-Taylor, 2009).

**Daily 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*). Momentary anxiety data were collected and managed using REDCap (Research Electronic Data Capture) hosted at Vanderbilt University (Harris et al. 2009). REDCap is a secure, web-based application designed to support data capture for research studies and is supported by UL1 TR000445 from NCATS/NIH. Average daily anxiety was calculated by averaging the momentary anxiety responses across the 7-day period and was selected to indicate anxiety, as ecological momentary assessment (EMA) reduces recall bias inherent in retrospective measures and enhance ecological validity (Shiffman, Stone, & Hufford, 2008).

**Depression, Anxiety, and Stress Scales-Short Form (DASS; Lovibond and Lovibond 1995).** The DASS is a 21-item self-report measure of symptoms of depression, anxiety, and stress over the past week. Only the 7-item depression subscale was used in the present analysis. Scores on the DASS short form can be multiplied by 2 to be converted to the full scale (Lovibond & Lovibond, 1995). Items on the DASS are rated on a Likert scale from 0 (*did not apply to me at all*) to 3 (*applied to me very much, or most of the time*), and higher scores indicate higher symptoms of depression. A short form score of 7 or higher suggests moderate depression (Lovibond & Lovibond, 1995). The depression subscale demonstrated adequate internal consistency ( $\alpha = .87$ ) in the present sample. The DASS depression subscale was selected to indicate negative affect given associations between negative affect and depressive symptoms (Nargon-Gainey, 2019).

**Distress Tolerance Scale (DTS; Simons & Gaher, 2005):** The DTS is a 15-item self-report measure of the ability to tolerate or withstand aversive emotions and experiences. Items are rated on a Likert scale from 1 (*strongly agree*) to 5 (*strongly disagree*), and higher scores indicate higher distress tolerance. The DTS demonstrated good internal consistency ( $\alpha = 0.90$ ) in the present sample. The DTS was selected to indicate negative affect given that low distress tolerance is implicated in experiencing elevated negative affect (Bernstein, Zvolensky, Vujanovic, & Moos, 2009).

**Mini International Neuropsychiatric Interview (MINI; Sheehan et al., 1998):** The MINI is a structured diagnostic interview that assesses 17 DSM-IV disorders. The MINI was administered by bachelor- and master-level students trained and supervised by a licensed clinical psychologist. Anxiety disorder status was dichotomized (i.e., met criteria for an anxiety disorder, did not meet criteria for an anxiety disorder) and was selected to indicate anxiety. PTSD and OCD were included in anxiety disorder status, as these disorders are similar in symptom content (i.e., fear, distress, and avoidance) to anxiety disorders as defined by DSM 5, and sleep disturbance and chronotype have been linked to both PTSD and OCD (Cox & Olatunji, 2016; Nota et al., 2015; Hasler et al., 2013).

**Paced Auditory Serial Addition Task (PASAT):** The PASAT is a computerized behavioral distress tolerance task (Lejuez, Kahler, & Brown, 2003). Numbers are presented in succession on a computer screen, and participants are instructed to add the presented number to the most previously presented number and select the sum. The participant then adds the next presented number to the most previously presented number. If the participant responds correctly, the participant gets a point. If the participant responds incorrectly or if a sum is not selected before subsequent number onset, the participant hears an aversive tone. The task consists of three levels with increasing difficulty. Level 1, which lasts for three minutes, is low difficulty and has a 3-second latency between presentations of numbers. Level 2, which lasts for five minutes, is medium difficulty and has a 1.5-second latency between numbers. Level 3 is high difficulty and has a 1-second latency between numbers. During level 3, a box labeled “Quit” appears on the screen. Participants are instructed before the task begins that clicking the box will end the task. Level 3 can last for up to 10 minutes, depending on when the participant chooses to end the task, if at all. Self-report ratings of current levels of anxiety and irritation were collected before the task begins and during a two-minute break between Levels 2 and 3. Anxiety and irritation response to the PASAT were calculated by subtracting baseline ratings from ratings during the task. Anxiety response to the PASAT was selected to indicate anxiety given associations between elevated anxiety reactivity to stressors and trait anxiety (Rudaizky, Page, & MacLeod, 2012). Irritation response to the PASAT was chosen to indicate negative affect given that irritability is a core feature of negative affect (Watson, Clark, & Tellegen, 1988). Previous research indicates that the PASAT induces anxiety and irritation in clinical and nonclinical samples (see Dixon-Gordon et al., 2015 for a review).

## Procedure

Data collection was completed through a combination of laboratory and EMA methods over a 9-day period. On day 1, participants attended a laboratory session that included informed

consent and administration of the MINI, MEQ, ISI, and PSQI. Participants were then given the CSD, an actigraph, and instructions for the upcoming week. During days 2–8, participants were instructed to complete the CSD each morning. Participants also received a survey via email with the momentary anxiety item and SSS at 8am, 2pm, and 8pm and were instructed to complete each survey within 2 hours of receipt. On day 9, participants returned to the lab to complete the ASI, DASS, DTS, and PASAT and return the CSD and actigraph. They were then debriefed. Data collection took place throughout the calendar year but did not include final exam periods or summer or winter breaks. All data collection periods included one weekend. Day 1 took place on Monday, Tuesday, Wednesday, or Thursday, and day 9 took place on the following Tuesday, Wednesday, Thursday, or Friday. This study was approved by the university's Institutional Review Board and conformed to the principles of the Declaration of Helsinki. All participants provided written informed consent prior to enrollment in the study.

Surveys that were completed outside of the specified 2-hour period were excluded from analysis (5.6% of observations). Incomplete surveys were considered missing (15% of observations). These rates are similar to rates of missingness in previous EMA studies (e.g., Short et al., 2017).

### Data Analytic Strategy

Structural equation modeling (SEM) was conducted with Mplus version 7 (Muthen & Muthen, 2015). SEM involves first using confirmatory factor analysis (CFA) to extract latent factors (e.g., anxiety) from observed indicators (e.g., measures that contain both anxiety and measurement error) by testing whether the covariance between observed indicators is due to a common underlying process. Path analysis is then used to determine the relative strength of each proposed relation in the model (Loehlin & Beaujean, 2017). Consistent with this approach, CFA was first used to identify a well-fitting measurement model. Latent variables were specified by observed indicators as follows (see Table 1): 1. chronotype: MEQ score, average mid-sleep, modal time of day of peak sleepiness; 2. sleep disturbance: ISI score, PSQI score, objective and subjective sleep efficiency; 3. anxiety: anxiety disorder diagnostic status, ASI score, anxiety response to PASAT, average daily anxiety; 4. negative affect: DTS score, DASS depression subscale score, irritation response to PASAT. Residuals were left uncorrelated, with the exception of the residuals of anxiety and irritation response to the PASAT, which were correlated due to being responses to the same stimulus (Cole, Ciesla, & Steiger, 2007).

Weighted least squares with means and variances adjusted (WLSMV) was chosen as the estimator given the inclusion of both categorical and continuous observed indicators (Muthen & Muthen, 2015). WLSMV is designed for categorical observed indicators and performs well compared to estimators designed for continuous observed indicators, such as robust maximum likelihood (MLR; Li, 2016). Model fit was determined with the following indices and cutoffs: chi square ( $p < .05$ ), Comparative Fit Index (CFI;  $> .95$ ; Hu & Bentler, 1999), Tucker Lewis Index (TLI;  $> .95$ ; Hu & Bentler, 1999), and Root Mean Square Error of Approximation (RMSEA;  $< .05$ ; Steiger, 1990).



The structural model tested the relations between chronotype and anxiety and negative affect controlling for sleep disturbance by regressing anxiety and negative affect onto chronotype and covarying chronotype and sleep disturbance. Path coefficients were standardized by fixing the variance of each latent variable to 1.

## Results

### Sample characteristics and associations between study variables

25.3% met criteria for an anxiety-related disorder, and 13.3% met criteria for major depressive disorder as determined by the MINI. This indicates slightly elevated rates of affective disorders relative to national prevalence rates (Kessler, Chiu, Demler, & Walters, 2005). Most participants (59.4%) were classified as an intermediate chronotype according to the MEQ, consistent with previous epidemiological findings (Adan & Natale, 2002; Paine, Gander, & Travier, 2006), followed by morning types (16.1%) and evening types (24.5%). Average level of insomnia symptoms was in the nonclinical range ( $M = 6.88$ ,  $SD = 4.94$ ) according to the ISI, and 8% screened positive for insomnia, consistent with reported prevalence rates for adults (Buysse et al., 2008). Average level of depression symptoms was in the nonclinical range ( $M = 3.64$ ,  $SD = 3.82$ ) according to the DASS. See Table 2 for zero-order correlations between study variables.

### Measurement Model

Results of the measurement model (see Figure 1) indicated that all factors loadings were significant ( $p < .05$ ), with the exceptions of anxiety response to the PASAT ( $p = .12$ ) and objective sleep efficiency ( $p = .26$ )<sup>2</sup>. The measurement model demonstrated good fit to the data ( $\chi^2(470) = 83.44$ ,  $p = .13$ ; CFI = .96; TLI = .94; RMSEA = .04).

### Structural Model

Results of the structural model (see Figure 2) indicated a significant correlation between chronotype and sleep disturbance, such that eveningness was associated with increased sleep disturbance,  $\phi = -.25$ ,  $SE = .08$ ,  $p < .05$ . Increased sleep disturbance significantly predicted increased anxiety,  $\gamma = .55$ ,  $SE = .09$ ,  $p < .001$ , and increased negative affect,  $\gamma = .47$ ,  $SE = .09$ ,  $p < .001$ . Likewise, chronotype was significantly associated with anxiety, such that eveningness significantly predicted increased anxiety, over and above the effect of sleep disturbance,  $\gamma = -.22$ ,  $SE = .11$ ,  $p < .05$ . In contrast, chronotype was unrelated to negative affect after controlling for sleep disturbance,  $\gamma = -.09$ ,  $SE = .10$ ,  $p = .37$ .

## Discussion

The present study utilized SEM to examine the relations between chronotype, sleep disturbance, anxiety, and negative affect. Results indicated that the latent sleep disturbance variable significantly predicted the latent anxiety variable, such that increased sleep disturbance was associated with medium increases in anxiety. This finding replicates

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<sup>2</sup>The model was also tested without the inclusion of these indicators. The measurement model demonstrated good fit and the pattern of structural model results was unchanged; therefore, these indicators were retained.

previous evidence linking poor sleep to anxiety symptoms (Dickinson et al., 2018) and provides more robust evidence for this relation by utilizing both self-report and behavioral indicators of sleep and anxiety, as well as prospective and retrospective measures. The latent sleep disturbance variable also significantly predicted the latent negative affect variable, such that increased sleep disturbance was associated with medium increases in negative affect, again providing further evidence for a sleep-mood relation (Bouwman, Bos, Hoenders, Oldehinkel, & de Jonge, 2017; de Wild-Hartmann et al., 2013; McCrae et al., 2008; Simor, Krietsch, Koteles, & McCrae, 2015). This is consistent with accumulating evidence implicating both subjective and objective sleep disturbance in the experience of affective symptoms (Bei et al., 2017). Poor sleep may limit the ability to effectively regulate emotions, potentially through the detrimental cognitive effects of sleep loss (Palmer & Alfano, 2017), thus conferring vulnerability for affective symptoms. Indeed, acute sleep loss impairs perceived and objective indicators of emotion regulatory abilities (Baum et al., 2014; Zhang, Lau, & Hsiao, 2018). Similarly, a recent study found that difficulties with emotion regulation mediate the relations between sleep and anxiety and mood symptoms (Palmer, Oosterhoof, Bower, Kaplow, & Alfano, 2018). Finally, objective and subjective indicators of poor sleep are associated with less activity in brain regions associated with emotion regulation during a reappraisal task in individuals with affective disorders (Klumpp et al., 2017). Taken together, these findings suggest that sleep disturbances may contribute to both anxiety and mood pathology.

Consistent with predictions, results also indicated that the latent chronotype variable significantly predicted the latent anxiety variable, such that eveningness was associated with small increases in anxiety. This finding replicates previous research showing that chronotype as indicated by self-report questionnaires is associated with anxiety (e.g., Markarian, Gildner, Pickett, & Warnke, 2019; Park et al., 2015) and extends these findings by linking multiple indicators of chronotype to anxiety, including the preferred indicator, average mid-sleep (Roenneberg et al., 2007; Kantermann & Burgess, 2017). It is notable that this is the first study to use a multimethod approach to link chronotype and anxiety. Several possible mechanisms may account for this relation. Chronotype is due in part to multiple genetic contributions (Kalmbach et al., 2017), and recent evidence indicates genetic overlap between chronotype and fear response systems (Lane et al., 2016). Thus, eveningness and anxiety may represent a phenotype of a shared underlying genotype. However, it is important to note that the magnitude of this effect is small, suggesting that chronotype may be one of many contributors to anxiety-related processes.

The link between eveningness and anxiety may also suggest underlying circadian disruption in anxiety pathology. Such disruption could be due to upstream genetic factors or a consequence of maladaptive behavior. Considerable research has delineated the negative effects of “living against the circadian clock” (Roenneberg & Mellow, 2016). So-called social jetlag, or a misalignment between the internal circadian clock and environmental demands (Wittman, Dinich, Mellow, & Roenneberg, 2006), can be conceptualized as a milder form of shift work and has been linked to poor mental health (see Taylor & Hasler, 2018 for a review). Indeed, alterations in circadian processes, including diurnal cortisol and body temperature, are evident in individuals experiencing social jetlag (Polugrudov et al., 2016; Rutters et al., 2014). Similarly, modern lifestyles (i.e., indoor living and exposure to

artificial light at night) can shift chronotype towards eveningness (Roenneberg & Merrow, 2016) and such a shift may have negative consequences for circadian synchrony. Combined with the present study, the existing literature suggests that disruptions in circadian regulation may then confer vulnerability for anxiety pathology.

Another putative mechanism linking chronotype to mental health outcomes is sleep disturbance. That is, perhaps a later chronotype, due to possible misalignment between desired timing and environmental demands, shift work, or lifestyle habits (Fabbian et al., 2016), results in difficulties with sleep initiation, insufficient sleep duration, and/or poor quality sleep, and these sleep disturbances then contribute to affective symptoms. Indeed, recent findings from cross-sectional samples indicate that sleep disturbances partly account for the relations between eveningness and symptoms of depression and anxiety in unselected samples (Dickinson et al., 2018; Simor et al., 2015). Similarly, a recent prospective study found that insomnia symptoms partially mediated the relation between eveningness and obsessive-compulsive symptoms, though a direct effect of eveningness remained (Cox et al., 2018). Consistent with extant findings, results of the anxiety model indicated that the latent chronotype variable was associated with the latent anxiety variable, over and above the significant association between the latent sleep disturbance variable and the latent anxiety variable. Though the cross-sectional design of the present study precludes the ability to examine sleep disturbance as a mechanism linking chronotype and anxiety, this finding suggests that the relation between chronotype and anxiety is not fully accounted for by sleep disturbance. That is, while sleep disturbance is likely one mechanism by which eveningness confers risk for anxiety pathology, other mechanisms remain to be identified. Notably, the magnitude of the association between chronotype and anxiety was smaller relative to that between sleep and anxiety, suggesting that chronotype may be a small but robust factor that contributes to anxiety together with other processes, like sleep disturbance.

In contrast, the relation between the latent chronotype variable and the latent negative affect variable was nonsignificant after controlling for the latent sleep disturbance variable. Thus, these findings suggest that the link between eveningness and mood pathology may be better explained by sleep disturbance. This interpretation is consistent with recent studies showing that the relation between eveningness and depression symptoms is fully mediated by sleep disturbance in unselected samples (Bakotic, Radosevic-Vidacek, & Bjelajac, 2017) and among individuals with major depressive disorder (Selvi et al., 2018). Taken together with the findings from the anxiety model, these results suggest that disruptions in circadian-related processes may distinguish mood and anxiety pathology. However, additional research is needed to clarify the physiological underpinnings of chronotype that may yield novel insight into divergent etiologies of affective disorders.

Evidence that the role of chronotype in the experience of anxiety may not simply be an artifact of sleep disturbance suggests that circadian-related interventions may be useful targets in the treatment of excessive anxiety symptoms. Accumulating evidence suggests that cognitive behavior therapy for insomnia (CBT-I) is effective at reducing general anxiety (Belleville, Cousineau, Levrier, & St-Pierre-Delorme, 2011), as well as disorder-specific anxiety symptoms (Ho et al., 2016). Importantly, though present findings suggest the utility of moving beyond sleep-specific interventions to identify novel circadian-related targets for

anxiety disorder treatment, there is a dearth of literature on chronotherapies for anxiety disorders. Although previous findings have established the utility of light therapy for major depressive disorder (Al-Karawi & Jubair, 2016), no study to date has examined light therapy for any anxiety disorder. However, one recent pilot study found preliminary evidence for the efficacy of cognitive behavioral social rhythm therapy (CBSRT), an intervention that targets circadian rhythms by regularizing the sleep/wake cycle, increasing light exposure, and increasing contact with *zeitgebers*, or environmental cues for circadian synchrony, for veterans with comorbid PTSD and MDD (Haynes et al., 2016). Additional research is needed to determine whether CBSRT might be effective for other anxiety disorders with and without comorbid MDD. Likewise, agomelatine, a melatonin agonist, has been shown to be effective for generalized anxiety disorder (Stein et al., 2018), suggesting that chronotherapies recommended for DSPD (Auger et al., 2015) may also be beneficial for anxiety disorders. Further, these findings suggest that assessment of sleep and chronotype in individuals seeking treatment for anxiety disorders and anxiety in individuals seeking treatment for sleep and circadian rhythm disorders may enhance case conceptualization and promote a more holistic treatment approach.

The present results indicate a unique relation between chronotype and anxiety, such that increased eveningness was associated with increased anxiety, over and above the link between sleep disturbance and anxiety. In contrast, the relation between chronotype and negative affect was better explained by sleep disturbance. This study is the first to utilize a multimethod SEM approach to examine these processes. However, the present findings must be considered within the context of the study limitations. For example, the sample was unselected; therefore, the present findings may not generalize to those with affective disorders. Although 25.3% and 13.3% of the sample met criteria for an anxiety disorder or major depressive disorder, respectively, these findings should be replicated in clinical populations. Similarly, the homogeneity of the sample, particularly with regards to gender, also limits the generalizability of these findings. Likewise, given that the majority of the sample were college-aged, these findings may not generalize to older adults, though previous findings indicate a chronotype-anxiety link in middle-aged adults (Diaz-Morales & Sanchez-Lopez, 2008). Although the utilization of SEM decreases measurement error, another study limitation is that some gold-standard indicators of the latent constructs were not sampled (e.g., polysomnography for sleep disturbance; dim light melatonin onset for chronotype, psychophysiological indicators of anxiety and negative affect). Thus, each latent variable remains an imperfect estimation of the true construct and additional research utilizing different indicators is necessary to determine the robustness of the present results. Additionally, replication is needed in a larger sample.

Another important limitation is that the cross-sectional nature of the study design precludes determination of temporal ordering and/or causality. Future research utilizing experimental paradigms is necessary to delineate any causal links between study variables. It is important to note that chronotype represents one facet of circadian rhythms; therefore, these findings may not reflect underlying physiology, and additional experimental and naturalistic research is necessary to fully characterize circadian physiology in anxiety symptoms and disorders. Similarly, mood pathology is heterogeneous, and findings related to negative affect may not generalize to depression symptoms or major depressive disorder. Thus, depression-specific

replication is necessary. Further, other processes related to psychopathology have been linked to chronotype, such as anger, impulsivity, and substance use (Fabbian et al., 2016). Thus, while the present findings suggest that the relation between anxiety and chronotype may be independent of negative affect, it remains unclear whether the observed effect is unique from other psychopathology-related processes. Likewise, given high conceptual overlap between anxiety and negative affect, replication using more precise and distinct indicators of these constructs is needed. Finally, the present study did not examine the potential effects of substance or medication usage. Despite these limitations, the present study highlights a potentially unique role for chronotype in the experience of anxiety. Future research addressing the study limitations may further clarify the mechanisms that may account for this association and extend these findings to specific anxiety disorders.

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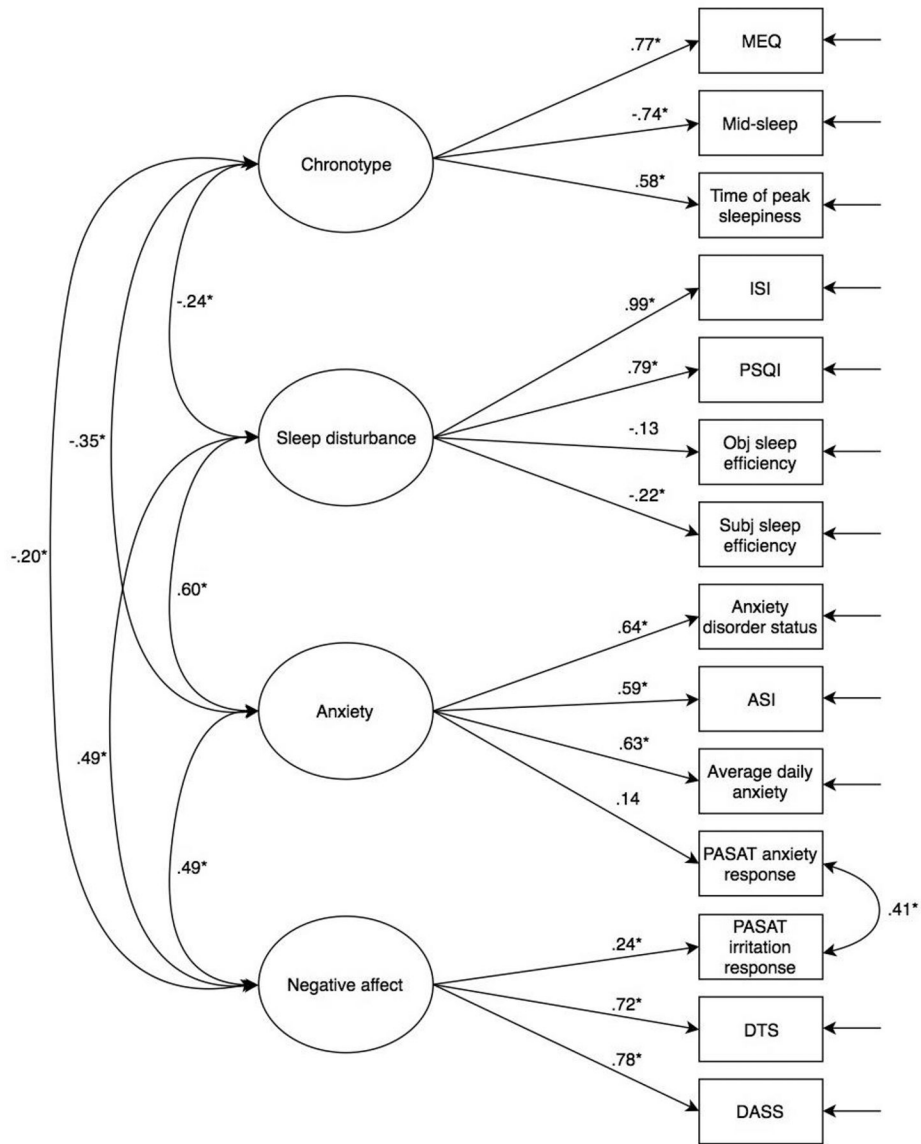
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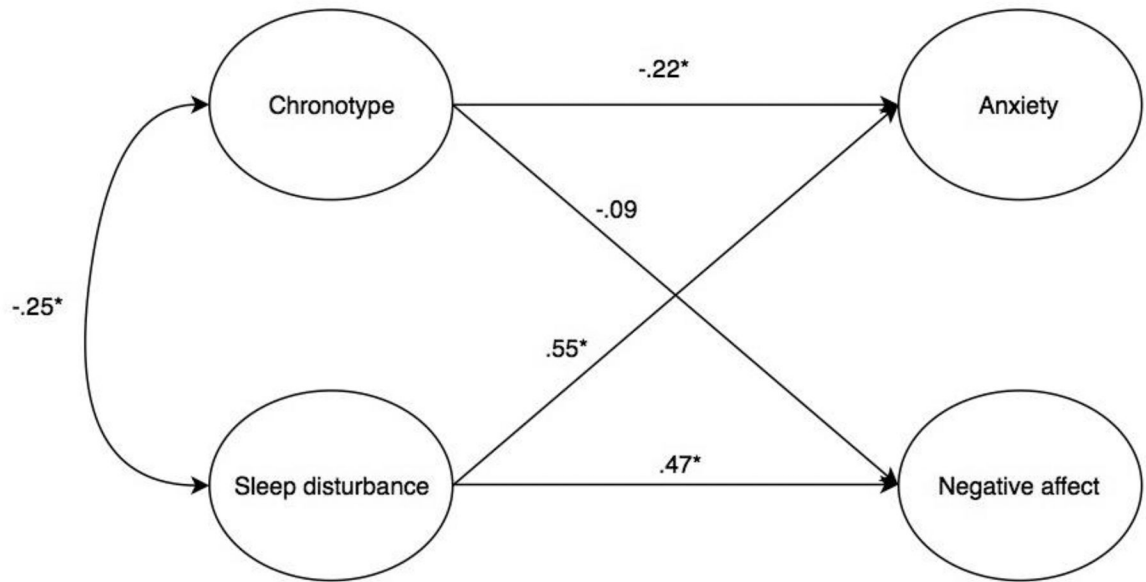
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### Highlights

- Eveningness associated with increased anxiety
- Effect independent of sleep disturbance
- Effect of eveningness on increased negative affect explained by sleep disturbance
- Chronotype may reflect underlying circadian dysregulation in anxiety pathology



**Figure 1.** The measurement model depicting factor loadings of manifest indicators onto the latent constructs and associations between latent constructs.



**Figure 2.**  
The structural model depicting the relations between latent chronotype and anxiety and negative affect, controlling for sleep disturbance.

**Table 1**

Observed indicators of latent chronotype, sleep disturbance, anxiety, and ne-gative affect.

<b>Latent Variable</b>	<b>Observed Indicator</b>
Chronotype	Morningness-Eveningness Questionnaire (MEQ)
	Mid-sleep
	Time of peak sleepiness
Sleep disturbance	Insomnia Severity Index (ISI)
	Pittsburgh Sleep Quality Index (PSQI)
	Objective sleep efficiency
	Subjective sleep efficiency
Anxiety	Anxiety disorder status
	Anxiety Sensitivity Index (ASI)
	Average daily anxiety
	Anxiety response to the Paced Auditory Serial Addition Task (PASAT)
Negative affect	Irritation response to the PASAT
	Distress Tolerance Scale (DTS)
	Depression Anxiety and Stress Scale, depression subscale (DASS)

**Table 2**Descriptive statistics and correlations for study measures ( $N = 151$ ).

Measures	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
<b>1. MEQ</b>	--													
<b>2. Mid-sleep</b>	-.56**	--												
<b>3. Peak Sleepiness</b>	.34**	-.49**	--											
<b>4. PSQI</b>	-.12	.10	-.17	--										
<b>5. ISI</b>	-.20**	.20*	-.20	.77**	--									
<b>6. Obj SE</b>	.18*	-.08	-.04	-.08	-.07	--								
<b>7. Subj SE</b>	-.04	-.04	.04	.25**	-.24**	.33**	--							
<b>8. Anx DO</b>	-.24*	-.03	.14	.47**	.46**	.02	-.17	--						
<b>9. ASI</b>	-.17*	.17	-.16	.20**	.31**	.06	-.05	.35**	--					
<b>10. PASAT Anxiety</b>	.10	.03	.10	.02	.14*	.06	-.09	.17	.14	--				
<b>11. Daily Anxiety</b>	-.24**	.15*	-.15	.33**	.35**	.24	.01	.33**	.41**	.12	--			
<b>12. DASS</b>	-.18*	.11	-.05	.31**	.35**	-.18	-.05	.39**	.41**	.11	.39**	--		
<b>13. DTS</b>	-.11	.06	-.13	.27**	.36**	-.03	-.07	.31**	.39**	.01	.41**	.58**	--	
<b>14. PASAT Irritation</b>	-.04	.01	.11	.04	.19*	-.13	-.07	.12	.14	.42**	.14	.16*	.17*	--
<b>M</b>	48.63	4:38am		6.42	6.88	78%	88%		19.63	14.63	14.60	3.64	2.49	19.72
<b>SD</b>	9.33	61 min		3.07	4.94	8.09	0.55		10.29	22.94	14.42	3.82	.79	25.59
<b>Range</b>	29–71	1:52–7:40am		0–17	0–23	47–92%	65–98%		2–53	–73–88	0–80	0–19	1.17–4.21	–70–99

Note. MEQ = Morningness-Eveningness Questionnaire; PSQI = Pittsburgh Sleep Quality Index; ISI = Insomnia Severity Index; Obj SE = Objective sleep efficiency; Subj SE = Subjective sleep efficiency; Anx DO = Anxiety disorder status; ASI = Anxiety Sensitivity Index; PASAT Anxiety = Anxiety response to Paced Auditory Serial Addition Task; DASS = Depression, Anxiety, and Stress Scale, Depression Subscale; DTS = Distress Tolerance Scale; PASAT Irritation = Irritation response to Paced Auditory Serial Addition Task.

\*  $p < .05$ ,

\*\*  $p < .01$