THE THEORY OF PLANNED BEHAVIOR AND SLEEP OPPORTUNITY: AN ECOLOGICAL MOMENTARY ASSESSMENT OF INTRA-INDIVIDUAL VARIABILITY

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DOCTOR OF PHILOSOPHY

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ABSTRACT

Insufficient sleep duration is associated with poor physical and mental health outcomes, and many Americans report that they are not meeting sleep duration recommendations. Many individuals choose to restrict their own sleep, yet little is known about the source of this sleep deficit. Recent research efforts have used the Theory of Planned Behavior (TPB) to predict sleep health behavior. However, this research is limited in that it fails to measure volitional sleep behavior and focuses exclusively on between-person differences. This study addressed these limitations by using an intensive longitudinal design to test how constructs of the TPB relate to nightly sleep opportunity. Healthy college students (N=79) completed a week long study in which they completed 4 ecological momentary assessment signals per day that measured their attitudes, perceived norms, perceived behavioral control (PBC), and intentions relating to their nocturnal sleep opportunity. Participants wore an actiwatch each night of the study to measure their sleep opportunity. Analyses revealed between- and within-day variability of attitudes, perceived norms, PBC, and intentions. Further, there were significant between- and within-day trajectories of these constructs. Mixed linear models demonstrated that both intentions and PBC were significant predictors of subsequent sleep opportunity, and that PBC was the strongest predictor of future intentions. The between-and within-day patterns of these constructs highlight important considerations for their measurement, and provide insight into the potential refinement of sleep promotion efforts. Results also demonstrate that within-person changes in PBC and intentions predict subsequent sleep opportunity, demonstrating the need for a daily framework when using the TPB to predict sleep health behavior.

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INTRODUCTION

Insufficient sleep duration is associated with many health-related outcomes, including mortality (Cappuccio, D'Elia, Strazzullo, & Miller, 2010), obesity (Gangwisch, Malaspina, Boden-Albala, & Heymsfield, 2005; Buxton & Marcelli, 2010), type 2 diabetes (Yaggi, Araujo, & McKinlay, 2006), cardiovascular disease (Cappuccio, Cooper, D'elia, Strazzullo, & Miller, 2011), poor quality of life (Strine & Chapman, 2005), poor neurobehavioral performance (Van Dongen, Baynard, Maislin, & Dinges, 2004), health risk behaviors (McKnight-Eily, Eaton, Lowry,Croft, Presley-Cantrell, & Perry, 2011; Strine & Chapman, 2005), depression (Cole & Dendukuri, 2003), and anxiety (Papadimitriou & Linkowski, 2005). Although sleep is important for both mental and physical health, many Americans report that they do not get enough sleep, presenting a major public health issue in the United States (Institute of Medicine, 2016). In fact, approximately 66% of adolescents (National Sleep Foundation 2006; Wheaton, Jones, Cooper, & Croft, 2018), 70% of college students (Buboltz, Brown, & Soper, 2001; Lund, Reider, Whiting, & Prichard, 2010), and 35% of adults (CDC, 2016; Liu, 2016) report restricted sleep. However, the source of the U.S. sleep deficit is not entirely understood.

It is estimated that 10% of adults in the U.S. have a clinical sleep disorder (Ram, Seirawan, Kumar, & Clark, 2010), and 7.7% of college students have insomnia (Schlarb, Kulessa, & Gulewitsch, 2012). These prevalence rates demonstrate that only a small percentage of restricted sleep can be attributed to sleep disorders, suggesting that many individuals do not get enough sleep by choice. Behavioral sleep restriction (BSR) occurs when an individual's sleep opportunity (i.e., the amount of time that an individual allows themselves to try to sleep) is shorter than the sleep duration (i.e., the actual amount of sleep obtained within the sleep opportunity window) recommended, thus making adequate sleep impossible to obtain. Whereas sleep duration is influenced by a broad range of behavioral, environmental, and physiological factors (Klerman & Dijk, 2005; Irish, Kline, Gunn, Buysse, & Hall, 2015), sleep opportunity is directly within behavioral control, and therefore represents an important target for sleep health promotion efforts. Research on BSR is still in its infancy, but preliminary work suggests that a number of factors, such as social obligations and work, often prevent healthy sleepers from achieving an ideal sleep opportunity (Dickerson, Klingman, & Jungquist, 2016), despite the proximal and distal benefits of sleep to health and functioning. We do not yet understand why or how individuals make decisions about establishing healthy sleep opportunities or engaging in BSR.

The Theory of Planned Behavior

The Theory of Planned Behavior (TPB) offers an ideal theoretical framework to study sleep opportunity. The TPB has been used for decades to study why people participate, or do not participate, in various health behaviors. The TPB states that volitional behavior results from intentions to perform that behavior, and intentions are influenced by: attitudes, subjective norms, and perceived behavioral control (PBC) of that behavior (Ajzen, 1991; Fishbein & Ajzen, 2011). Attitudes toward a behavior are determined by one's beliefs about the behavior (e.g., allowing myself to sleep at least 8 hours per night can benefit my mental and physical health) and the evaluation of those outcomes (e.g., mental and physical health are important to me). Subjective norms toward a behavior are determined by normative beliefs (e.g., my friends think I should be getting more sleep) and a motivation to comply with those beliefs (e.g., my friends' beliefs are important to me). Further, normative beliefs consist of injunctive norms (i.e., the perception of what they think others want them to do) and descriptive norms (i.e., the perception of whether those close to them perform the given behavior themselves). PBC is the perception of barriers or facilitators of a given behavior, and are determined by control beliefs (e.g., I can watch less TV at night to allow myself more time to sleep) and perceived power (e.g., watching TV at night is an easy barrier to overcome). If an individual has a favorable attitude towards a behavior, believes that others think they should engage in a behavior, and has a high perception of control over the behavior, then they are likely to form an intention to perform the behavior. The TPB has been used to study the prediction of other health behaviors, such as diet and physical activity (Godin, & Kok, 1996; Hausenblas, Carron, & Mack, 1997; Downs & Hausenblas, 2005). Using the TPB not only provides a framework to predict health behavior, but also allows for the development of theory-based interventions to modify that behavior. In fact, the TPB has been used to successfully modify a range of health behaviors, including diet and physical activity (Kelley & Abraham, 2004; Darker, French, Eves, & Sniehotta, 2010; White et al., 2012), and theoretically based interventions are more effective in modifying health behavior than atheoretical interventions (Glanz & Bishop, 2010).

The Theory of Planned Behavior Applied to Sleep Health

Given the success of the TPB in both predicting and modifying health behaviors, it can provide tremendous benefit when applied to the study of sleep (Mead & Irish, 2019). To date, 6 studies have used the TPB to predict sleep-related behavior, such as coffee consumption or keeping a consistent sleep schedule (Kor & Mullan, 2011; Lao, Tao, & Wu, 2016; Tagler, Stanko, & Forbey, 2017a-c; Strong, Lin, Jalilolghadr, Updegraff, Broström, & Pakpour, 2018). However, the focus of the current study is sleep duration, and an additional 4 studies have specifically examined sleep duration intentions and behavior (Knowlden, Sharma, & Bernard, 2012; Stanko, 2013; Robbins & Niederdeppe, 2015; Tagler, Stanko, & Forbey, 2017d). These studies demonstrate that the attitudes, norms, and PBC significantly predict sleep intentions, and that intentions and PBC significantly predict sleep behavior. Knowlden and colleagues (2012) found that more positive attitudes, subjective norms, and PBC were all associated with stronger intentions to achieve a healthy sleep duration, explaining 36.2% of the variance. Moreover, higher PBC and greater intentions both significantly predicted longer sleep duration, explaining 34.5% of the variance. While this study found that all components of the model were significant predictors, this has not been demonstrated elsewhere. Stanko (2013) found that only subjective norms and PBC were positively associated with intentions to obtain 7-8 hours of sleep, but this still accounted for 62.6% of the variance in these intentions. Further, intentions did not significantly predict sleep duration, but PBC was a significant predictor and explained 9.1% of the variance in sleep duration. In another study of college students, more positive attitudes and perceived norms, but not PBC, predicted stronger intentions to obtain a healthy sleep duration, and explained 44% of the variance in intentions (Robbins & Niederdeppe, 2015). Similar to Stanko (2013), intentions were not a significant predictor of sleep duration, but PBC significantly predicted 41% of the variability in sleep duration (Robbins & Niederdeppe, 2015). Lastly, Tagler and colleagues (2017d) found that more positive attitudes, subjective norms, and PBC all predicted stronger intentions to obtain a healthy sleep duration, and predicted 55% of the variance. However, only intentions predicted sleep duration behavior, and explained 15% of the variability in subjective sleep duration and 11% of the variability in objectively measured sleep duration.

Taken together, these studies demonstrate that, as a whole, the TPB is an effective framework for predicting sleep duration. However, there are mixed findings regarding which components of the model best predict intentions and behavior. There are two key limitations in the literature that may be contributing to the inconsistent results. First, the current research does not focus on volitional behavior. Most studies measure intentions and behavior for sleep duration, and not sleep opportunity, with only one exception. Tagler and colleagues (2017d) assessed sleep opportunity intentions and subjective sleep behavior, but their objectively measured sleep behavior was sleep duration. Although sleep opportunity and sleep duration are strongly associated with one another in healthy samples, the discrepancy between opportunity and duration can be substantial, and the TPB is most appropriately applied to sleep opportunity intentions and behavior, not sleep duration. In fact, specific definitions of the behavior's action, target, context, and time (TACT) are crucial components of the TPB (Fishbein & Ajzen, 2011). Specifically, defining sleep *duration* as the behavior's action is inappropriate, as it is not the behavior in question. Rather, sleep *opportunity* is the behavior's action being studied, due to its volitional nature.

The second major limitation of the current literature investigating sleep through the TPB is its exclusive focus on between-person effects, which fails to account for the intra-individual variability of attitudes, perceived norms, PBC, intentions, and behavior. Moreover, the findings from between-person methods do not always translate to within-person processes (Curran & Bauer, 2011). Research has demonstrated that nightly sleep parameters vary within individuals, and this intra-individual variability, even after controlling for mean level sleep, is associated with poor physical and mental health (Bei, Wiley, Trinder, & Manber, 2016). Further, these between-person studies tend to examine more distal relationships between attitudes, perceived norms, PBC, intentions, and behavior by using a single assessment to predict behavior days, weeks, or even months later. Thus, these designs fail to identify both the intra-individual fluctuations (Molenaar & Campbell, 2009) and the more proximal (i.e., daily) relationships between attitudes, perceived norms, PBC, intentions, and behavior (Maher, Rhodes, Dzubur, Huh, Intille, &

Dunton, 2017). The emphasis on more distal prediction is contrary to the natural human view of behavior as a daily experience. Accordingly, we are more likely to be influenced by proximal behaviors and cognitions (Conroy et al., 2013; Dickerson, Klingman, & Jungquist, 2016). The TPB offers a framework in which to address these limitations by studying sleep-related attitudes, perceived norms, PBC, intentions, and behaviors in a daily context.

Intra-Individual Variability of Physical Activity Theoretical Constructs and Intentions

To date, no studies have examined intra-individual variability in sleep attitudes, perceived norms, PBC, intentions, and behavior using the TPB. However, this daily framework has been used in the study of physical activity. Like sleep opportunity, physical activity is essential for health, occurs every day, and is largely under volitional control. Consistent with methodological trends, research on physical activity has focused primarily on between-person effects (Hagger, Chatzisarantis, & Biddle, 2002; McEachan, Conner, Taylor, & Lawton, 2011), and only recently have studies begun to test the intra-individual variability of intentions to engage in physical activity. For example, Conroy and colleagues (2011) conducted weekly assessments of intentions to engage in exercise for 10 weeks and reported that when an individual’s weekly intentions were stronger than their average intentions, this was significantly associated with more exercise behavior that week. While this study examined weekly fluctuations in intentions, more recent studies have used a daily framework. Conroy and colleagues (2013) followed these findings of weekly intra-individual variations in exercise intentions and behaviors with a study focused on a daily intra-individual variability design. Findings revealed that both between- and within-person intention strength predicted sedentary behavior, but within-person fluctuation in intentions was a stronger predictor of subsequent behavior than between-person differences in intentions. Students with higher overall intentions to not be sedentary displayed less sedentary behavior, and on days in which participants had greater than usual intentions to not be sedentary they had reduced sedentary behavior. In another study of college students, more than half of the variability in intentions to exercise was within, rather than between-persons, but daily intentions were not related to same day physical activity (Rebar, Elavsky, Maher, Doerksen, & Conroy, 2014). However, on days with weaker than an individual's usual intentions, physical activity habit strength was related to greater levels of physical activity that day. Similarly, a study in older adults found that daily intentions to engage in physical activity were not associated with subsequent physical activity, but greater positive affect strengthened intention-behavior coupling (Maher, Rhodes, Dzubur, Huh, Intille, & Dunton, 2017). These studies clearly demonstrate that there is a considerable amount of intra-individual variability in physical activity intentions and behavior, in which case the TPB would predict considerable variability in related attitudes, social norms, and PBC.

However, few studies have measured intra-individual variability in the theoretical constructs that influence exercise intentions in the TPB. Hobbs and colleagues (2013) conducted 6 separate N of 1 designs in which participants self-reported their attitudes, perceived norms, self-efficacy (i.e., one's perception that they are able to perform a particular behavior), and intentions towards engaging in physical activity twice a day over a 6-week period. For all participants, there was meaningful, daily intra-individual variability for attitudes, perceived norms, PBC, self-efficacy, and intentions. Moreover, intentions predicted physical activity behavior in all but one participant. Another study of 63 college students measured attitudes, perceived norms, self-efficacy, intentions, and moderate-vigorous physical activity (MVPA) once per day for 14 consecutive days (Conroy, Elavsky, Doerksen, & Maher, 2013). Intentions to engage in MVPA were stronger on days with more positive than usual attitudes, injunctive norms, or self-efficacy, and greater than usual intentions during the evening were associated with more activity the following day. Together, these studies suggest that daily intentions to engage in physical activity fluctuate due to intra-individual variability in attitudes, perceived norms, and PBC. This research illustrates between-day intra-individual variability in these constructs, and it is also reasonable to expect that they would fluctuate *within* days as well.

Two studies have assessed within-day variability of physical activity self-efficacy and intentions. A study of 116 adults tested whether self-efficacy and intentions varied both within- and between- study days. Participants completed 3 separate, 4 day samplings of ecological momentary assessment (EMA) protocols (Maher, Dzubur, Huh, Intille, & Dunton, 2016). During the week, intentions were highest in the morning, while self-efficacy was relatively high and stable throughout the day until drastically declining at around 5:00PM. Over the weekend, self-efficacy was high until around 10:45AM and declined the rest of the day, and similarly, intentions to engage in physical activity sharply declined throughout the day starting at 1:00PM. Further, on weekdays, intentions predicted subsequent MVPA in the morning and evening, but not at any other point during the day. Another study demonstrated that self-efficacy varies across different contexts throughout the day (e.g., home vs. work, indoors vs. outdoors), and that MVPA was more likely in the following two hours when self-efficacy or intentions were higher than usual (Pickering, Huh, Intille, Liao, Pentz, & Dunton, 2016). Taken together, these results illustrate remarkable patterns of behavioral self-efficacy and intentions to engage in physical activity, and have implications for the use of the TPB in health behavior research. Specifically, studies that aim to identify associations between daily intentions and behavior may not capture the true relationships between them if they are measured at only one time point per day. Given the findings from Maher and colleagues (2016), study designs that assess PBC and intentions in the morning would likely find strong intentions and PBC towards physical activity, whereas they would be lower if the same individuals were assessed in the evening. This inconsistency may contribute to mixed findings regarding the coupling of behavioral intentions and behavior. Therefore, assessing attitudes, perceived norms, PBC, and intentions throughout the day provide a more comprehensive perspective of an individual's intentions toward engaging in health behavior.

The Current Study

The current literature examining intra-individual variability of physical activity attitudes, perceived norms, PBC, and intentions have several important takeaways that can be applied to inform and advance sleep research. It demonstrates that attitudes, perceived norms, PBC, and intentions to perform physical activity fluctuate within individuals at the weekly, daily, and within-day level, and that utilizing a between-person design to predict behavioral intentions fails to capture significant within-person variability in intentions and behavior. Both physical activity and sleep are experienced in a 24-hour context, and thus a daily design is better suited to predict these health behaviors. Examining the intra-individual variability in sleep attitudes, perceived norms, PBC, intentions, and behavior can provide important insight into why people may choose to restrict their sleep and how sleep health promotion efforts may be improved or refined. The current study builds upon this work by using an intensive longitudinal design and has three primary aims: 1) to characterize the between- and within-day variability of attitudes, perceived norms, PBC, and intentions toward nocturnal sleep opportunity, 2) to test whether daily deviation from one's typical trend intentions and PBC predicts subsequent sleep opportunity, and 3) to identify which constructs of the TPB best predict daily sleep opportunity intentions. It was hypothesized that participants who generally had greater intentions and PBC than the sample average would obtain a longer sleep opportunity each night, and on days in which intentions or PBC were greater than an individual's typical trend, sleep opportunity would be longer that same night. It was also hypothesized that on days with more positive than usual attitudes, perceived norms, and PBC, participants would have greater intentions towards sleep opportunity at each time point (afternoon, evening, bedtime). It was further hypothesized that at time points when an individual has more positive than their daily typical attitudes, perceived norms, and PBC, this predicted greater future intentions.

METHODS

Participants

Participants were recruited from the North Dakota State University Department of Psychology's undergraduate research pool. To be eligible for participation, students had to be between the ages 18-25 and have a mobile phone with the capability of receiving text messages and connecting to websites. This age range was selected to reduce the confounding effect of age on sleep and to better align with the target population for the primary measure of the TPB constructs in this study. Participants had to be able to receive text messages to participate in the daily protocol. Additional exclusion criteria were selected to minimize medical and behavioral confounds likely to affect sleep-related behaviors. Individuals were ineligible for participation if they had an atypical sleep schedule (e.g., shift work), were currently being treated for a sleep disorder, were binge drinkers (more than 5 drinks in a single episode more than once per month), smoked cigarettes or e-cigarettes (more than once cigarette in the last month), used sleep aids or medications that can disrupt sleep, or had a medical condition that can influence sleep (e.g., chronic migraines, rheumatoid arthritis, hypertension).

Procedure

Inclusion and exclusion criteria were assessed with an online screening questionnaire. Eligible individuals received an email which briefly described the study's purpose, procedures, and compensation. Individuals who wished to participate signed up for an appointment via SONA, an online study management system maintained by the NDSU Department of Psychology.

All study materials and procedures were approved by the NDSU IRB. Participants had to sign up at least 72 hours in advance of their initial session in the lab. Three days before the lab session, participants received an email with instructions to begin the study and a digital consent form. After consenting to participate, participants completed bedtime and morning assessments in the 3 days leading up to their time 1 session. This was implemented to get participants used to thinking about their sleep and to reduce reactivity during the one-week-in-home assessment period. Upon arrival at the lab for their time 1 session, participants met with a research assistant in a private room to complete a demographic questionnaire. Participants then received instructions for completing the one-week in-home assessment. Participants received an actiwatch which they wore on their non-dominant wrist to measure sleep opportunity for 7 consecutive nights. Concurrently, an EMA protocol was used to assess sleep attitudes, perceived norms, PBC, and intentions throughout each of the study days. EMA is a measurement tool that allows for momentary assessment of psychological constructs and behaviors, which reduces recall bias and improves ecological validity (Smyth & Stone, 2003; Schwarz, 2007). Participants responded to 4 daily signals of sleep-related attitudes, norms, PBC, and intentions (morning, afternoon, evening, and bedtime) which were administered through Psych Data, a secure, online program. The bedtime and wake time assessments were event contingent, and were initiated by participants before they went to bed and when they woke up in the morning. The afternoon and evening EMA signals were prompted by a text message containing the Psych Data link. All afternoon signals were sent between 12:00PM-2:00PM, and all evening signals were sent between 5:00PM-7:00PM. During the initial session, participants indicated a fixed time during each of these time periods to receive their afternoon and evening signals. This accommodated individual school and work schedules to maximize adherence to the EMA protocol. As an additional incentive for protocol adherence, participants were told that if they completed at least 95% of the EMA assessments during the study they would be eligible for two $50 raffles.

Adherence checks were conducted daily, and participants who missed any signal were contacted via email with encouragement to adhere to the study protocol. Following the week long in-home assessment, participants came back to the research lab to return the actiwatch device. All participants received credit toward their psychology course as compensation for their participation along with a copy of their sleep report.

Measures

Sleep

Actigraphy was used to measure objective sleep parameters each night of the study period. Each participant wore an actiwatch (Philips Respironics, Bend OR) on their non-dominant wrist and were instructed to wear the watch continuously for 7 consecutive days and nights. An actiwatch is a wrist-worn accelerometer which infers sleep and wake states from movement-based algorithms, and is an effective tool for objective sleep measurement, especially when measuring sleep over an extended period of time (Ancoli-Israel, Cole, Alessi, Chambers, Moorcroft, & Pollak, 2003). Actigraphy provides multiple measures of sleep duration and continuity, but the variable of interest for the current study was sleep opportunity (i.e., the number of minutes that participants allow themselves to sleep at night). For example, if a participant tries to start sleeping at 10:00PM and were done trying to sleep at 6:00AM, this would be a sleep opportunity value of 480 minutes. Actiwatch's algorithms compute a rest period, indicating when participants try to fall asleep at night and wake up in the morning. However, several steps were taken to improve the validity of this measurement. First, participants were instructed to press a marker button each night when they try to begin sleeping, and each morning when they have woken up for the final time and do not intend to try to get back to sleep. This places a marker in the sleep data and assists in accurately defining the rest interval. In addition, each morning participants self-reported, using a modified version of the Pittsburgh Sleep Diary (Monk et al., 1994), what time they tried to start sleeping and what time they have woken up for the final time and do not intend to try to get back to sleep. The device algorithm, marker button, and morning sleep diaries were used together to identify participants' sleep opportunity each night of the study.

Constructs of the TPB

Attitudes, perceived norms, PBC, and behavioral intentions to allow adequate sleep opportunity were assessed with 4 items collected 4 times daily using EMA. These questions were adapted from Robbins & Niederdeppe (2015), in which they conducted an elicitation study in college students to identify behavioral beliefs regarding nighttime sleep. The constructed measure consists of 14 items that assess attitudes, perceived norms, PBC, and intentions to sleep 8-9 hours most nights of the week. Responses for each belief were on a 7 point scale. For the current study, responses for each question ranged from 1-11 to reduce possible restriction of range in repeated assessment. Adding more response choices to TPB measures does not diminish their reliability (Ajzen, 2002). To minimize participant burden, one item for each TPB construct were included in the EMA signals. Attitudes were assessed with the following item: "Overall, I think allowing myself the time to sleep 8-9 hours tonight is" 1 (*good*) – 11 (*bad*). Perceived norms were assessed with the following item: "People who are important to me think that I should allow myself the time to sleep 8-9 hours tonight" 1 (*strongly disagree*) – 11 (*strongly agree*). PBC was assessed with the following item: "For me to allow myself the time to sleep for between 8-9 hours tonight is" 1 (*easy*) – 11 (*difficult*). Lastly, intentions were assessed with the following item: "I intend to allow myself the time to sleep for between 8-9 hours tonight" 1 (*definitely don't*) – 11 (*definitely do*).

Data Analysis

Before testing study aims, multilevel model assumptions and data missingness were evaluated. Skewness and kurtosis were tested for sleep opportunity and it was normally distributed (skew= .03(.11), kurtosis= .46(.21)). Missing data were not related to any study variables (all p's > .05). Thus, data were missing completely at random and no corrections to the model were needed. Overall protocol adherence was 92%. Participants with some missing data were included in analyses (e.g., only 6 nights of actigraphy). Days on which participants missed more than 50% of EMA signals were removed from analyses, and participants missing more than 50% of EMA study days were removed from all analyses. Twenty-five total signals were removed from analyses due to being taken at incorrect times (e.g., taking the afternoon assessment right before bed). Two total study days from two participants were removed due to having less than 50% of EMA signals. Only one participant was removed from final analyses, and this was due to non-adherence to the EMA protocol. Out of 548 study days, there were 29 days with only 2 signals, and 92 days with 3 signals. Intraclass correlations (ICCs) were computed. In this 3-level model, there are two ICCs to calculate: percent of variance in sleep opportunity between-and within-days. 30.20% of the variability in sleep opportunity exists within days, and 30.74% of the variability exists between days.

Study Aim 1: Characterizing between- and within- Day Variability

The first study aim was to characterize the between- and within-day variability of attitudes, perceived norms, PBC, and intentions toward obtaining a sleep opportunity of 8-9 hours each night of the study. Between-day variability indicates each individual's variability of these variables day to day. Within-day variability indicates the extent to which these variables fluctuate within each day, across the 4 daily signals, for each participant. To characterize the between-day variability of these constructs, observations from all 4 daily time points were averaged into a daily score for each person. The between-day variability was then assessed by calculating the standard deviation across the 7 days of the study period. The within-day variability of these constructs was assessed by calculating the standard deviation within each of the 7 study days. Each study day had a standard deviation for each of its attitudes, perceived norms, PBC, and intentions, and this standard deviation was averaged across the 7 days into a single measure of within-day variability for each participant.

Study Aim 2: Test Whether Sleep Opportunity Intentions and PBC Predict Behavior

Hypotheses. Testing between-person effects examines whether individual mean differences from the sample mean predict subsequent sleep opportunity. In contrast, within-person effects test whether deviation from an individual's typical trend predicts subsequent sleep opportunity. It was hypothesized that participants who generally had greater intentions and PBC than the sample average would obtain a longer sleep opportunity each night, and on days in which intentions or PBC were greater than an individual's typical trend, sleep opportunity would be longer that same night.

Data preparation: Intentions. First, daily means of intentions were calculated by averaging scores within days to obtain one value for each variable for each study day. Prior to hypothesis testing, it was necessary to center each of the predictors to determine daily deviation from the mean. To calculate daily deviation from one's average intentions, it was first tested whether daily intentions had a significant slope throughout the week. If there was a significant slope throughout the week, intention scores would be centered on each participant's weekly slope. If there was no significant slope, intentions would be centered on the weekly mean. To test this, a mixed linear model was conducted with intentions as the dependent variable, study day as the predictor, and a random intercept. The results of this mixed linear model revealed that there was a significant effect of time ($b= .07$, $p= .025$), such that intentions significantly increased throughout the week. Thus, in order to create the between- and within-person predictor variables, individual intercepts and slopes were calculated. To do this, the data file was split by participant ID, and ordinary least squares regressions for each individual participant were run with intentions as the dependent variable and study day as the predictor variable. This provided the intention intercept and slope for each participant. In addition, predicted intention scores were saved for each study day.

Between- person calculation: Intentions. The between-person variable was created by subtracting the sample intercept mean from the participant's intercept; each participant had one score across all study days, indicating whether their average intentions were more or less than the sample mean.

Within- person calculation: Intentions. The within-person variable was created by subtracting each day's predicted intention score from each day's measured intention score. For each study day, this score indicated the degree to which their measured score was higher or lower than their predicted score for that study day.

Data preparation: PBC. First, daily means of PBC were calculated by averaging scores within days to obtain one value for each study day. PBC did not significantly change throughout the week ($b= .03$, $p= .484$) and centered variables were calculated differently than intentions.

Between- and within person calculations: PBC. The between-person variable was calculated by subtracting the sample mean from the participant mean (i.e., grand mean centered), and the within-person variable was calculated by subtracting the participant's weeklong mean from their daily score.

The final model. Mixed linear modeling was used to test whether daily deviation from one's typical intentions and PBC predicted sleep opportunity each night. Heterogenous autoregressive covariance structure was used to allow the variances at each timepoint to covary and the intercept in the full model was random to allow for mean differences between participant sleep opportunity. The between- and within-person variables for intentions and PBC were entered as fixed effects into the final model. Age and gender were tested as possible covariates in the initial model. However, neither variable was a significant predictor of sleep opportunity, and these variables were removed from the final model.

Study Aim 3: Test Whether Attitudes, Perceived Norms, and PBC Predict Sleep Opportunity Intentions

Hypotheses. Testing a between-person effect examines whether on days when an individual differs from the sample grand mean predicts subsequent intentions. Testing a within-day, within-person effect examines whether at signals when individuals deviate from their daily trend predicts subsequent intentions. It was hypothesized that on days with more positive than usual attitudes, perceived norms, and PBC, participants would have greater intentions towards sleep opportunity at each signal (afternoon, evening, bedtime). It was further hypothesized that at signals when an individual has more positive than their daily typical attitudes, perceived norms, and PBC, this predicted greater intentions at the next signal.

Data preparation. Within each study day, there were three lagged relationships that could be tested: 1) morning attitudes, perceived norms, and PBC predicting afternoon intentions 2) afternoon attitudes, perceived norms, and PBC predicting evening intentions 3) evening attitudes, perceived norms, and PBC predicting bedtime intentions. Before calculating the between- and within-person predictor variables, the final within-day interval (bedtime signal) was excluded because there are no future intentions to predict; only the first 3 signals (morning, afternoon, and evening) were included to create the centered variables. The between- and within-day slopes for attitudes, perceived norms, PBC, and previous time point intentions were tested by entering each of these variables (each were tested in a separate model) as the dependent variable, and both signal and study day as predictor variables. Study day was added as a random effect to account for the nesting of the signals. These slopes are different than the slopes tested in study aim 1, because this specific analysis examined trajectories across the first three signals, while the slopes in aim 1 tested trajectories across all four signals. Attitudes significantly increased during the week ($b = .10$, $p = .002$) and significantly decreased throughout the day ($b = -.12$, $p = .04$). Perceived norms significantly increased throughout the week ($b = .10$, $p = .016$) and decreased throughout the day, but was not significant ($b = -.05$, $p = .163$). PBC increased throughout the week ($b = .04$) and decreased throughout the day ($b = -.05$), but neither were significant (p's $> .30$). Intentions significantly increased throughout the week ($b = .06$, $p = .008$) and significantly decreased throughout the day ($b = -.16$, $p = .005$).

Within- person centering. To center attitudes on the within-day slopes, the data file was split by participant ID and study day, and ordinary least squares regressions were used to calculate the within-day intercepts and slopes, with attitude as the dependent variable and signal as the predictor variable. This created an attitude intercept and slope for each study day, for each participant. The within-day variable was calculated by subtracting the predicted score from the observed score for each signal. This was repeated for perceived norms and intentions. Since PBC did not significantly change throughout the day or week, it was within-person centered by subtracting the individual mean PBC score from each momentary score.

Between-person centering. The between-day variables for attitudes, perceived norms, and previous intentions were created by subtracting the sample mean of all intercepts from the intercept for each day. PBC was between-day centered by subtracting the sample mean from the individual mean (aggregated across all of the first three intervals).

The final model. Mixed linear modeling was used to test, on a within-day level, whether attitudes, perceived norms, and PBC predict sleep opportunity intentions. The lagged between- and within-centered variables for attitudes, perceived norms, PBC, and previous intentions were entered simultaneously into the same model to predict future sleep opportunity intentions. Age and gender were tested as possible covariates in the initial model. However, neither variable was a significant predictor of sleep opportunity, and these variables were removed from the final model.

Power Analyses

Prior to the study, two power analyses were conducted using Monte Carlo simulation in Mplus version 8.1 to determine whether a sample size of 60, with 85% adherence, would provide adequate power to test study aims 2 and 3. For study aim 2, there is adequate power (.83) to detect a medium effect size (d=.4). For study aim 3, there is adequate power (.87) to detect a small effect size (.1). Thus, a sample size of 60 will provide adequate power to test study aims 2 and 3. Given our final sample (N=79) and adherence (92%), there was adequate power to test study aims 2 and 3.

RESULTS

Descriptives

Participants were majority female (58.2%) and white (83.5%), with an average age of 19.01(1.16) years (see Table 1). On average, participants tried to sleep for just under 8 hours (SD= 94.44 minutes), had positive attitudes (M= 9.45, SD= 2.24) and perceived norms (M= 9.01, SD= 2.10), and moderate PBC (M= 7.16, SD= 3.19) and intentions (M= 7.43, SD= 3.04) to allow themselves the opportunity to sleep at least 8 hours. Thus, participants had positive attitudes towards sleep and generally perceived that those close to them think they should try to sleep for at least 8 hours at night. In contrast, participants reported modest levels of perceived control in their ability to, and intentions toward, obtaining a sleep opportunity of at least 8 hours.

Table 1

Demographic and Health Characteristics (N=79)

Gender, *n(%)*	
Male	33(41.8%)
Female	46(58.2%)
Race, *n(%)*	
White	66(83.5%)
Black	4(5.1%)
Asian	9(11.4%%)
Age, *mean(SD), years*	19.01(1.16)
Sleep opportunity, *mean(SD), minutes*	479.34(94.44)
*Attitudes, *mean(SD)*	9.45(2.24)
*Perceived norms, *mean(SD)*	9.01(2.10)
*Perceived behavioral control, *mean(SD)*	7.16(3.19)
*Intentions, *mean(SD)*	7.43(3.04)

*11 point scale with higher values indicating more positive values

Aim 1

Across the sleep attitudes, perceived norms, PBC, and intentions (each measured on an 11-point scale), there were low to moderate levels of between- and within- day variability (see Table 2). Perceived norms had the lowest between-day (M= .65, SD= .75) and within-day variability (M= .60, SD= .52). Attitudes also had somewhat low between-day (M= .71, SD= .71) and within-day (M= .71, SD= .68) variability. Thus, both between-and within-days, participants generally did not fluctuate more than 1 point from their typical trend. Of the three, PBC had the greatest between-day (M= 1.15, SD= .76) and within-day (M= 1.30, SD= .70) variability. Lastly, intentions had both between-day (M= 1.18, SD= .64) and within-day (M= 1.45, SD= .68) variability. In general, participants fluctuated more than one point from their between- and within- day PBC and intention trends.

Table 2

Characterizing the Intra-individual Variability of Sleep Attitudes, Perceived Norms, Perceived Behavioral Control, and Intentions

	[a] Between Day SD	[b] Within Day SD	[c] Weeklong Slope: b(SE)	[d] Within Day Slope: b(SE)
Attitudes	.71(.70)	.71(.68)	.10(.03)*	-.04(.03)
Perceived Norms	.64(.75)	.60(.52)	.11(.04)*	-.04(.02)
Perceived Behavioral Control	1.15(.76)	1.28(.70)	.03(.04)	-.19(.04)*
Intentions	1.18(.64)	1.15(.68)	.06(.04)	-.33(.04)*

[a] Degree to which variables varied day to day
[b] Degree to which variables varied within each day
[c] Linear slope of variables across the 7 study days
[d] Linear slope of variables within each day

Attitudes, perceived norms, PBC, and intentions also showed patterns of between- and within-day slopes across the 7 study days and 4 within-day signals, respectively (see Table 2). Attitudes had a non-significant decrease during the day (b= -.04, p= .09) and significantly increased throughout the week (b= .10, p= .003). Perceived norms had a marginally significant, negative slope during the day (b= -.04, p= .054) and significantly increased during the week (b= .11, p=.005). PBC significantly decreased during the day (b= -.19, p<.001), had a non-significant positive slope throughout the week (b= .03, p= .484). Intentions significantly decreased during the day (b= -.33, p<.001) and had a non-significant positive slope throughout the week (b= .06, p=.085).

Aim 2

Between-Person Effects

Results of the mixed linear model (see Table 3) revealed that the between-person effects of PBC (b= 7.43, p= .01) were a significant predictor, in that participants who were generally higher in PBC had longer sleep opportunity each night of the study. Intentions were not a significant predictor of sleep opportunity (b= 1.49, p= .63).

Table 3

Sleep Intentions and Perceived Behavioral Control Predicting Sleep Behavior

	b	SE	t	p
Intentions BP	1.49	3.11	.48	.63
Intentions WP	20.50	3.29	6.25	<.001
Perceived behavioral control BP	7.43	2.91	2.56	.01
Perceived behavioral control WP	13.32	2.78	4.78	<.001

*BP= between-person, WP= within-person

Within-person Effects

The mixed linear model revealed that both within-person effects were significant (see Table 3). The within-person effect of intentions was significant (b= 20.49, p<.001), in that days with higher than usual intentions to obtain a sleep opportunity of at least 8 hours were associated with longer sleep opportunity that night. In addition, the within-person effect of PBC was significant (b= 13.32, p<.001). Specifically, days in which individuals had greater than their usual PBC predicted longer sleep opportunity that night.

Aim 3

Between-person Effects

Results of the mixed linear model revealed that after controlling for previous intentions, there was only one significant between-person effect (see Table 4). PBC significantly predicted intentions (b= .43, p<.001), in that days on days when PBC was higher than the sample average, this predicted greater intentions at each time point on that day. The between-person effects of attitudes (b= -.02, p=.61) and perceived norms (b=.07, p= .07) were not significant.

Table 4

Attitudes, Perceived Norms, and Perceived Behavioral Control Predicting Future Sleep Opportunity Intentions

	b	SE	t	p
Previous intentions BP	.32	.03	9.73	<.001
Previous intentions WP	-.75	.08	-10.36	<.001
Attitudes BP	-.02	.04	-.52	.61
Attitudes WP	-.02	.09	-.17	.87
Perceived norms BP	.07	.04	1.81	.07
Perceived norms WP	-.02	.10	-.15	.89
Perceived behavioral control BP	.43	.05	7.69	<.001
Perceived behavioral control WP	.25	.03	7.79	<.001

*BP= between-person, WP= within-person

Within-person Effects

The mixed linear model revealed one significant within-person effect after controlling for previous intentions (see Table 4). PBC significantly predicted future intentions (b= .25, p<.001), in that signals when participants indicated greater PBC than their trend for that day predicted greater intentions at the next signal. Attitudes (b= -.02, p= .87) and perceived norms (b= -.02, p= .89) were not significant predictors.

DISCUSSION

Sleep is important for both physical and mental health, yet many Americans choose to restrict their sleep at night. Little is known about behavioral sleep restriction, and the current study sought to learn more about why people may choose to do so.

Study aim 1 sought to characterize the between-and within-day variability of attitudes, perceived norms, PBC, and intentions toward obtaining a sleep opportunity of 8-9 hours each night of the study. Attitudes and perceived norms had high mean levels in this sample, with average scores of 9.45 and 9.01 (on an 11 point scale), respectively. In contrast, PBC and intentions were lower, with average scores of 7.16 and 7.43, respectively. Attitudes and perceived norms had the lowest intra-individual variability, with their between- and within- day variability deviating 6-7% from an individual's typical trend. This demonstrates that attitudes and perceived norms relating to sleep opportunity may be both positive and relatively stable. In contrast, participants deviated between 11-13% both between- and within-days, in their typical PBC and intentions. This indicates that one's perception that they can obtain adequate sleep, and their intentions to do so, may fluctuate due to states or experiences that also vary throughout the day. For instance, an individual may believe in the morning they have control in their ability to sleep for 8 hours that night, but experiences throughout the day can limit their ability to achieve a sleep opportunity of at least 8 hours. Sleep opportunity attitudes, perceived norms, PBC, and intentions also showed between- and within-day trajectories across all four signals. All four items showed increases throughout the week, but only attitudes and norms were significant. Specifically, each increased by approximately .7 points over the 7 day study period. It is possible that these increases throughout the week are explained by participant reactivity; the more they pay attention to their sleep, the more they develop positive perceptions about their sleep.

Attitudes, perceived norms, PBC, and intentions also showed within-day patterns, and decreased as the day went on. However, only PBC and intentions showed significant decreases; PBC decreased approximately .60 points during the day, and intentions decreased 1 point during the day. Taken together, these results show that sleep opportunity attitudes, perceived norms, PBC, and intentions show distinct patterns of intra-individual variability and between- and within-day trajectories. These within-day patterns highlight methodological considerations when using the TPB to study sleep, particularly in cross-sectional and daily designs. Specifically, the time of day in which these constructs are measured may impact the construct validity of this measurement. For example, assessing intentions in the morning, as compared to later in the day, may show higher than average intentions. These results also have implications for interventions. For instance, both PBC and intentions significantly decrease throughout the day, which provides insight for new trends in health behavior promotion research. Just time adaptive interventions (JITAIs) adapt to an individual's needs, and identify specific times and contexts in which intervention efforts would be most effective (Spruijt-Metz et al., 2015; Nahum-Shani, Smith, Spring, Collins, Witkiewitz, Tewari, & Murphy, 2018). These results would suggest that intentions to obtain at least 8 hours of sleep opportunity may be highest in the morning, and thus intervention efforts at different times of the day may require different approaches. Efforts in the morning may aim to maintain high levels of intentions and PBC throughout the day. For example, time management interventions may be effective (Gipson, Chilton, Dickerson, Alfred, & Haas, 2019) by teaching skills to effectively allocate time throughout the day, thus reducing the need to stay up late completing daily tasks. In addition, implementation intention interventions (Gollwitzer, 1999) could help translate these intentions into achieving a healthy sleep opportunity. In contrast, interventions later in the day may focus on increasing intentions and PBC towards sleep opportunity.

Study aim 2 tested whether daily deviation from one's typical intentions and PBC predicts sleep opportunity each subsequent night. Results supported the hypothesis that on days with greater intentions and PBC there would be longer sleep opportunity that same night. The between-person effects of intentions were not significant, suggesting that mean level sleep opportunity intentions do not translate into a longer sleep opportunity each night. However, days on which participants had greater intentions than their own typical trend achieved a longer sleep opportunity that night. Specifically, when participants had one point higher than their typical trend, this predicted an increase of 20.5 minutes of sleep opportunity that night. The magnitude of this effect illustrates that increasing intentions may be an effective avenue for sleep health promotion. Given the within-person effect of intentions was significant and there is both between- and within-day a variability, adaptive interventions that provide messaging on days in which intentions are low may be most effective. PBC showed significant between- and within-person effects. Participants who were one point higher than the sample average allowed themselves 7.4 more minutes of sleep opportunity. In addition, days on which participants were one point higher in PBC than their typical day obtained approximately 13 more minutes of sleep that night. Thus, both mean level and momentary aspects of PBC may play a role in nightly sleep opportunity. An exploratory analysis was conducted to test whether the between- or within-person effects of intentions and PBC were stronger predictors of sleep opportunity. The model was re-run after standardizing the between- and within-person variables of intentions and PBC. The within-person effect (β= 23.87, p<. 001) of intentions was a stronger predictor of sleep opportunity than the between-person effect (β= 3.47, p= .64). The between-person effect (β=

18.97, p=.01) of PBC was a slightly stronger predictor of sleep opportunity than the within-person effect (β= 17.98, p<.001). In general, these findings illustrate that both intentions and PBC are significant predictors of sleep opportunity, and collectively, it is the within-person variability of these factors that play a significant role in sleep opportunity. However, the findings from cross-sectional research is mixed. Some studies have identified PBC as the significant predictor (Stanko, 2013; Robbins & Niederdeppe, 2015), while others found only intentions to be significant (Tagler, Stanko, & Forbey, 2017; Strong, Lin, Jalilolghadr, Updegraff, Broström, & Pakpour, 2018). These mixed findings could be due to testing the relationships between intentions and PBC and sleep exclusively from a between-person perspective. Thus, further replication and extension of this daily framework is needed. For example, this study solely examined the role of the TPB in predicting nightly sleep opportunity, and future studies could use this approach to study other aspects of sleep (e.g., sleep timing, sleep hygiene). Several studies have used a cross sectional approach to study sleep hygiene (Kor & Mullan, 2011; Tagler, Stanko, & Forbey, 2017; Strong, Lin, Jalilolghadr, Updegraff, Broström, & Pakpour, 2018) but none to date have used a daily framework.

Study aim 3 was to test, on a daily level, whether attitudes, perceived norms, and PBC predicted sleep opportunity intentions. It was hypothesized that, after controlling for previous time point intentions, all three would significantly predict intentions, but that PBC would be the strongest predictor. As predicted, both the between- and within-person effects of previous intentions predicted future intentions. However, the within-person effect was negative, indicating that higher intentions at a given time point predicted lower future intentions. This is likely explained by the fact that intentions significantly decreased throughout the day. Neither the between- or within- person effects of attitudes or perceived norms on intentions were significant, suggesting that on a daily level, they are not significant predictors of sleep opportunity intentions. As results from study aim 1 showed, participants in this sample scored high in both attitudes and perceived norms, and also showed low intra-individual variability. Thus, it is possible that these null results are explained by this ceiling effect and restricted range. More research is needed to determine whether these are true null effects. Lastly, the between- and within-person effects of PBC on subsequent intentions were both significant. The between-person effect showed that on days in which their PBC was a point higher than the sample average, intentions for that day increased by .43 points. The within-person effect demonstrated that following signals which were a point higher than their typical trend for that day, subsequent intentions increased by .25 points. Taken together, results suggest that within a day, PBC is the only belief to significantly predict future intentions. This contradicts previous literature that has utilized cross-sectional designs, which have shown attitudes, perceived norms, and PBC to all be significant predictors of sleep duration intentions (Knowlden, Sharma, & Bernard, 2012; Stanko, 2013; Robbins & Niederdeppe, 2015; Tagler, Stanko, & Forbey, 2017; Branscum, Fay, & Senkowski, 2018). This discrepant finding could be due to the use of a daily framework, which would suggest that momentary attitudes and perceived norms are not significant predictors of intentions, while PBC remains a significant predictor of intentions regardless of context. Thus, PBC may be the most robust predictor of intentions. This discrepancy may also be due to the fact that this study focused on sleep opportunity, and not duration. While the distinction between these two outcomes may be small, these findings highlight that focusing on *volitional* aspects of sleep are key, and future studies need to take this into consideration. In addition to sleep duration, previous research has focused on whether attitudes, perceived norms, and PBC predict intentions for other sleep-related behaviors, such as sleep hygiene (Kor & Mullan, 2011; Tagler, Stanko, & Forbey, 2017; Strong, Lin, Jalilolghadr, Updegraff, Broström, & Pakpour, 2018), sleep patterns (Lao, Tao, & Wu, 2016), and late night electronic use (Zhao, Feng, & Kelly, 2019). Given that the predictors of intentions may differ between cross-sectional and intensive longitudinal designs, further research is need to determine whether attitudes and perceived norms remain significant predictors of intentions for these sleep-related behaviors. Moreover, future studies should assess the salient beliefs that influence attitudes, perceived norms, and PBC.

There are several other areas for future research. One limitation of the TPB is the intention-behavior gap, which demonstrates that intentions do not always translate to behavior (Sheeran & Webb, 2016). Rebar and colleagues (2020) posit that this may also be true for sleep-related behaviors. For instance, individuals may have strong intentions to obtain a sleep opportunity of at least 8 hours, but then as they approach bedtime, they avoid going to bed (e.g., nightly routine consists of reading in bed for an hour). Thus, automatic processes (e.g., habits) may explain the intention-behavior gap. In the current study, intentions were a significant predictor of behavior, but accounting for automatic processes may improve this framework. Future research efforts should consider the use of dual process theories (Strack & Deutsch, 2004), which account for both reflective and automatic processes. These may be particularly effective frameworks for studying sleep-related behaviors (Rebar, Reynolds, Ferguson, Gardner, 2020). Accordingly, intensive longitudinal designs are an effective framework for testing dual process theories (Dunton, Rothman, Leventhal, & Intille, 2019), and the current study provides the first example of how to implement this methodology in the context of health behavior theory and sleep health. However, there is very limited data on the use of dual process theories in the study in sleep health, and expectancy-value theories (e.g., The Theory of Planned Behavior) have shown promise (Mead & Irish, 2020). As noted by Mead and Irish (2019), theory evaluation and comparison is an important next step in the study of health behavior theory and sleep health. In addition to using dual process theories to address the intention-behavior gap, future research could collect qualitative data identifying barriers to achieving a sleep opportunity of at least 8 hours.

Results of this study will have implications for the development of theoretically based interventions to reduce BSR. For example, both intentions and PBC significantly predict sleep opportunity, and support calls for the testing of theoretically based interventions for sleep (Mead & Irish, 2019). Moreover, given that intentions were identified as a significant predictor of behavior, identifying whether attitudes, perceived norms, or PBC predict sleep opportunity intentions would likely improve the efficacy of these interventions. Accordingly, results from this study indicate that increasing one’s perception of control over their sleep opportunity could increase sleep opportunity intentions and behavior. Thus, perception of control over sleep opportunity may provide a very effective target for intervention efforts. Results also have implications for various intervention strategies. For example, the between-person effect of intentions on sleep opportunity was not significant, and the within-person variability of intentions was a stronger predictor. This suggests that dynamic interventions (e.g., JITAIs) targeting participants on days of low intentions may be a more effective approach than a single time point intervention (e.g., 1 hour session detailing sleep hygiene). Both the between- and within-person effects of PBC on sleep opportunity were significant, with the between-person effect a slightly stronger predictor. Thus, various intervention strategies targeting PBC may be effective. While promising, theoretically based interventions to improve sleep are nearly non-existent. To date, no studies have specifically targeted sleep duration or opportunity using the TPB as a framework, but one recent study targeting sleep hygiene behavior does show promise.

Lin and colleagues (2018) constructed an intervention based on the TPB and the Health Action Process Approach and randomly assigned high school students into an intervention group or a control group (education material related to sleep hygiene). At both 1 and 6 month follow ups, the intervention group had significantly greater improvements in sleep hygiene than the control group. Moreover, mediation analyses revealed that a change in sleep hygiene beliefs following the intervention predicted the improved sleep hygiene. While this is only one study, the results are encouraging, especially given the success of the TPB modifying other volitional behaviors such as diet and exercise (Kelley & Abraham, 2004; Darker, French, Eves, & Sniehotta, 2010; White et al., 2012). While encouraging however, results from the current study suggest that one size fits all approaches may not be nearly as effective in promoting healthy sleep as individually tailored approaches. In fact, tailored health messaging may be more effective than non-tailored approaches (Noar, Benac, & Harris, 2007; Krebs, Prochaska, & Rossi, 2010). Given recent advancements in eHealth and mHealth interventions (Mohr, Schueller, Montague, Burns, & Rashidi, 2014), dynamic interventions targeting sleep intentions and PBC ought to be considered in future intervention efforts.

There were several strengths to this study. This is the first study to use an intensive longitudinal design to test how attitudes, perceived norms, PBC, and intentions relate to sleep. Cross-sectional research designs fail to capture how individuals may vary both between- and within-days. This study is the first to describe these patterns, and illustrated why this framework is warranted. Relatedly, this study used an advanced analytical approach, and was able to parse apart between- and within-person factors at the between- and within-day level (Curran & Bauer, 2011). This analytical approach illustrates how social cognitive changes within a person influence behavior, which provide insight into the development of more individually tailored health promotion efforts. Lastly, this study used actigraphy to assess sleep opportunity. Most research to date has relied on self-reported sleep duration, which tends to overestimate sleep duration (Lauderdale, Knutson, Yan, Liu, & Rathouz, 2008). When assessing sleep opportunity, actigraphy provides a momentary record of the time a participant attempts to sleep at night and when they are done trying to sleep in the morning, which greatly improves the accuracy of sleep opportunity measurement. While these are great strengths, the results of this study must be interpreted in the context of its limitations. Given the use of a convenience sample, study participants were a mostly homogeneous group of healthy (e.g., excluded binge drinkers and smokers) college students and these results may not generalize to other samples. Sleep restriction is not exclusive to college students, and future research should extend this framework to other samples. As noted by Mead and Irish (2019), one barrier to using the TPB as a framework in other populations is that elicitation studies are needed to develop TPB measures for different populations. Thus, existing measures based on elicitation studies in college samples may not adequately capture attitudes, perceived norms, and PBC in different samples. This study was likely limited by its measurement of attitudes and perceived norms, given the lack of variability. This study adapted a measure constructed by Robbins and Niederdeppe (2015), and only one item from each subscale was chosen. It is possible that the other items for attitudes (Overall, I think allowing myself the time to sleep 8-9 hours tonight is: unpleasant, pleasant) and perceived norms (I feel social pressure to allow myself the time to sleep 8-9 hours tonight: strongly disagree, strongly agree) could capture more intra-individual variability. In addition, each construct of the TPB was assessed with a single item, and single item measures tend to be more unreliable than multi-item measures. The original measure had several items for each construct, but one was chosen to adapt to the EMA protocol and limit participant burden. Future studies should utilize the full measure to increase the reliability of attitudes, perceived norms, PBC, and intentions. Lastly, this study was likely limited by participant reactivity (Robbins & Kubiak, 2014) and length of the study. In fact, self-monitoring is a strategy for sleep health improvement (Adachi, Sato, Kunitsuka, Hayama, & Doi, 2008). In order to minimize possible reactivity, participants completed a three day "practice" period before starting the week long assessment. This allowed participants a few nights to habituate to sleep tracking, as well as getting used to thinking about their attitudes, perceived norms, PBC, and intentions regarding their own sleep. Future research should consider a longer study period. This could provide more days and nights of data collection not confounded by reactivity, and in addition, could provide more reliable estimates of variability (Rowe et al., 2008; Wang & Grimm, 2012).

This study provides insight into the processes underlying sleep health improvement that could inform the development and improvement of sleep health interventions. While limited, the recent use of the TPB has improved our understanding in factors that influence sleep. This study advanced this work by characterizing the intra-individual variability in sleep opportunity attitudes, perceived norms, PBC, and intentions, demonstrated that daily intentions and PBC predict sleep behavior, and that within a given day, PBC significantly predicts future intentions. In addition, this study highlights the need for more use of intensive longitudinal designs in studying sleep. In conclusion, this study addressed significant gaps in our understanding of how sleep health intentions predict behavior, and has the potential to influence and inform the development of sleep health intervention strategies.

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