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Results

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Research Directions

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Sleeping and thinking: An examination of insomnia symptoms, global sleep health and sleep regularity

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Abstract

Introduction: Subjective cognition is a predictor of cognitive decline and previous work has identified age, education and depression as predictors of subjective cognition. This study aimed to investigate whether several sleep characteristics were associated with subjective cognition above-and-beyond known predictors.

Methods: Participants (N=3284, M_{age}=42.7 years, 48.5% female) completed an online study that included the Patient Health Questionnaire-4 (PHQ-4), Insomnia Severity Index (ISI), RU-SATED, Sleep Regularity Questionnaire (SRQ) and the 6-item PROMIS Cognitive Function. A 3-step hierarchical regression model predicted PROMIS Cognition scores, with Step 1 including age and education as predictors, Step 2 including age, education, and PHQ-4 scores, and Step 3 including all previous variables and sleep variables.

Results: In Step 1 (R^2=.03), age and education were significant predictors, while in Step 2 (R^2=.36), PHQ-4 and education were significant, and age was no longer significant. In Step 3 (R^2=.48), PHQ-4, ISI, RU-SATED, and SRQ scores were significant, while age and education were not significant. All steps accounted for a significant increase in variance (p's<.001).

Conclusions: Sleep characteristics were associated with subjective cognition above-and-beyond known predictors of age, education and mood. Further research is needed to investigate whether changes in sleep characteristics are associated with changes in subjective cognition.

Introduction

Subjective cognition (AKA metacognition or subjective cognitive functioning) refers to an individual's awareness of, and thoughts about, their own thoughts and cognitive functioning. Subjective cognition is salient across the lifespan as an individual ages and experiences changes in cognitive capabilities. For example, emerging adults' subjective cognitive functioning can impact their ability to learn new information and skills, while individuals' negative beliefs about their cognitive functioning are associated with poorer mood and increased anxiety (Arora et al., 2021; Barahmand et al., 2008; Sheffler et al., 2022). Indeed, accurate assessments of one's cognitive functioning may play an especially salient role for older adults as declines in subjective cognitive functioning have been associated with increased risk of mild cognitive impairment and dementia (Jiang et al., 2022; Mitchell et al., 2014; Sella et al., 2019). Further, a meta-analysis demonstrated that older adults with subjective memory complaints were twice as likely to develop dementia than older adults without subjective memory complaints (Mitchell et al., 2014). Because of its implications for an individual's health, investigating the predictors of subjective cognitive functioning, and especially predictors of its potential decline in older adulthood, has been a priority of the field.

Previous studies into predictors of subjective cognitive functioning across the lifespan have highlighted demographic factors including age and level of education, as consistent predictors of subjective cognitive functioning, such that older age and lower levels of education are associated with worse subjective cognitive functioning (Baumgart et al., 2015; Dzierzewski, 2022). Moreover, mental health factors, including symptoms of depression, have been shown to be associated with poorer subjective cognitive functioning as well (Doos Ali Vand et al., 2014; Molinuevo et al., 2017; Zlatar et al., 2018). One study reported that individuals with higher levels of both depression and subjective cognitive decline were at the highest risk of mild cognitive impairment and dementia, compared to individuals who had just one or the other (Liew, 2019). Thus, age, education and mental health have all been shown to be important in understanding an individual's subjective cognitive functioning. However, it is currently unknown whether and how sleep, an aspect of health that changes across the lifespan and is highly associated with mental health, is associated with subjective cognitive functioning in light of known predictors.

Sleep is essential to an individual's health and functioning. Poor sleep has been associated with increased health risks including increased risk of cardiovascular disease, obesity, diabetes

and all-cause mortality (Bansil et al., 2011; Cappuccio et al., 2010, 2011). Previous work has also demonstrated that sleep is essential for optimal cognitive functioning (Dzierzewski, 2022; Dzierzewski et al., 2022; Kronholm et al., 2009; Wardle-Pinkston et al., 2019). Specifically, better sleep health, including more regular sleep, has been previously associated with better cognition (Boeve et al., 2022; Gildner Theresa et al., 2024; Sletten et al., 2023). Moreover, one daytime deficit commonly associated with insomnia symptoms is poor cognitive performance (Wardle-Pinkston et al., 2019). Although how sleep impacts cognition remains poorly understood, Dzierzewski et al. (2022) proposed a model that suggests various biological (e.g., inflammation, metabolic processes), psychological (e.g., depression, anxiety) and social (e.g., loneliness) processes that may underlie the sleep-cognition association, including the association between sleep and subjective cognitive functioning.

An emerging area of research has begun to investigate how sleep is associated with an individual's subjective cognitive functioning. Previous studies have demonstrated that poor sleep, including symptoms of insomnia, is associated with poorer subjective cognition across the lifespan, including one study which observed that middle-aged and older adults who reported worse sleep 3 years after a baseline survey showed significantly increased odds of reporting declines in their cognitive capacities (Costa et al., 2023; Doos Ali Vand et al., 2014; Joo et al., 2021; Zhao et al., 2022). Moreover, another study observed that the association between subjective cognitive decline and insomnia symptoms was mediated by depression, thereby indicating that there may be underlying factors that affect this association (Jiang et al., 2022). Other studies have demonstrated that poor sleep quality and short and long sleep durations are associated with increased risk of subjective decline in cognition (Joo et al., 2021; Kang et al., 2017). However, few studies have investigated whether other aspects of sleep health, including global sleep health and sleep regularity, are associated with subjective cognitive functioning despite previous evidence suggesting their association with objective cognition and better health (Boeve et al., 2022; Gildner Theresa et al., 2024; Sletten et al., 2023). Investigation of sleep characteristics outside of insomnia symptoms, including sleep health and sleep regularity, may further clarify the association between sleep and subjective cognitive functioning. Further, research that investigates how subjective cognitive functioning is associated with sleep characteristics while accounting for previously identified predictors of subjective cognitive functioning, may help differentiate whether these previously identified predictors (e.g., mood) underlie the sleep-subjective cognition association.

This study aimed to investigate whether sleep characteristics, including insomnia symptoms, global sleep health and sleep regularity, were associated with subjective cognitive functioning above-and-beyond known predictors of age, education and mood. Based on previous research, it was hypothesized that fewer insomnia symptoms, better sleep regularity and better global sleep health would be associated with better subjective cognitive functioning.

Methods

Protocol

Data were collected as part of an online survey investigating sleep and health across the lifespan. Participants were recruited through Amazon's Mechanical Turk (MTurk), an online platform that allows individuals to participate in a variety of research studies for compensation. To be eligible for inclusion, individuals had to be at least 18 years old, be able to respond to surveys in English, and have access to a computer or tablet that they could use to complete the survey. Participants signed up for the study in MTurk, gave electronic informed consent, and completed the survey through Qualtrics. All protocols and procedures for the study were approved by the local Institutional Review Board (#HM20020410) and were carried out in accordance with the Declaration of Helsinki. Participants were compensated $0.25 upon completion of the survey. It has been previously shown that compensation amounts do not affect the quality of data received through MTurk (Buhrmester et al., 2011). Although Amazon's MTurk data collection has been observed to be as reliable as paper and pencil surveys (Buhrmester et al., 2011), two validity checks were incorporated into the survey. First, participants were asked to report their age at the beginning of the survey and then report their birth year at the end of the survey. Secondly, at a specific point in the survey, participants were asked to respond to a question (i.e., "We are interested in whether respondents are reading the instructions for each question. Please choose the once or twice-a-week response option to show you are paying attention") with a specific response to certify that they were paying attention during the survey. Individuals who did not pass these validity checks were excluded from all analyses.

Measures

Demographics: Demographic questions included age, self-reported sex, level of education, race and ethnicity.

Patient Health Questionnaire-4 (Kroenke et al., 2009): The Patient Health Questionnaire-4 (PHQ-4) is a 4-item questionnaire that measures the frequency of symptoms of depression and anxiety over the past two weeks (e.g., "over the past 2 weeks, how often have you been bothered by the following problems . . . Little interest or pleasure in doing things)." Each item includes a 4-point Likert-type scale with answer choices ranging from 0 (not at all) to 3 (nearly every day). The total score ranges from 0-12, with higher scores indicating increased severity. Separate sub-scores for symptoms of depression and anxiety can be calculated, though the total score combining the two subscale scores was utilized in these analyses. The Cronbach's alpha for the PHQ-4 in the present study was 0.895.

Insomnia Severity Index (Bastien et al., 2001): The Insomnia Severity Index (ISI) is a well-known, widely used self-report questionnaire that evaluates nighttime and daytime symptoms of insomnia over the past two weeks (e.g., "Please rate the severity of your current insomnia problem", "To what extent do you consider your sleep problem to INTERFERE with your daily functioning"). This 7-item questionnaire is scored on a 5-point Likert Scale and has a range of 0-28, with higher scores indicating more severe insomnia symptoms. A cutoff score of 10 or higher has been noted to be sensitive to detecting insomnia status in community-based samples (Morin et al., 2011). The Cronbach's alpha for this measure in the present study was 0.884.

RU-SATED sleep health questionnaire (Buysse, 2014; Ravyts et al., 2021): The RU-SATED questionnaire is a 6-item measure that assesses six dimensions of sleep health including regularity, satisfaction, alertness, timing, efficiency and duration. Participants are asked how often they follow the sleep health guidelines regarding these six dimensions (e.g., "Do you spend less than 30 minutes awake at night?") on a 3-point Likert type scale ranging from 0 (Rarely/Never) to 2 (Usually/Always), with total scores ranging from 0-12. Higher scores indicate better sleep health. One

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previous study reported a 2-factor structure of the RUSATED scale, though further research is needed to replicate this factor structure (Ravyts et al., 2021). The total score was used for the analyses in the present study. Cronbach's alpha for this measure in the current sample is 0.637.

Sleep Regularity Questionnaire (Dzierzewski et al., 2021): The Sleep Regularity Questionnaire (SRQ) was used to assess the degree to which individuals engage in consistent sleep behaviors (e.g., "I go to bed at about the same time every night," "I wake up at about the same time each morning"). Participants rated each of the 6 items on a scale from 1 (not at all) to 5 (very much), with scores ranging from 6-30. Higher scores indicate more regularity in sleep. Cronbach's alpha for the 6-item measure in the current sample was 0.869.

PROMIS Cognitive Function-Short Form (Iverson et al., 2021; Lai et al., 2014): The PROMIS Cognitive Function Short form is a 6-item measure derived from the greater PROMIS cognitive function measure. Sample items include "My thinking has been slow" and "It has seemed like my brain was not working as well as usual . . . " Items use a 1-5 scale with options ranging from "very often" to "never", with scores ranging from 6-30. Higher scores indicate better subjective cognitive functioning. The Cronbach's alpha for this measure in the present study was 0.958.

Analyses

IBM SPSS Statistics version 29 was used to conduct analyses (IBM Corp., 2023). Hierarchical linear regression, in which predictors are entered into the model in blocks to determine whether subsequent predictors account for a significant change in the variance explained, was used to investigate whether ISI, RU-SATED and SRQ scores predicted PROMIS Cognitive Function scores after accounting for age, education and PHQ-4 scores. PROMIS Cognitive Function scores were the outcome variable in every step. In step 1 of the model, known demographic predictors of age and level of education were entered into the model. In step 2, PHQ-4 total score was added to the model, while age and education were kept in the model. In step 3, all previous variables were entered into the model, followed by the three sleep variables (i.e., ISI, RU-SATED, SRQ). Due to the conceptual overlap between the sleep variables, multicollinearity was inspected based on the variance inflation factor (VIF), with VIFs greater than 10 indicating a bias in the model due to multicollinearity (Field, 2018).

Results

Participant demographics are reported in Table 1. In brief, participants (N=3284) were generally middle-aged adults (M_{age}=42.7 years), split between males and females (48.5% female), and had a 4-year bachelor's degree. Participants had sub-clinical levels of depression (M =1.59) and anxiety (M = 1.73) symptoms, with the total score of the PHQ-4 also being in the sub-clinical range (M = 3.32). Regarding sleep, participants generally reported sub-clinical insomnia symptoms (M = 8.49), and moderate levels of sleep health (M = 7.59) and sleep regularity (M = 22.39). The RU-SATED scale has been previously shown to have a two-factor structure, with one factor relating to sleep quality & quantity and the other factor relating to circadian rhythm (Ravyts et al., 2021). In this study, participants reported moderate levels of sleep quality and quantity (M = 3.23), and slightly higher levels of sleep health characteristics related to circadian rhythm (M = 4.35). Subjective cognitive functioning was in the moderate range (M = 22.01).

Table 1. Demographic characteristics (N = 3284)

Characteristic	M (SD) or n (%)	Reported range
Age, years	42.74 (16.71)	18–99
Sex		
Female	1594 (48.5%)	
Male	1479 (45%)	
Other	211 (6.4%)	
Education		
High school/GED or below	354 (10.7%)	
Some college	853 (26%)	
2-year associate degree	387 (11.8%)	
4-year bachelor's degree	1171 (35.7%)	
2-year post-bachelor's degree (master's)	372 (11.3%)	
4-year post-bachelor's degree (doctorate)	147 (4.5%)	
Race		
White	2652 (80.8%)	
Black	263 (8.0%)	
Hispanic/Latinx	216 (6.6%)	
Asian	208 (6.3%)	
Other	122 (3.8%)	
PHQ-4, total score	3.32 (3.34)	0–12
PROMIS Cognitive Functioning, total score	22.01 (6.22)	6–30
Insomnia Severity Index, total score	8.49 (6.42)	0–28
RU-SATED, total score	7.59 (2.69)	0–12
Sleep Regularity Questionnaire, total score	22.39 (5.32)	6–30

Note: Participants could select more than one race/ethnicity.

Table 2 reports the results of the hierarchical linear regression models. All VIFs were less than 10, indicating no issues with multicollinearity (Field, 2018). In Step 1 (R^2=0.03) of the model, which included only age and level of education as predictor variables, older age and higher education predicted better subjective cognitive functioning (β =.146, t=8.44, p <.001; β =.086, t=4.97, p <.001, respectively). In Step 2 (R^2=.36), PHQ-4 scores and education were significant while age was no longer significant (β= −.589, t= −40.56, p<.001; β =.03, t=2.10, p=.036, respectively), such that better mental health and higher education predicted better subjective cognition. Lastly, in Step 3 (R^2=.48), scores on the PHQ-4, ISI, RUSATED and SRQ were significant predictors of subjective cognitive functioning (β = −.346, t=−21.93, p<.001; β = −.380, t=−20.20, p<.001; β = 0.040, t=2.13, p =.033; β = 0.037, t=2.35, p =.019, respectively), such that better mental health, fewer insomnia symptoms and better sleep health and sleep regularity predicted better subjective cognition, while age and education were not significant predictors. All steps accounted for a significant increase in variance explained (Step 1:

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Table 2. Hierarchical regression models

Model	*B*	*SE*	*β*	*t*	*p*
Step 1 (R^2 = .03)					
Age	0.054	0.006	0.146	8.443	**<.001**
Education	0.352	0.071	0.086	4.974	**<.001**
Step 2 (R^2 = .36)					
Age	0.004	0.005	0.012	0.797	.425
Education	0.121	0.058	0.030	2.096	**.036**
PHQ-4	−1.095	0.027	−0.589	−40.556	**<.001**
Step 3 (R^2 = .48)					
Age	0.002	0.005	0.005	0.393	.695
Education	−0.001	0.052	0.00	−0.010	.992
PHQ-4	−0.644	0.029	−0.346	−21.934	**<.001**
Insomnia Severity Index	−0.368	0.018	−0.380	−20.202	**<.001**
RU-SATED	0.092	0.043	0.040	2.133	**.033**
Sleep Regularity Questionnaire	0.043	0.018	0.037	2.355	**.019**

Note: Bold indicates significance. The PROMIS Cognitive Functioning Questionnaire was the outcome variable in each model. Each model was significant at p <.001 and accounted for a significant increase in variance.

ΔR^2=.031, F=53.09, p<.001; Step 2: ΔR^2=.324, F=1644.79, p<.001; Step 3: ΔR^2=.121, F=251.80, p<.001).

Conclusions

This study found that sleep characteristics, including insomnia symptoms, global sleep health and sleep regularity, were associated with subjective cognitive functioning above-and-beyond known predictors of age, education and mood. Of note, adding in the sleep variables accounted for an additional 12% of the variance in subjective cognition. Those who reported less insomnia symptoms, greater sleep health and more regular sleep reported higher levels of subjective cognition. This study also observed that older age and higher levels of education were associated with better subjective cognitive functioning, though these variables were not significant when including sleep characteristics, which might suggest that non-demographic factors may have more salience than demographic factors when considering the sleep-subjective cognition association. Future research that replicates and extends these findings could potentially elucidate underlying factors that are implicated in the sleep-subjective cognition association, including the potential role of sleep and mood disorders, and whether changes in sleep health correspond with changes in subjective cognition.

The results of the present study align with previous literature examining the association between sleep and subjective cognitive functioning. Previous work has demonstrated that poor sleep quality is associated with poorer subjective cognition, while sleep duration had a U-shaped association, such that long (>9 hours) and short (<5 hours) sleep durations were associated with poorer subjective cognition (Joo et al., 2021). Further work observed that increased insomnia symptoms are associated with poorer subjective cognition (Costa et al., 2023; Zhao et al., 2022), which was also observed in the present study. This study extended the current literature by observing that other sleep characteristics beyond insomnia symptoms, including sleep health and sleep regularity, are associated with subjective cognition, thereby demonstrating that sleep characteristics outside of disordered sleep may be important in understanding the sleep-subjective cognition association. Sleep health and sleep regularity have been previously shown to be associated with cognitive performance, and have ties to other health outcomes such as inflammation, metabolic outcomes, cardiovascular disease and mortality (Baron et al., 2017; Dzierzewski et al., 2020; Grandner et al., 2014; Sletten et al., 2023; Wallace et al., 2018). Importantly, these results also suggest that sleep health across the spectrum, rather than just disordered sleep, is associated with subjective cognition, alluding to the importance of maintaining healthy and regular sleep. Although it is still unknown what mechanisms underlie the sleep-subjective cognition association, the model proposed by Dzierzewski et al. (2022) suggests biological (e.g., inflammation), psychological (e.g., depression) and social (e.g., loneliness) mechanisms that may underlie this association and provides potential avenues for future research. For example, this study found that mood (i.e., depression and anxiety) symptoms were associated with subjective cognition, even when accounting for sleep characteristics, which may suggest that mood may be an important factor in the sleep-subjective cognition association. Clinically, this study suggests that sleep characteristics, including insomnia symptoms, global sleep health and sleep regularity, are an important factor to consider in subjective cognition and future studies which investigate how changes in sleep characteristics are associated with changes in subjective cognition could elucidate how clinical interventions in sleep may affect changes in subjective cognition.

Limitations and future directions

Due to the cross-sectional nature of the study, we are unable to examine directionality in the sleep-subjective cognition association. Future research that examines temporal associations between sleep and subjective cognitive functioning may help elucidate if changes in subjective cognitive functioning precede changes in sleep, or vice versa. Moreover, because of the self-report nature of the data, results may have been affected by recall bias, social desirability bias and other biases that commonly affect self-report data, though the anonymous nature of the survey may have helped limit the effect of these biases. Another limitation of the present study is that we did not include other sleep behaviors such as total sleep time, sleep onset latency and wake after sleep onset. While the present study is an important first step in extending our understanding regarding the sleep-subjective cognition association, investigating how these sleep behaviors are associated with one's subjective cognitive functioning may elucidate whether the association differs based on the actual nighttime sleep of an individual. Moreover, future studies that investigate whether and how other demographic factors (e.g., race, ethnicity, socioeconomic status, marital status, employment status) affect the association between sleep and subjective cognition could help elucidate whether this association is modified by social determinants of health. For example, there have been mixed results regarding the association between race/ethnicity and subjective cognition (Katz et al., 2023; Wooten et al., 2023) and few, if any studies, have investigated how race and ethnicity potentially affect the sleep-subjective cognition association. Such research would help to elucidate whether cultural factors (e.g., discrimination,

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acculturation, neighborhood noise) affect the sleep-subjective cognition association. A final limitation to note about the present study is that, although the present data were collected from a community-based sample, we are unable to generalize the results of the present sample to other populations due to the convenient nature of the present sample. Future studies that utilize more random samples can provide insight into whether this association is generalizable.

This study observed that people reporting fewer insomnia symptoms, greater sleep health and more regular sleep were more likely to also experience greater subjective cognitive functioning. Future research that investigates how sleep behaviors, including total sleep time and sleep efficiency, are associated with one's subjective cognitive functioning, and whether changes in sleep are associated with changes in subjective cognition, may help further elucidate underlying factors of the sleep-subjective cognition association.

Data availability statement. The data are not available publicly because they were derived from a larger dataset not yet publicly available. Raw data were generated at Virginia Commonwealth University. Derived data supporting the findings of this study are available from the corresponding author JMD upon reasonable request.

Author's contributions. **Spencer A. Nielson:** Conceptualization, Formal analyses, Writing – original draft.

Natalie D. Dautovich: Writing – original draft, Supervision

Joseph Dzierzewski: Conceptualization, Methodology, Formal analyses, Investigation, Writing – original draft, Supervision, Project administration.

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All other co-authors have no interests to disclose.

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