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Habitual Sleep, Reasoning, and Processing Speed in Older Adults with Sleep Complaints

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Abstract

The relationship between habitual sleep and cognition in older adults with sleep complaints is poorly understood, because research has focused on younger adults, used experimental or retrospective quasi-experimental designs, and generally produced equivocal results. Prospective studies using sleep diaries are rare, but may provide important insights into this relationship as they offer greater ecological validity and allow for examination of the impact of night-to-night variability in sleep (an often overlooked aspect of sleep) on cognitive performance. Seventy-two older adults (M_{age} = 70.18 years, SD_{age} = 7.09 years) completed fourteen consecutive days of sleep diaries and paper/pencil self-administered cognitive tasks, including measures of processing speed (Symbol Digit) and reasoning (Letter Series). Regression analyses revealed increased average total wake time (TWT) during the night was associated with higher Symbol Digit scores, $\beta = 0.45$, $P < 0.05$. Night-to-night variability in either total sleep time (TST) or TWT was not associated with either cognitive measure. Implications and potential explanations for these initially counterintuitive findings are discussed.

Keywords

Older adults; Sleep complaints; Cognitive performance; Variability; Reasoning; Processing speed

Introduction

Sleep architecture changes with age, such that the sleep of older individuals is shorter, lighter, and more fragmented compared to that of younger individuals (Bixler et al. 1984; Brezinova 1975; Carskadon et al. 1982; Gillin et al. 1981). The combination of these changes and increases in chronic medical conditions make older adults particularly vulnerable to sleep difficulties. Epidemiological evidence indicates that more than half of older individuals report at least one sleep complaint (i.e., trouble falling asleep, waking up, awaking too early, needing to nap, or not feeling rested) (Foley et al. 1995). Despite the intuitive appeal of a strong link between sleep and cognition and the common co-occurrence of sleep and cognitive performance complaints in older individuals (Roth and Ancoli-Israel 1999), research in this area has primarily focused on younger adults and has produced equivocal results.

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Sleep Deprivation and Cognition

The bulk of the research examining sleep and cognition has involved controlled experimental trials in which participants are sleep deprived (partially or totally) for one or more days and then undergo a neuropsychological evaluation following a night or two of polysomnography. Across studies, sleep deprivation has been shown to impair all (Drummond et al. 2000; Drummond et al. 1999; Harrison and Horne 1997, 1999; Horne 1988), some (Cain et al. 2011; May and Kline 1987), and none (Binks et al. 1999; Pace-Schott et al. 2009) of the measures of executive functioning, processing speed, and other aspects of cognitive functioning administered to younger individuals. Unfortunately, these studies do not offer much insight into the sleep/cognition relationship in older adults, because all but two have excluded older adults. Those studies (Webb 1985; Webb and Levy 1982) found greater impairments in older adults compared to younger adults following 2 nights of sleep deprivation on tests of vigilance, visual search, reaction times, word detection, addition, anagrams, and object uses.

Sleep deprivation studies have been criticized for lacking ecological validity as it is unclear how findings based on manipulated sleep deprivation in the laboratory setting translate to the types of sleep difficulties that older adults experience in the real world. While some individuals with poor sleep may go without sleep occasionally, the typical sleep patterns of poor sleepers are remarkable for their variability with extremely poor sleep often followed by less poor or even good nights of sleep (Edinger et al. 1991). For this reason, studies examining habitual sleep patterns have the potential to provide ‘real world’ insights into the sleep/cognition relationship in older adults.

Habitual Sleep and Cognition

Relatively fewer studies have examined the habitual sleep/cognition relationship, but a greater number of them have included older participants. Generally, studies of habitual sleep have used quasi-experimental designs in which retrospective self-reported sleep is correlated with cognitive performance. Again, the findings have been mixed. In one study, older good and poor sleepers did not differ in processing speed, inhibition or memory, but poor sleepers exhibited worse executive functioning than good sleepers (Nebes et al. 2009). Additionally, sleep onset latency and sleep efficiency, measures of sleep fragmentation, were related to worse executive functioning, while sleep duration was not related to any of the cognitive measures. This former finding stands in contrast to epidemiological findings demonstrating sleep duration/cognition relationships. A study of Spanish elders (n = 3212) found cognition decreased as sleep duration increased from 7 to 11 h/night (Rodriguez-Artalejo et al. 2009). Another study of Finish elderly (n = 5177) found poorer verbal fluency and list memory performance for both short and long sleep durations (Kronholm et al. 2009). Yet another study of older women (n = 1844) founder poorer global cognition in those with shorter sleep duration (<5 h/night) compared to those with longer sleep durations (>7 h/night; (Tworoger et al. 2006).

Prospective sleep measurement has been used only rarely to study the habitual sleep/cognition relationship. One such study found better sleep quality and efficiency were associated with better attention and concentration, but worse memory in older good sleepers compared to those with insomnia (Bastien et al. 2003). Better sleep onset latency and total wake time were related to better processing speed in good sleepers only, while increased total wake time was related to poorer memory performance for poor sleepers. In another set of studies, older poor sleepers exhibited better verbal fluency and faster simple reaction times, but slower complex reaction times than older good sleepers (Altena et al. 2008a, b). While prospective measurement is rarely used, such an approach is less vulnerable to recall bias, and also offers the advantage of allowing researchers to take a closer look at the potential influence of variability in individuals' sleep patterns on their cognitive performance. Unfortunately, to date, no published studies have examined the impact of sleep variability on cognitive performance.

Explanations for Equivocal Findings

Explanations for the equivocal and often counterintuitive nature of the findings previously described include increased effort (Drake et al. 2001) and hyperarousal (Bonnet and Arand 2010). Researchers have speculated that poor sleepers recognize that they have slept poorly and in response, put forth greater effort or more resources to maintain performance. Hyperarousal has been hypothesized as the mechanism underlying insomnia, and some have speculated that it not only interferes with sleep at night, but also continues into the daytime where it serves to maintain (or even bolster) cognitive performance in poor sleepers (Bonnet and Arand 2010). To explain instances in which poor sleepers have shown better performance on simpler but not more complex cognitive tasks, it has been suggested that additional effort or arousal can only go so far in maintaining/improving performance, and may not be enough for more complex tasks. Other explanations are available [e.g., attention control (Pilcher et al. 2007), top down vs. bottom up processing (Harrison and Horne 2000; Jones and Harrison 2001)], but rather than describe them all, it is more important here to note that they are all based on the underlying tenet that individuals can compensate (at least to some extent) for the effects of poor sleep on some aspects of cognition.

Night-to-Night Variability in Habitual Sleep

Researchers have commented on the relevance of variability for broadening our understanding of habitual sleep and have even suggested that high levels of variability in sleep may lead to insomnia complaints (Espie 1991). While night-to-night variability in sleep has received some attention in the literature, the majority of research has focused solely on characterizing that variability. In a notable exception, McCrae and colleagues (Mccrae et al. 2008) demonstrated a sleep/affect link in older adults such that nights with greater reported awake time or lower sleep quality were associated with days characterized by less positive affect and more negative affect. A tentative conclusion that can be drawn from that study is that variability may provide important insights into the relationships between sleep (a modifiable behavior) and other potentially modifiable behaviors (e.g., affect, cognition). Although causal inferences cannot be drawn from that quasi-experimental study, it has important implications for the potential improvement of certain behaviors (e.g., cognitive performance) through the manipulation of other behaviors (e.g., sleep). The present study is the first to examine whether variability in sleep might be related to cognitive performance in older adults.

The Current Study

The present study examines sleep prospectively over 14 days and explores whether the average of that data or its variability is a better predictor of cognitive performance in older adults with sleep complaints. This study will examine two sleep variables—total sleep time (a measure of sleep duration), and total wake time (a measure of sleep fragmentation), and two cognitive outcomes—Symbol Digit total score (a measure of processing speed; Smith 1982) and Letter Series total score (a measure of executive functioning; Thurstone 1962). These sleep variables were chosen because they represent distinct aspects of older adults' subjective sleep experience (sleep and wake time during the night), and the cognitive variables were chosen, because they represent a relatively simple (Symbol Digit) and a more complex task (Letter Series). Additionally, previous research suggests these sleep and cognitive variables may capture different aspects of the sleep/cognition relationship. Older adults with suspected apnea or other physiological sleep disorders were excluded as the focus here is on insomnia type sleep complaints. Additionally, the physiological mechanisms underlying apnea (e.g., nocturnal respiratory system dysfunction) are distinct from those hypothesized to underlie insomnia (e.g., hyperarousal), and as a result, have their own distinct relationships with cognition.

Method

Participants

Recruitment—Seventy-two older adults (60+ years) were selected from a larger parent study, examining sleep and cognition over the course of cognitive behavioral therapy for insomnia in older adults with insomnia. Participants were recruited from Gainesville, FL and the surrounding area via newspaper, radio, and television advertisements. Participants in the parent study completed 2 week baseline, post-treatment, and 3 month followup assessments involving daily sleep and cognition diaries. The present study is based upon that study's baseline data only. Unlike the parent study, which focused on individuals with an insomnia diagnosis, the present study includes all individuals who complained of poor sleep and did not exhibit symptoms of other sleep disorders according to either self-report (apnea, periodic limb movements disorder) or ambulatory screening (apnea). This approach allows for an examination of sleep and cognition across the full range of sleep behaviors exhibited by individuals who complain of poor sleep. Inclusion criteria: (a) complaint of poor sleep, (b) daytime dysfunction due to poor sleep (mood, cognitive, social or occupational impairment); (c) no prescribed or over-the-counter sleep medication for at least 1 month, or stabilized on medication for 6+ weeks. Exclusion criteria: (a) significant medical (e.g., cancer) or neurological disorder (e.g., dementia); (b) major psychopathology (e.g., psychotic disorders, substance abuse); (c) other sleep disorders (e.g., sleep apnea, periodic limb movements); (d) cognitive impairment based on Mini-Mental State Exam (MMSE; Folstein et al. 1975) score lower than 23 (>9th grade education) or 19 (<9th grade education); (e) severe depressive symptomatology based on Beck Depression Inventory—2nd Edition (BDI-II; Beck et al. 1996) score of 24 or higher or Geriatric Depression Scale (GDS; Yesavage et al. 1982) score of 13 or higher; (f) suspected sleep disordered breathing based on single-night ambulatory monitoring (Compass F10; Embla) of blood-oxygen saturation and respiration indicating an apnea-hypopnea index (AHI) of >15 and minimum O_2 desaturation <93%; (g) missing more than 7 days of sleep data for 14-day baseline period. This study was approved by the University of Florida's Institutional Review Board (IRB-01), and all participants signed informed consent forms prior to participation.

Measures

Sleep Measure—Participants completed sleep diaries (Lichstein et al. 1999b) each morning for 14 days, providing subjective estimates of the following sleep parameters: (1) total sleep time (TST), the total amount of time spent sleeping during the night, was derived by subtracting sleep onset latency (SOL), wake time after sleep onset (WASO), and time spent awake in bed in the early morning following the last awakening (EMA) from the total amount of time spent in bed (TIB), (2) total wake time (TWT), the total amount of time spent awake in bed from the time the individual got into bed intending to go to sleep until the final time they got out of bed in the morning, was derived by summing SOL, WASO, and EMA. For purposes of the analyses, both mean levels and variability indices were computed for TST and TWT. Mean TST and TWT = their respective 14-day averages. TST and TWT variability indices = within-person standard deviations representing one's fluctuation around one's average level of sleep (see Analyses for details).

Sleep Complaint—Participants completed a 2-page questionnaire that collected information on demographics, sleep disorders symptoms, physical health, mental health, and consumption of common sleep disrupting substances. Sleep complaint was defined as a 'yes' to the follow question: “Are you currently experiencing difficulty with your sleep at night?” Participants who reported a sleep complaint were also asked to report its duration. Complaint duration was defined as the number of months since first developing a sleep complaint.

Cognitive Measures—Cognition was measured in two broad domains: processing speed and reasoning. Both cognitive domains were assessed daily via self-administered paper and pencil tasks for fourteen consecutive days.

The Letter Series Task [original version (Thurstone 1962)] was used to measure inductive reasoning. Inductive reasoning is related to components of executive functioning (Lezak 1995). In this task, participants had to identify the pattern for a series of letters. Participants were asked to choose the letter that would continue the established pattern (A B D A B D A B ___?) in a series of letters from five answer choices. Participants were given four minutes to complete as many items as possible and a timer to self-monitor time limits. The maximum score is 30. The Letter Series total score is the number of correct responses.

The Symbol Digit Modalities Test [original version (Smith 1982)] was used to measure perceptual/processing speed. In this test, the participant was presented with a series of nine symbols paired with unique digits in a key at the top of an 8.5 × 11 inch sheet. The rest of the page displays a randomized sequence of symbols with blank spots below each. The participant was instructed to write the digit that corresponds to each symbol in the key below that symbol as quickly as possible. The participant was given 90 s to complete as many items as possible and a timer to self-monitor time limits. The Symbol Digit total score is the total number of correct responses recorded in the allotted 90 s.

Over the course of the study, fourteen alternate forms of the Letter Series (Allaire and Marsiske 2005) and Symbol Digit (McCoy 2004) tests were given, one per day. The alternate versions of the Letter Series and Symbol Digit tests were constructed to be comparable in difficulty and cognitive resources needed to complete them. No two forms of the test contained identical questions. All participants were instructed to complete the daily assessments in the morning hours. For the purposes of this report, the 14-day mean level of the Letter Series and Symbol Digit total scores were used as the cognitive outcome variables. This was done in order to increase the reliability of the cognitive outcomes and to achieve more stable/precise estimates of cognitive performance than are typically achieved with single assessments.

Analysis

Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity, multicollinearity, and homoscedasticity. Within-persons variability indices were calculated for both TST and TWT. Within-persons variability refers to the extent that a person’s repeated scores fluctuate around their own mean (i.e., a standard-deviation within the individual). First, the sleep variables were detrended in order to capture fluctuations that are unrelated to time (e.g., fluctuations are not due to the effects of observing behavior over time). Detrending for time effects distinguishes between fluctuations that may be time-dependent (e.g., adaptation or homeostatsis) and fluctuations that are randomly ordered in time, that are of interest in the present study (random variations in a person’s behavior; Ram and Gerstorf 2009). Detrending consisted of calculating linear regressions for TST and TWT for all participants with time (linear, quadratic, and cubic functions) as the independent variable, and TST and TWT as the dependent variables. As a result, the unstandardized residuals resulting from the linear regression consisted of time-independent values (the possible impact of linear, quadratic, and cubic functions were removed from the TST and TWT variables).

A 3-block hierarchical regression was run for each cognitive outcome variable (i.e., Letter Series and Symbol Digit). In block 1, demographic information (i.e., age, education, and sleep complaint duration) was entered. In block 2, Mean TST and TWT were entered. In block 3, the TST and TWT variability indices were entered. Models were limited to one index of sleep duration (i.e., TST) and one indicator of sleep fragmentation (i.e., TWT) due to sample size limitations and power considerations. Models were run with mean replacement for missing data. Specifically, missing sleep and cognitive data were replaced with their respective individual means; missing demographic data was replaced with the respective group mean.

Results

Characteristics of the Sample

Seventy-seven participants were recruited during the baseline screening of the parent study. However, two participants were excluded from present study due to suspected sleep disordered breathing based elevated AHI levels (i.e., >15). Three other participants were also excluded, because they were missing more than 7 out of the 14 days of sleep and/or cognitive data. The final sample included seventy-two older adults with sleep complaints (M = 70.18 years, SD = 7.09 years). Descriptive demographic, sleep, and cognition data are shown in Table 1.

Sleep Predicting Reasoning

Block 1 (i.e., age, education, and complaint duration) of the regression model was significant [$F(5, 66) = 3.13$, $P < .05$], accounting for approximately 12% of the variance in Letter Series performance [$F(5, 66) = 3.13$, $P < .05$]. However, blocks 2 and 3, which were the main focus of the study, were not significant. Age was the only significant predictor ($\beta = -.37$, $P < .01$) of reasoning (i.e., Letter Series total score). See Table 2 for a complete listing of standardized and unstandardized regression coefficients for the final model, as well as R^2 values for each block.

Sleep Predicting Processing Speed

Blocks 1 and 3 were not significant, but block 2 (i.e., age, education, complaint duration, Mean TST, Mean TWT) of the regression model was significant, [$F(5, 66) = 2.31$, $P < .05$], accounting for approximately 15% of the variance in Symbol Digit performance. Mean TWT was the only significant predictor of processing speed (i.e., Symbol Digit total score). These results indicate that as average total amount of time spent awake in bed (TWT) increases, average Symbol Digit total score (i.e., processing speed) also increases in older adults who complain of poor sleep. See Table 3 for a complete listing of standardized and unstandardized regression coefficients for the final model, as well as R^2 values for each block.

Discussion

The present study examined the relationship between habitual sleep, reasoning, and processing speed in a sample of 72 older adults with a complaint of poor sleep. Because previous research has produced equivocal results, no specific hypotheses were made. Instead, the present study explored whether measures of habitual sleep duration (total sleep time) and fragmentation (total wake time) would predict performance on a relatively simple processing speed task (Symbol Digit) and a more complex reasoning task (Letter Series). This study was also the first to examine whether night-to-night variability in sleep would be a better predictor of cognitive performance than mean level. The results revealed that average wake time during the night was related to processing speed, but that neither sleep variable was related to reasoning. Not surprisingly, increased age predicted decreased reasoning. Nightly variability of either sleep measure did not predictcognitive tasks.

Converging evidence has shown that executive functioning changes more than other aspects of cognition with aging (Altena et al. 2010). Thus, while the finding that increased age predicted decreased reasoning is not novel, it nonetheless adds to the growing literature capturing this phenomenon. Although no sleep variables were related to reasoning, previous research has shown that after controlling for age and depression, sleep disturbances are related to measures of executive functioning in older adults with cognitive impairment (Naismith et al. 2010). One explanation for the lack of relationship in the present study is that participants were screened for cognitive impairment. It is possible that the sleep/executive functioning relationship only occurs in the context of cognitive impairment. Alternatively, it may occur but in an attenuated form in older adults without cognitive impairment. Another possible is that this study’s relatively small sample size lacked sufficient power to detect this relationship. The finding that greater average wake time during the night predicted better processing speed (i.e., Symbol Digit) performance seems somewhat counterintuitive. Nonetheless, this finding combined with the lack of a sleep/reasoning relationship in the present study is consistent with other research demonstrating superior cognitive performance on simple as opposed to complex tasks in good versus poor sleeping older adults (Altena et al. 2008a, b). Specifically, Altena and colleagues found that older adults with insomnia responded faster than good sleepers on a simple vigilance task yet performed more poorly on a more complex vigilance task (Altena et al. 2008a, b). Findings such as these raise interesting questions regarding older adults’ sleep needs (Chambers and Keller 1993; Riedel and Lichstein 2000). While these questions are beyond the scope of this discussion, the present findings contribute to the need for daytime performance indicators, such as cognitive performance, to be taken into consideration when determining sleep needs in aging. Potential explanations for these counterintuitive findings include increased effort and hyperarousal (Altena et al. 2008a, b; Drake et al. 2001). In terms of effort, it is possible that poor sleepers are aware of the potential impact of poor sleep and thus, increase their effort in an attempt to compensate. Another possibility is that hyperarousal compensates for the effects of poor sleep. Researchers have hypothesized that individuals with insomnia are hyperaroused not just at night, but 24 h a day (Bonnet and Arand 2010). If this is the case, hyperarousal may operate as a double-edge sword—interfering with sleep during the night, while compensating for the impact of poor sleep on cognitive performance during the day (Lichstein et al. 1994). The addition of sleep variables to the model did explain an additional 9% of the variance in processing speed ability [a medium effect (Cohen 1988)].

Regardless of whether increased effort or hyperarousal (or some other mechanism) is compensating for the effects of poor sleep on cognitive performance, the results of the present study as well as that of others (Altena et al. 2008a, b) suggest that such compensation may be limited. Specifically, it appears to have a differential impact based on task complexity such that more complex tasks may remain more vulnerable to the ill effects of poor sleep. Thus, increased effort and/or hyperarousal may not be enough to maintain and/or boost performance as task demands increase. Clearly, additional research is needed to gain further insight not only into the nature of the sleep/cognition relationship, but also its underlying mechanism(s).

The findings of this study and other studies of sleep and cognition in older adults are important, because the US population is aging at an increasing rate (Howden and Meyer 2011). Thus, the sleep disturbances and cognitive impairments associated with aging are placing increasing burden on already taxed public health resources. Since both cognition and sleep represent modifiable health-related behaviors, better understanding of the relationship between these behaviors in older adults may have important treatment implications. While the present study was quasi-experimental and cannot be used to both draw causal inferences, at least one study found that following behavioral sleep treatment, older poor sleepers who received treatment performed similarly to the good sleepers on reaction time tasks (Altena et al. 2008a). Researchers have speculated that a holistic model for cognitive remediation training that takes into account other health promoting factors (e.g., sleep) may be needed for patients to fully benefit from remediation training (Vance et al. 2010). Clearly, more research on sleep and cognition in older adults is warranted as is additional research examining the impact of behavioral and cognitive-behavioral treatments for insomnia singly as well as combined with cognitive remediation training on cognitive performance. Interestingly, unlike a recent examination in older adults without sleep complaints (Oosterman et al. 2009), the present study found no statistical evidence that night-to-night fluctuation in either total sleep time or total wake time was related to daytime cognitive functioning. Several important distinctions between respective methodologies may have contributed to the divergent results. This study recorded self-report sleep for 14-consecutive days in a sample of older adults with a complaint of poor sleep. Oosterman et al. (2009) recorded 7 nights of actigraphically-measured sleep in a sample of older adults with known cardiac conditions, but without sleep complaints (Oosterman et al. 2009).

There are a few limitations that need to be acknowledged. This study's relatively small sample size precluded the detection of significant relationships that a larger sample would have had suitable power to detect. Generalizability of results may be hindered by the sample characteristics. Specifically, study participants were above-average educated, mostly Caucasian, and healthy. Excluding adults with underlying sleep disorders, other than insomnia, may have led this study to find results divergent from previous studies, which did not exclude participation based on the presence of other sleep disorders. The participants in the current study may not represent the normal sample of older adults with insomnia, as an undiagnosed sleep apnea disorder is common in adults reporting primary insomnia (Lichstein et al. 1999a). However, the limitation this imposes on generalizability is at least partially offset by the importance of the knowledge gained—specifically, that insomnia symptoms alone are related to cognition in older adults. The use of self-administered daily assessments and the resulting loss of experimental control must be acknowledged. However, the increase in ecologically validity may offset this loss of experimental control. All participants were instructed to complete their daily tests during the morning hours; however, no check was performed to insure all participants followed this practice. In addition, a recall bias may be present and individuals could have misrepresented either their duration of poor sleep complaint or their nightly sleep parameters. However, as poor sleep is ultimately a subjective complaint, the concern of recall bias is minimized.

Future investigations would be well suited to collect multiple indicators of both sleep and cognitive functioning in samples that include individuals complaining of poor sleep, individuals with no such complaint, and individuals with diagnosed insomnia. Such an approach would allow for intriguing comparisons and may better delineate the relationship between sleep disturbance and cognitive functioning in older adults.

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Table 1

Participant descriptive statistics of demographics, cognitive performance, and sleep characteristics (N = 72)

Variable	***M* (SD)**	**Range**
Demographics		
Age	70.18 (7.09)	60–90
Gender	1.66%	–
Education	16.31 (2.18)	12–22
Sleep complaint duration	14.88 (14.40)	.50–60
Cognitive performance		
Letter series	11.73 (5.01)	2.36–24.21
Symbol digit	41.15 (11.48)	2.64–73.82
Sleep		
TWT mean	133.36 (79.05)	24.64–454.29
TWT variability	44.14 (28.41)	4.68–157.39
TST mean	362.67 (80.83)	148.64–489.62
TST variability	54.88 (31.55)	12.82–189.86

Age and education measured in years. Gender measured as 1 = male, 2 = female. Cognitive data presented as units correct. All sleep variables measured in minutes

Table 2

Hierarchical multiple regression predicting letter series (N = 72)

Variable	***B***	***SE B***	***β***	**R^2**	**ΔR^2**
Step 1	–	–	–	.12*	.12*
Age	−.24**	.08**	−.34**	–	–
Education	.14	.26	.06	–	–
Complaint duration	−.00	.04	−.01	–	–
Step 2	–	–	–	.13	.01
Age	−.24**	.08**	−.35**	–	–
Education	.12	.27	.05	–	–
Complaint duration	−.00	.04	−.01	–	–
TWT mean	−.01	.01	−.11	–	–
TST mean	−.01	.01	−.12	–	–
Step 3	–	–	–	.14	.01
Age	−.26**	.09**	−.37**	–	–
Education	.11	.27	.05	–	–
Complaint duration	.00	.04	.01	–	–
TWT mean	−.01	.01	−.22	–	–
TST mean	−.01	.01	−.14	–	–
TWT variability	.03	.03	.17	–	–
TST variability	−.01	.02	−.06	–	–

TWT Total Wake Time, *TST* Total Sleep Time

[*] *P* < .05,

[**] *P* < .01

Table 3

Hierarchical multiple regression predicting symbol digit (N = 72)

Variable	*B*	*SE B*	β	R^2	ΔR^2
Step 1	–	–	–	.06	.06
Age	−.14	.19	−.08	–	–
Education	−.87	.62	−.16	–	–
Complaint duration	−.13	.09	−.16	–	–
Step 2	–	–	–	.15*	.09*
Age	−.09	.19	−.06	–	–
Education	−.65	.61	−.12	–	–
Complaint duration	−.14	.09	−.17	–	–
TWT mean	.06**	.02**	.41**	–	–
TST mean	.03	.02	.23	–	–
Step 3	–	–	–	.15	.00
Age	−.08	.19	−.05	–	–
Education	−.62	.62	−.12	–	–
Complaint duration	−.14	.09	−.18	–	–
TWT mean	.07*	.03*	.45*	–	–
TST mean	.03	.02	.24	–	–
TWT variability	−.01	.07	−.02	–	–
TST variability	−.02	.05	−.05	–	–

TWT Total Wake Time, *TST* Total Sleep Time

* $P < .05$,

** $P < .01$