

The Relationship Between Sleep, Working Memory, and Decision Making in Young and Old Adult Populations

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THE RELATIONSHIP BETWEEN SLEEP, WORKING MEMORY, AND
DECISION MAKING IN YOUNG AND OLD ADULT POPULATIONS

by

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A thesis submitted in partial fulfillment of the requirements
for the Honors in the Major Program in Psychology
in the College of Sciences
and in the Burnett Honors College
at the University of Central Florida
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Abstract

Sleep is known to influence basic tasks concerning working memory, reaction time and executive functioning (Silva, Wang, Ronda, Wyatt, & Duffy, 2010; Nebes, Buysse, Halligan, Houck, & Monk, 2009). However, the amount that sleep influences these functions varies from study to study possibly due to differences in age and task design. Aim 1A of this study is to determine if sleep quality affects working memory. Aim 1B of this study is to determine if age affects sleep quality and working memory in comparison of young and old adult populations. Finally, Aim 2 of this study is to determine if there is a relationship between sleep quality, working memory, and decision making in the younger adults. These aims were researched using a validated and commonly used sleep questionnaire: the Pittsburgh Sleep Quality Index (PSQI). In addition, the study utilized an n-back test to measure working memory and executive functioning, and an economic decision task to measure decision making accuracy. Results show that sleep quality did not significantly influence accuracy on an n-back test in either age group, but age was significantly correlated with accuracy on an n-back test in the older adults. The study also found a relationship between working memory performance and complex decision making among younger adults, but this relationship was not modulated by sleep quality. Our findings suggest that self-reported sleep quality is not a strong predictor of working memory or complex decision making, particularly in early adulthood. Future research on this topic may benefit from a more objective measure of sleep quality and from larger samples across different phases of the lifespan.

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Introduction

Background

With the ability to affect a wide range of mental and physical functions, sleep has intrigued scientists for centuries. Young adult sleep habits are concerning due to irregular schedules and unhealthy lifestyles (Lund, Reider, Whiting & Prichard, 2010), and older adult sleep habits are alarming because they are often disrupted due to other health issues which increase in prevalence with age (Foley, Ancoli-Israel, Britz & Walsh, 2004). Furthermore, sleep has been heavily linked to learning, as well as memory patterns (e.g., Huber, Ghilardi, Massimini & Tononi, 2004; Maquet, 2001). Poor sleep quality has also been shown to impair cognitive functioning and behavioral performance (Curcio, Ferrara & De Gennaro, 2006).

Sleep is known to affect cognitive functions and simple behaviors including working memory, reaction time, and executive functioning (Silva, Wang, Ronda, Wyatt, & Duffy, 2010; Nebes, Buysse, Halligan, Houck, & Monk, 2009). However, the proposed mechanisms by which sleep quality affects these functions varies among studies due to differences in domains such as participant age, task design, task difficulty, and individual difference measures. Silva and colleagues (2010) studied age and cognitive performance, including working memory. This study followed a within-subjects design, and participants were forced to endure a series of desynchronized sleep cycles for up to 18 days. This level of sleep deprivation is at the extreme end of human experience, and may have limited generalizability. In contrast, individual differences in sleep quality may be a more generalizable factor. Studies with older adults by Nebes, Buysse, Halligan, Houck, and Monk (2009) and Miyata et al. (2013) examined sleep quality and working

memory. They found that sleep quality and age were significantly correlated with working memory. The inclusion of younger adult participants in these studies would allow insight into the impact of sleep quality and cognitive functioning across ages. The current study aims to advance this area of study – specifically examining relationships between age, sleep quality and cognitive functions including working memory and decision making.

Memory Types

Memory is commonly divided into three parts: long-term memory, short-term memory and working memory. According to Cowan (2008), long-term memory can be defined as a possibly infinite storage of past experiences. In contrast, short-term memory is temporary and has a smaller capacity, as well as a shorter duration to hold information (Cowan, 2008). Finally, working memory can be understood as a component of short-term memory that also uses other processing mechanisms to hold certain information in the mind while solving more complex cognitive tasks (Cowan, 2008).

Working Memory

Working memory plays a fundamental role in all methods of complex thinking (Just & Carpenter, 1992) and impacts daily functioning tasks such as driving while remembering a grocery list, or cooking and attempting to remember the ingredients. It is therefore beneficial to understand the factors that influence the working memory process. In behavioral studies, working memory is frequently studied using an n-back test. An n-back test is a continuous performance test where subjects must match the current stimulus shown with a previous stimulus. “N” is used to represent

the lag in stimuli that participants must use for their comparisons (e.g., 1-back, 2-back, etc.; see Fig. 1 for example).

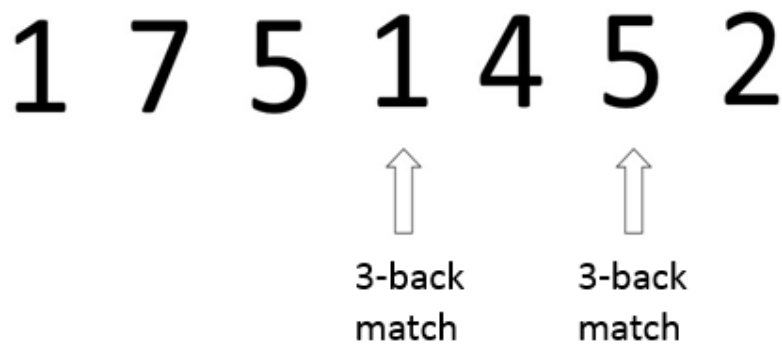


Figure 1: 3-back test used to study working memory.

Working Memory and Sleep

Considerable research has observed a relationship between working memory and sleep. The specific brain regions involved with executive function and working memory are vulnerable to sleep loss (Durmer & Dinges, 2005). Smith, McEvoy, and Gevins (2002) reported that after an extended wakefulness period, young adult participants performed significantly worse in regards to accuracy on both a working memory task and a reaction time test compared with a normal sleep condition. While intense sleep deprivation strongly affects working memory, researchers suggest that even modest sleep loss compromises working memory function and attention (Smith, McEvoy, & Gevins, 2002).

A study completed by Silva and colleagues (2010) compared forced desynchronized sleep cycles on older and younger adult populations. In their experimental design, participants were

allowed three days of typical circadian synchrony, and were then forced into three days of desynchronized cycles. Subjective sleepiness, cognitive performance, and reaction time were studied using the Karolinska Sleepiness Scale (KSS), the Psychomotor Vigilance Test, and a basic reaction time task (Silva, Wang, Ronda, Wyatt, & Duffy, 2010). Results showed that overall, older adults reported themselves less sleepy than younger adults. Additionally, in both age groups, a significant effect concerning time awake and neurobehavioral performance was found, showing that reaction time lapses increased as time awake also increased in both populations (Silva et al., 2010). Furthermore, there was a second significant result found regarding age and time awake, showing that older adults had faster reaction times and fewer mistakes than younger adults as time awake increased (Silva et al., 2010). Therefore, results showed that while time awake increased, errors tended to stay consistent within the older adult population from their original baseline, while errors increased within the younger adult population as time increased (Silva et al., 2010). This is indicative of premise that older adults are able to better tolerate sleep deprivation than younger adults (Duffy, Willson, Wang, & Czeisler, 2009).

The memory types most affected by age are working memory and episodic memory (Daselaar, & Cabeza, 2013). Based on positron emission tomography (PET) scans, the frontal components of the working memory system are most vulnerable to age (Reuter-Lorenz, Jonides, Smith, 2000). Clapp and Gazzaley (2012) reported that while interference (distraction and interruption) during a working memory task affected both young and older adults, older adults were more affected. These changes may be due to the older adult's slower processing of simple tasks (Salthouse, 1991). However, these results could also be attributed to attentional differences in older adults rather than the processing speed of information. A study completed by Nebes,

Buyse, Halligan, Houck, and Monk (2009) focused strictly on older adults (ages 65-80). Participants completed a basic reaction time task, an n-back task, and a letter-number sequencing subtest of the Wechsler Adult Intelligence Scale III to measure working memory. Inhibitory function, attention shifting and abstract reasoning were also measured. Participants that were considered poor sleepers performed significantly worse than the good sleepers on various tasks, including the n-back task (Nebes et al., 2009). Researchers did not find significant results supporting the idea that sleep affects verbal memory, inhibitory function or information-processing speed (Nebes et al., 2009). However, researchers did find that lower sleep efficiency was predictive of poorer performance on the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS), the Test of Nonverbal Intelligence (TONI), the n-back, and the Geriatric Depression Scale (GDS) (Nebes et al., 2009). This study did not research young adult sleep patterns.

Cognitive impairments from poor sleep quality in older adults has also been researched by Miyata et al. (2013). This study measured total sleep time using an actigraph, which is a wearable device that measures movement, and therefore wakefulness and sleep periods. Cognitive performance was measured using an n-back test and identical pairs test. The results reported that total sleep time, age, and sleep efficiency were correlated with reaction time performance, while working memory via the n-back test (1-back) was correlated with age and sleep efficiency. Additionally, participants who reported sleep efficiency < 85% via the Pittsburgh Sleep Quality Index (PSQI) or Epworth Sleepiness Scale (ESS) showed a decrease in accuracy in basic reaction time tasks and on working memory task such as the n-back.

Working Memory, Sleep and Decision Making

Working memory, sleep, and decision making are likely interdependent, but very little research has been conducted to examine their relationship directly. However, working memory can be considered a necessary component of decision making, and many studies have researched the relationship between sleep and decision making. Of these studies, Harrison and Horne (1999) found that even a single night without sleep can influence performance on tasks that require intricate thought and updating information. When completing a laboratory-based marketing strategy simulation game, sleep deprived participants became unable to follow the rapidly changing information, and could no longer make or maintain profits, often leading to bankruptcy (Harrison & Horne, 2000). Additionally, with the use of a gambling task, researchers concluded that sleep deprivation influences the activation of the nucleus accumbens and insula, two brain regions that are associated with risky decision making and emotional processing (Venkatraman, Chuah, Huettel & Chee, 2007). This suggests that sleep deprivation may have an impact on risky decision making. Sleep deprivation also reduced participant's responses to losses (Venkatraman et al., 2007). The above studies were all completed with young adults.

Proposed Research

Many studies have researched the link between sleep and working memory, but many of these studies have included only older adult populations (Nebes, Buysse, Halligan, Houck, and Monk, 2009; Miyata et al., 2013). Other studies, which have compared sleep and working memory between young and old adults, have forced participants into desynchronized states (Silva, Wang, Ronda, Wyatt, & Duffy, 2010). This experimental design may produce results which are not

generalizable to the normal population. Additionally, a study has yet to be completed which specifically investigates the relationship between sleep quality, working memory, and decision making in young adults. A study which addresses this gap in the literature will give insight into the differences between young and old adult populations in regards to sleep and working memory, and will also determine if there is a correlation between young adults and sleep quality, working memory, and decision making.

Method

Participants

Participants in this project were drawn from two larger studies currently in progress at the University of Central Florida's Adult Decision and Development Lab regarding memory and economic decisions over time. The first study included younger adults and used an economic decision task adapted from Kuhnen (2015). The second study included healthy older adults and a novel "consumer judgment task" developed in the lab (data not presented here). An n-back test was used to measure working memory in both studies (Callicott et al., 2003). The current study includes data from 142 young adults (ages 18-35). Fifteen young adults were excluded due to data loss, or due to incorrect completion of the study. Data was also analyzed from 21 older adults (ages 65-85). Three older adults were excluded because they could not complete the n-back task correctly. To contribute, all participants were required to have normal or corrected-to-normal vision. The studies were approved by the University of Central Florida's (UCF) Institutional Review Board and all participants gave verbal informed consent before taking part in the study. Younger participants were recruited through the UCF's SONA system or by flyer advertisements. Older participants were recruited through the Learning and Longevity Research Network at the UCF or by flyer. All participants were provided monetary compensation for their participation. Compensation amounts included a flat rate for participation and a bonus based on accuracy within the decision task.

Materials

This project added the Pittsburgh Sleep Quality Index (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) and the Saint Mary's Hospital Sleep Questionnaire (Ellis et al., 1981) to the aforementioned larger studies of judgment and decision making. Other surveys already used in the experiments include the Positive and Negative Affect Schedule (Watson, Clark, & Tellegan, 1988) and the General Decision Making Style Survey (Scott & Bruce, 1995). While two different decision-making tasks were used in the larger studies, the data compared here (the n-back and surveys) was the same within the two groups.

The Pittsburgh Sleep Quality Index (PSQI). PSQI is a frequently used questionnaire that measures many items including sleep quality, latency, disturbances, and sleeping medication usage over the past thirty days. The PSQI totals each participant's responses and scores the participant as a good (<5) or bad (>4) sleeper.

The Saint Mary's Hospital Sleep Questionnaire (SMHSQ). SMHSQ measures sleep aspects, such as sleep duration, sleep quality, and sleep satisfaction. This measure is solely interested in the participant's previous night of sleep. Using these two questionnaires will not only allow assessment of the participant's typical sleep habits, but will also give insight to determine participants whose previous night's sleep is unusual compared to the past thirty days.

The Number-Back Test (n-back). N-back is a working memory and executive function test, given on a computer. This is a continuous performance test where participants must match a number shown on the screen with a number that was shown previously. The difficulty of an n-back test can change depending on the number of previous trials the participant must remember. A 1-

back test requires the participant to match the current number with the number shown before it; a 2-back test requires the participant to match the current number with the number shown two turns back, and so on. The specific version used in this experiment was a 3-back test.

Economic Decision Task. The economic decision task was used to examine interactions of memory, attention, and motivation during financial decision making. The task was adapted from Kuhnen (2015). Participants must estimate outcome probabilities of a stock based on the previous payout of a stock in a stock vs. bond choice scenario. The task investigates stock probability estimations in both gain and loss conditions, and also contains a surprise memory test to examine the differences in value judgments and attention. Critically, task performance may depend on working memory as participants make stock/bond choices and stock outcome probability estimations based on recently experienced stock payouts.

Self-Report Questionnaires. Two additional scales were utilized in this study to measure individual differences: the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegan, 1988), and the General Decision Making Style Survey (GDMS; Scott & Bruce, 1995). Individual differences can be defined as the variability between persons in certain aspects such as cognitive styles, motivation, personality, self-regulation, and language (Winke, 2007). It is possible that differences between individuals can influence behavior and cognitive performance. For example, studies have shown that a negative mood can lead to riskier behaviors, while a positive mood can induce risk-aversion behaviors (Isen, Nygren, & Ashby, 1988). The PANAS is a highly reliable self-report scale used to measure human emotion, particularly the current positive and negative emotions of a participant. Participants answer twenty questions regarding their emotional state on a 5-point Likert scale. Half of the questions regard the negative affect of

the participant and half are in regards to positive affect. The GDMS is used to measure the degree to which people use five decision styles: rational, avoidant, dependent, intuitive and spontaneous. Understanding the particular decision making style of a participant in comparison to sleep could lead to greater understanding of the boundary conditions for sleep effects on decision making.

Statistical Analysis

Univariate ANOVAs were used to examine differences in working memory by age and sleep quality. Working memory performance was indexed via correct responses on a 3-back test, as well as reaction time for correct responses on the 3-back test. Participants were divided into good and poor sleeper categories using the PSQI. The PSQI totals each participant's responses and scores the participant as a good (<5) or bad (>4) sleeper. Participants were also grouped according to age: young adults ages 18-35 and older adults ages 65-85. Then, univariate ANOVAs were used to examine differences in complex decision-making by working memory performance among younger adults. Participants were split into working memory groups using a median split of correct responses on the n-back task. Additional ANOVAs were conducted to examine differences in affect and decision style on working memory. PANAS and GDMS were used to investigate the possibility that individual differences between participants affect the relationship between sleep and cognitive functioning. Participants were split into working memory groups using a median split of reaction time for correct responses on the n-back task. Finally, post-hoc correlation analyses were conducted to examine relationships between sleep quality and working memory among older adults. An ANOVA was conducted to compare good and bad sleepers and working memory, specifically the reaction times for correct responses (grouped by a median split).

To represent error, standard error of the mean (SEM) was used, and to represent effect sizes, partial eta squared (η_p^2) was used. Statistical analyses were performed using IBM SPSS Statistics 23.

Results

Sleep Quality in Young versus Older Adult Populations

The PSQI was used to determine sleep quality in both age groups. In the young adult group ($n = 142$), 51 of the participants were scored as “good sleepers” (PSQI score < 5), and 91 as “bad sleepers” (PSQI score > 4 ; $\sim 64\%$). In the older adult population ($n = 21$), a total of 13 participants were scored as good sleepers, and 10 as bad sleepers ($\sim 43\%$). However, analysis found no significant effect of age on sleeper type ($F_{(1,163)} = 2.11, p = .15, \eta_p^2 = .01$). A lack of significant differences in sleep quality by age may be related to the very limited sample size for older adults.

Age, Sleep, and the Number of Correct Responses on the N-Back Task

As expected, results revealed a significant age difference in working memory in the form of correct responses on the n-back test ($F_{(1,152)} = 10.83, p < .01, \eta_p^2 = .07$; Fig. 2), but no significant interaction between age, working memory, and sleep ($F_{(1,152)} = 2.27, p = .13, \eta_p^2 = 0.02$).

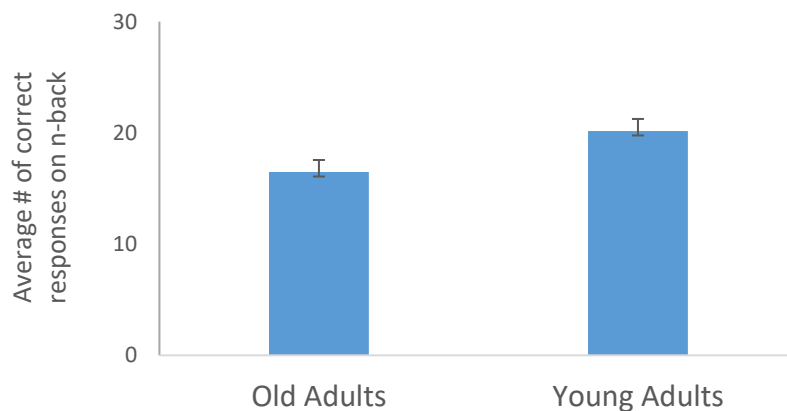


Figure 2: Average correct responses on the n-back task by age group.

Age, Sleep, and the Reaction Time for Correct Responses on the N-Back Task

Results showed that age also predicted working memory performance in the form of reaction times for correct responses on the n-back test ($F_{(1,152)}=14.21$, $p < .01$, $\eta_p^2 = .09$; Fig 3). Again, there was no significant interaction between age and sleep for reaction time (perhaps due to the small older group); however, interaction results were marginal ($F_{(1,152)}=2.27$, $p = .13$, $\eta_p^2 = .02$). A promising post-hoc test within the older group alone suggested that sleep may affect working memory in older adults with an adequately powered study ($F_{(1,17)}=3.00$, $p = .21$, $\eta_p^2 = .17$). The data also showed that overall, the good sleepers in the older adult population took numerically less time to answer correct responses in the n-back task ($M_{good\ sleepers} = 1247.97$ ms, $M_{bad\ sleepers} = 1399.70$ ms), while among younger adults this pattern was reversed ($M_{good\ sleepers} = 1099.96$, ms, $M_{bad\ sleepers} = 1054.63$).

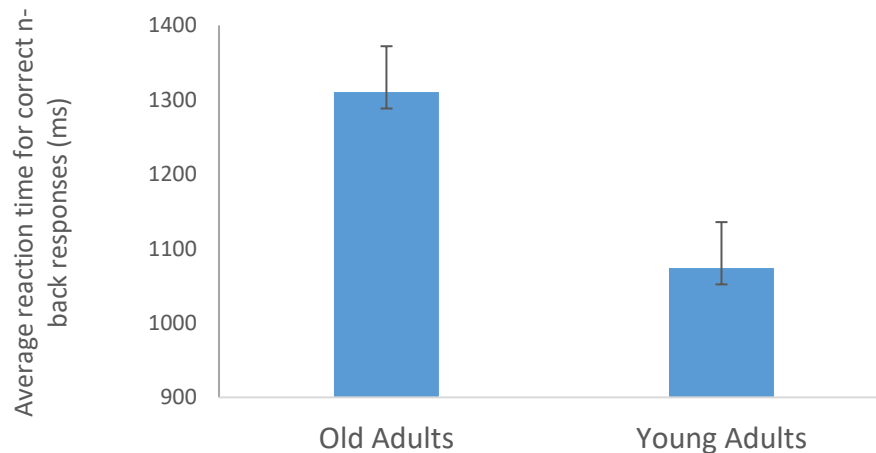


Figure 3: Average reaction times for correct responses on the n-back task by age group.

Working Memory and Decision Making in Younger Adults

Average estimation error on the economic decision task was correlated with working memory in young adults. The correlation was found specifically with the number of correct responses on the n-back test, which differed for younger adults with high versus low working memory performance ($F_{(1,140)}=.02$, $p = .01$, $\eta_p^2 = .04$; Fig. 4). However, optimal choice on the economic decision task did not differ by working memory group ($F_{(141)}=.38$, $p = .54$, $\eta_p^2 = .00$).

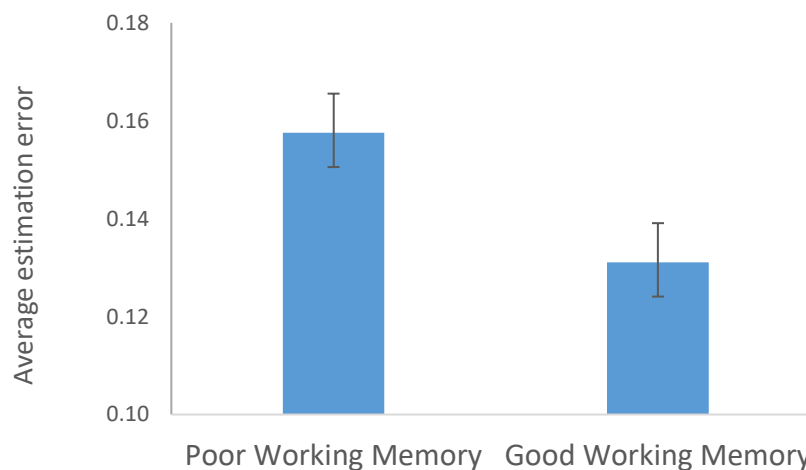


Figure 4: Working memory predicts younger adults' probability estimation errors during economic decision making.

Individual Differences, Sleep, and Decision Making

The Positive and Negative Affect Schedule (PANAS) and the General Decision Making Style Survey (GDMS) were used to consider the possibility that individual differences between participants affect the relationship between sleep and decision making. This was researched in the young adult population only. Decision making accuracy was researched for both optimal choice selection and for average estimation error in the Economic Decision Task. For the GDMS,

specifically rational and intuitive decision-making styles were investigated. Rational decision making did not show a correlation between sleep and optimal choice ($F_{(144)}=.05, p = .82, \eta_p^2 = .00$) or sleep and average estimation error ($F_{(140)}=.00, p = .94, \eta_p^2 = .00$). Intuitive decision making did not show a correlation between sleep and optimal choice ($F_{(144)}=.18, p = .67, \eta_p^2 = .00$) or sleep and average estimation error ($F_{(140)}=.11, p = .74, \eta_p^2 = .00$). Furthermore, positive affect did not show a correlation to optimal choice ($F_{(147)}=1.58, p = .21, \eta_p^2 = .01$) or average estimation error ($F_{(143)}=1.13, p = .29, \eta_p^2 = .01$), and negative affect did not show a correlation toward optimal choice ($F_{(147)}=1.76, p = .18, \eta_p^2 = .01$) or average estimation error ($F_{(143)}=.03, p = .86, \eta_p^2 = .00$). Therefore, all main effects related to individual differences were nonsignificant.

Discussion

Consistent with a wealth of previous research, our results showed an age-related decline in working memory. The current study did not find a significant interaction between age and sleep quality in predicting working memory, but our older sample was likely underpowered to observe such an effect. However, a trend-level interaction of age and sleep quality ($p = .21$) suggested that high versus low sleep quality predicted faster processing on the working memory for among older adults alone. In addition, young adults with better working memory obtained significantly less errors in an estimation task based on decision making.

Sleep deprivation and sleep quality are different sleep measures, and appear to influence cognition differently. It is logical to suggest that sleep quality will report a lesser effect on cognitive functioning than sleep deprivation. While researchers have suggested that even small amounts of sleep loss can compromise working memory function and attention (Smith, McEvoy, & Gevins, 2002), the data from the current study is inconclusive. If this hypothesis is correct, however, it suggests that even small declines in sleep quality, such as a restless night, can impair cognition. Results may also vary between individuals based on typical sleep habits.

Cognitive deficiencies from poor sleep quality in older adults have been researched by Miyata et al. (2013). This study measured total sleep time using actigraphy, and measured cognitive performance using an n-back test and identical pairs test. The results reported that the combined measures of total sleep time, age, and sleep efficiency were significantly correlated with reaction time performance (0-back test), but working memory via the n-back test (1-back) was correlated with age and sleep efficiency. This suggests that the easier 1-back test may show greater

differences than a more challenging 3-back test. The results from the current study have reported that age is associated with working memory performance (via a 3-back test), but sleep quality did not strongly affect this relationship. Another study completed by Nebes, Buysse, Halligan, Houck, and Monk (2009) focused strictly on older adults (ages 65-80), and reported that lower sleep efficiency was predictive of poorer performance on numerous tasks, including an n-back task. These results are consistent with the marginal findings for age and sleep quality in the current study.

In regards to the younger adult population, sleep was not shown to significantly affect working memory, but did predict ability to estimate stock outcome probabilities in a complex economic decision task. Due to assumptions that working memory is a strong component of decision making, and also because significant results were not found regarding young adults, sleep and working memory, key differences between the cognition components required to complete the n-back task and economic decision task may be assumed. These results are in agreement with current research, which shows that sleep deprivation impacts performance on decision making tasks (Harrison & Horne, 1999; Harrison & Horne, 2000). However, sleep quality did not affect optimal choice in a decision-making task. Venkatraman, Chuah, Huettel and Chee (2007) reported that sleep deprivation impacted specific brain regions which were involved with risky decision making. Nonetheless, our results do not suggest that poor sleepers were too impaired to choose the optimal option in the decision-making task, or were therefore more likely to take risks.

Limitations

The use of self-reported sleep quality has its limitations. While easier to implement into a study, these questionnaires may not be as reliable as other sleep measuring methods. Studies that did report significant results with respect to sleep typically utilized more objective sleep measures including actigraphy and polysomnography. Self-reported surveys are not always reliable, especially if the participant is not aware that he or she should be mindful of their sleep.

An additional limitation in this study was our ability to detect age differences due to a small older adult sample size. There was a promising trend-level interaction suggesting that sleep may affect working memory more in the older adult population, but the sample size was too small to determine statistical significance. Future studies should use a larger sample size that is more representative of the population as a whole.

In addition, the between-subjects design of this study may have veiled significant effects. Data from the same participant on multiple visits may allow for more reliable results regarding the impact of sleep quality on a group of individuals. This calls for longitudinal studies of aging, sleep, and cognition. Furthermore, it would be ideal to also control the time of day that each participant is tested, which would minimize variability.

Moreover, decision making is a complex entity and cannot be explained by working memory alone. Many cognitive components work together in the decision-making process, including executive functioning, individual differences, and attention (Del Missier, Mäntylä & Bruin, 2012; Ernst et al., 2003). This study did not look at attention directly, which would help to greater understand decision making and its relationship with working memory and sleep.

Nonetheless, this data should be taken into consideration, and healthcare professionals should consider altering sleep recommendations based on the age of the patient. As the brain and body change throughout a lifetime, health care recommendations should do the same.

Summary

Overall, working memory is associated with age, but did not predict sleep quality across age groups. A deficit of significant results in regards to sleep would seem to support the idea that sleep quality in general does not affect working memory and executive functioning. However, trends in the data may indicate differences between younger and older adults and how they react to sleep quality. In the older adult population, on average, the good sleepers took less time to answer correct responses in the n-back task. This was the expected result. However, in the younger adult population, the good sleepers took slightly longer to input correct responses than the poor sleepers. This may be because the younger adults were more cautious when selecting their answers. Furthermore, the accuracy in the younger adult population did not vary much between the good and bad sleepers. This suggests that sleep quality does not strongly impact working memory in young adults. In the older adult population, the good sleepers did have a higher accuracy on the n-back test in comparison with the bad sleepers.

Aim 1A of this study was to determine if sleep quality affects working memory. This hypothesis was not supported based on the data collected in this study. While age was shown to significantly affect working memory and executive functioning, sleep was not a contributing factor. Aim 1B of this study was to determine if age affects sleep quality and working memory in comparison of young and old adult populations. Once again, this hypothesis was not supported

based on the above data. Age did significantly affect accuracy and reaction times on the n-back test, but sleep was not a contributing factor. Finally, Aim 2 of this study was to determine if there is a relationship between sleep quality and decision-making in the young adult population, mediated by working memory. A significant reaction time difference was not found between sleep and complex decision making in the young adult population.

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