



Association between short-term sleep duration and cognitive performance: inhibitory control, problem solving, working memory, and idea generation rate

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Submitted: February 4, 2026, Revised: version 1, May 1, 2026, version 2, June 4, 2026, version 3, June 14, 2026, version 4, July 2, 2026, version 5, July 2, 2026

Accepted: July 2, 2026

Abstract

Sleep is essential for optimal cognitive function, but limited research has examined how sleep duration relates simultaneously to multiple executive function domains. This study examined associations between sleep duration and four cognitive domains: inhibitory control, problem solving, working memory, and idea generation rate. A sample of 169 United States adults (female = 61.9%, male = 19.6%, non-binary = 6.21%; Asian = 9.15%, Black = 6.33%, Latiné = 8.45%, White = 71.83%, *Mage* = 23.85, *SD* = 8.37) completed an online study consisting of cognitive tests and the Pittsburgh Sleep Quality Index (PSQI). Cognitive performance was assessed using the incongruent Stroop Test, Tower of Hanoi, Digit Span Memory Test, and Alternative Uses Task. A small but statistically significant negative association was found between sleep duration over the past two weeks and idea generation rate, such that participants who slept less generated more ideas ($\beta = -.49$, $p < .05$, partial $R^2 = .02$). Sleep duration was also negatively associated with problem solving, positively associated with working memory, and negatively associated with inhibitory control, although these associations were not significant. Among the four cognitive domains examined, only idea generation rate showed a statistically significant association with sleep duration, with the effect size being small.

Keywords

Sleep duration, Sleep quality, Executive function, Cognitive performance, Inhibitory control, Working memory, Problem solving, Divergent thinking, Alternative Uses Task, Creativity

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1. Introduction

Sleep is a fundamental physiological process vital for humans to maintain health and brain function. Modern lifestyles increasingly promote patterns of short or irregular sleep, and short sleep duration is a major concern for many U.S. adults, with researchers and public health experts citing it as an epidemic (1). Insufficient sleep can not only have negative effects on mental and physical health (2), but also result in poor cognitive performance and daily functioning (3). Although the role of sleep duration on cognitive well-being has been well-documented (4, 5), its specific association with various aspects of cognitive function is an area of ongoing research. A growing collection of research indicates both insufficient and excessive sleep durations can impair brain function, creating an inverted U-shaped association in which approximately seven hours of sleep per night yields the highest cognitive performance (5-7). Acute sleep (24h-48h) has been found to be associated with cognitive functioning, but there is less research pertaining to habitual sleep behaviors rather than one instance of sleep (8). Previous research which examined two-week timeframes (9, 10) found that sleep duration exhibited day-to-day variability among adults (11). Although recall bias is always a limitation for self-report sleep, even subjective reports of sleep have been shown to be associated with cognitive functioning (12, 13). In addition, few studies have examined the effect of poor sleep duration on different cognitive tasks (3, 14). There are consistent findings that adequate sleep is essential for optimal cognitive performance,

with insufficient sleep associated with a broad decline in cognition (4, 5, 15).

One aspect of cognitive performance is inhibitory control, the ability to suppress impulses, which is crucial for rational decision-making. Some studies have highlighted the negative effect of short sleep duration on inhibitory control, while others have found no significant difference in levels of inhibitory control between participants with optimal and insufficient sleep (16, 17). Studies using the Stroop test have found that participants sleeping fewer than six hours per night exhibit poorer inhibitory control, reflected by reduced accuracy in suppressing automatic responses, compared with those reporting normal sleep durations (14). Likewise, short or fragmented sleep disrupts prefrontal cortical activity and inhibitory control mechanisms, often associated with increased impulsivity and reduced cognitive regulation (16, 18, 19). Neuroimaging research shows these deficits are supported by impairing alterations in white matter structure and reduced efficiency in neural networks supporting executive function (4, 7).

Another aspect of cognition, problem solving, requires the cooperation of many different cognitive systems, from low-level functions like ability to maintain vigilance and attend to particular stimuli while ignoring distractions, to higher-level functions like encoding information into memory, manipulating information, and tracking multiple systems at one time. One study found that sleep facilitates problem solving abilities for difficult problems but does not facilitate entry-level problem

solving such as the Tower of Hanoi (TOH), also known as the Lucas Tower (20). Some studies have used the active systems consolidation theory (memory reactivates or reorganizes during sleep) to suggest that sleep improves problem solving (21) while others have found no significant relationship between sleep and problem solving skills in emerging adults (22). Experimental research suggests short sleep duration substantially impairs performance in reasoning (problem solving tasks), but does not affect short-term memory tasks (23).

Working memory, the system responsible for temporarily holding and recalling information, is highly susceptible to the effects of sleep (24). Unlike long-term memory, which stores information over extended periods, working memory is distinguished by its active role in processing and manipulating information. Recent studies have suggested that sleep deprivation mainly targets the non-executive processes of working memory such as vigilance and attention (25, 26). The relationship between sleep duration and working memory performance is not uniform across studies, however, as considerable individual variability on tasks like the Digit Span Memory Task (DSMT) has been documented regardless of the individual's sleep duration, suggesting personal differences in sleep need, cognitive vulnerability, or natural efficiency may have a meaningful influence on working memory capability (27).

Idea generation measures how many ideas are produced by an individual in a set time frame and is conceptually distinct from broader

constructs such as creativity or divergent thinking. Some studies indicate short sleep duration impairs this construct (28), while other studies note cases where reduced inhibitory control under sleep loss may foster less constrained, more associative thinking (29, 30). The latter aligns with the "disinhibition hypothesis," which claims a lack of inhibitory control is associated with more unusual associations in the brain, creating less of a filter when it comes to more free-form, random thought processes. Supporting this, some studies have found increased idea generation rate was associated with short sleep duration (31). Additionally, anecdotal accounts of sleep-deprived artists and musicians working late into the night link highly productive individuals with a lack of sleep (32, 33). Studies examining non-celebrities in stable work conditions, though, suggest there is a positive correlation between sleep duration and idea generation (34). The mixed findings across the literature underscore the importance of exploring the relationship between sleep duration and multiple cognitive domains.

1.1 Study objectives and hypotheses

Although previous studies have measured specific cognitive processes using individual cognitive tasks, these outcomes are frequently synthesized under the broad construct of executive functioning in the literature and meta-analyses (4, 5, 7, 35). Consequently, it remains unclear whether sleep duration is similarly associated with all executive function domains or whether some domains are more strongly related than others. As a result, while it appears sleep restriction may impair cognition as a

whole, it is not clear which cognitive domains are most associated (e.g. inhibition vs. problem solving), and the relative strength of these associations across domains. Furthermore, a majority of research has focused on *general* sleep patterns or acute sleep, but less research has been done on the association of shorter-term sleep behaviors on cognitive performance. The present study seeks to explore the association between sleep duration and four domains of cognition, specifically as separate outcomes. Based on previous literature, it is hypothesized that more sleep duration will be associated with better cognitive performance across all cognitive domains (higher scores in Digit Span Memory Test and Alternative Uses Task and lower scores in Stroop task and Tower of Hanoi task), underscoring a general negative relationship between sleep duration and cognitive performance.

2. Methods

2.1 Sample

A total of 240 adults (18 years or older) in the United States participated in the study (Asian = 9.15%, Black = 6.33%, Latiné = 8.45%, White = 71.83%, Other = 4.24%; cis-gender female = 61.9%, cis-gender male = 19.6%, non-binary = 6.21%, Other = 12.29%). After data clearing, 169 participants were included in the final analysis. Exclusion criteria were as follows: (1) participants failed to complete at least 90% of the survey or (2) provided illegitimate responses that could not be reliably interpreted by the researchers. The average age of the final sample was 23.85 (SD = 8.37) years old, representing a particularly younger population.

2.2 Procedure

The online study was IRB approved. Participants were required to be 18 years or older and residents in the United States at the time of the study. The study was advertised as the “Sleep and Cognition Study” and participants were recruited both from online sites (SurveyCircle, LinkedIn, Reddit, Facebook, and Skool) and at a small liberal arts college. Participants who were college students at the college received research credit or an entry for a \$25 raffle.

The study was conducted via an online Qualtrics survey ~ 15-20 minutes long. Participants were instructed to complete the study independently and in a room with no distractions. After completing an online consent form, participants proceeded to the survey where they completed four digital cognitive tasks, followed by questions about sleep, lifestyle, attitudes, mental health, demographics, device use, and distraction levels.. The current study focuses on the association between sleep duration and scores on the four cognitive tasks.

2.3 Metrics

2.3.1 Cognitive outcomes

Cognitive outcomes were measured using four separate tasks that have been widely used in past research in online studies (24, 36-38).

2.3.1.1 Task 1: Inhibitory control

The Stroop task has been commonly used as an accurate indicator of inhibitory control (14, 39). In this task, participants were presented with words denoting colors displayed in congruent

and incongruent font colors to the color words they represented. Participants were instructed to read aloud the font color of each of the words as rapidly as they could across both the congruent and incongruent tasks. After each task, respondents were directed to record their reaction times to the nearest millisecond. Longer reaction times in the incongruent Stroop task corresponded to decreased performance in the Stroop task.

2.3.1.2 Task 2: Problem-solving

Problem-solving ability was assessed using the TOH, which has been widely used in cognitive sciences to measure problem solving capabilities (36, 40). It is a mathematical game in which participants move three rings on one rod to another without placing a bigger ring atop a smaller one in the least number of moves possible. Participants interacted with the task through a drag-and-drop system and could not move bigger rings atop smaller ones. Participants were instructed to record the number of moves it took to complete the task in their first attempt. The number of moves required to move the three rings from rod one to rod three was recorded, with more moves corresponding to decreased performance in the TOH.

2.3.1.3 Task 3: Working Memory

The Digit Span Memory Test (DSMT) assesses working memory capabilities and asks the participant to recall an eight-digit sequence, a task that has multiple citations in sleep research (24, 27). Working memory ability was evaluated using the DSMT in which participants were presented with a series of eight digits that were

shown one-by-one in ‘slow mode,’ where each number was displayed for one second. Participants then had to reproduce the numbers in their correct order into the computer. Participants were instructed to record their first attempt from 0 to 8, with a lower number score indicative of decreased performance in the DSMT.

2.3.1.4 Task 4: Idea generation rate

The Alternative Uses Task (AUT) has been used as an effective cognitive measuring tool for idea generation rate (37, 41). The task asks participants to name as many nontypical uses for common objects – an example being paperclips - and provides an assessment of the ability to produce diverging uses from one prompt. Idea generation rate was assessed using the AUT. Participants were presented with an image of a water bottle and instructed to generate as many alternative uses for a water bottle besides ‘to drink from.’ There was a two-minute window in which participants could not exceed or skip ahead. Participants were scored on their number of answers, adjusted for repetition. Participants were not scored on the content or feasibility of their answers. Lower numbers of ideas generated corresponded to decreased fluency in the AUT.

2.3.2 Sleep duration

Sleep duration was measured using an item from Pittsburgh Sleep Quality Index (PSQI). Because this study was focused on the short-term effects, all questions were asked in the time frame of “the past two weeks.” Participants provided open-ended responses to the prompt, “*In the past two weeks, how many hours of actual sleep*

did you get per day? This may be different than the number of hours you spent in bed.” Participant responses were open-ended and re-scored to represent the number of hours.

2.4 Covariates

To isolate the relationship between sleep duration and cognitive performance, regression models were adjusted for specific demographic and environmental covariates such as gender, race/ethnicity, the type of device used for testing, and reported distraction level during the task. Although participants were advised to complete the survey on a laptop or computer, mobile devices were not excluded.

Gender was recorded via a self-report multiple choice question with the option to elaborate. Response options included: *Cisgender Man, Cisgender Woman, Non-Binary, Transgender Man, Transgender Woman, Agender*, or an open-ended self-identifying option available for participants whose gender identity was not represented in the listed categories. Race/ethnicity was similarly recorded via a self-report multiple choice question where participants could select all applicable items or expand on the following response options: *African/African American/Black, American Indian/Native American, Asian/Asian American, Biracial/Multiracial with an option to specify, Caucasian/European American/White, Hispanic/ Latino/ Latina/ Latinx/ Latine, Middle Eastern or North African (e.g., Lebanese, Iranian, Egyptian, Syrian, Moroccan, Algerian, etc.), Pacific Islander/Pacific Islander American*, or an open-ended self-identifying option for identities not

represented in the listed categories. Device type was recorded via a self-report multiple choice question with the following response options: *laptop/computer, cellular device, tablet/iPad*, or an open-ended ‘other’ option. Distraction level was assessed by asking participants to rate the degree to which their outside environment distracted them while completing this task on a scale from 1 (*Not distracting at all*) to 5 (*Extremely distracting*).

2.5 Analyses

New variables (i.e., number of items, difference between stimuli responses) were created based on responses to open-ended tasks (i.e., come up with as many alternative uses for a water bottle, subtracting response time from two different stimuli).

All analyses were performed using RStudio. Power analysis was conducted for a general linear model, with minimum desired power set to .80, a Type I error rate of 0.05, nine covariates, and a small effect size of 0.20. This resulted in a minimum sample size of $N = 72$. To explore the hypothesis of whether sleep duration would be negatively associated with cognitive performance, four separate linear regression models were constructed. Sleep duration was modeled as the primary predictor variable, with race, age, gender, education level, region, device, and distraction included as covariates for all models. Scores on the Stroop task, TOH, DSMT, and AUT fluency were included as separate outcomes.

The analysis determined the relationships between self-reported sleep duration and

performance across four core cognitive domains: performance in the Stroop task, performance in the DPMT, performance in the TOH, fluency in the AUT (inhibitory control, working memory, problem solving, and idea generation rate). Self-reported daily sleep duration was a main variable of interest (average of 7.13 [SD 1.24]).

In addition, a symmetry check was conducted by estimating bidirectional models for each cognitive outcome. Model A specified sleep duration as the predictor, while Model B was the opposite, positioning each cognitive variable as the predictor of sleep duration. Standardized β coefficients and partial R^2 values were compared across both model directions.

3. Results

The descriptive results are shown in Table 1. There was a marginally significant correlation between sleep duration and Tower of Hanoi scores (i.e. problem-solving; $r = .13$) as well as sleep duration and AUT fluency (i.e., idea generation; $r = -.15$). There was also a significant correlation between AUT fluency and the Stroop task ($r = -.16$). Participants who generated more alternative uses also tended to have a shorter response time to the Stroop task. In addition, AUT fluency scores were positively correlated with the digit span task ($r = .17$, Table 1). Participants who generated more alternative uses also tended to remember more digits. No other associations were significant.

Table 1. Bivariate correlations of all study variables

	Stroop response time	Tower of Hanoi	Digit Span Task	AUT Fluency	Sleep Duration
Stroop response time	—				
Tower of Hanoi	0.021	—			
Digit Span Task	-0.106	-0.118	—		
AUT Fluency	-0.160*	-0.013	0.168*	—	
Sleep Duration	0.040	0.132+	0.048	-0.149+	—

Note. + $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

The primary analysis used four linear regression models with Bonferroni correction to examine the association between sleep duration and cognitive performance: the Stroop task, TOH, DSMT, and AUT. Results indicated that sleep duration was not a significant predictor for

scores on the Stroop task ($\beta = 0.18$, $SE = .54$, $p > 0.05$), TOH ($\beta = 0.20$, $SE = .26$, $p > 0.05$), DSMT ($\beta = 0.02$, $SE = .26$, $p > 0.05$). However, a significant negative association was observed between sleep duration and AUT fluency ($\beta = -0.49$, $SE = .15$, $CI [-.95, -.2]$). (Table 2). Partial

R^2 values indicated sleep duration explained no unique variance in Stroop performance, TOH, or DSMT scores (partial $R^2 = .00$), and accounted for a small proportion of variance in AUT fluency (partial $R^2 = .02$).

Table 2. Results for sleep duration predicting cognitive task scores

Model	Unstandardized Beta	SE	95% CI	Standardized Beta	R^2	Partial R^2
Stroop ~ Sleep Duration	0.18	.54	[-.88, 1.24]	0.03	.26	.00
Tower of Hanoi ~ Sleep Duration	0.20	.26	[-.32, .71]	0.06	.25	.00
Digit Span Task ~ Sleep Duration	0.02	.15	[-.28, .31]	-0.01	.28	.00
AUT Fluency ~ Sleep Duration	-0.49*	.24	[-.95, -.02]	-0.18	.24	.02

Table 3. Results for cognitive tasks predicting sleep duration

Model	Unstandardized Beta	SE	95% CI	Standardized Beta	R^2	Partial R^2
Sleep Duration ~ Stroop	0.01	.01	[-.02, .34]	0.03	.20	.00
Sleep Duration ~ Tower of Hanoi	0.02	.03	[-.04, .08]	0.07	.20	.00
Sleep Duration ~ Digit Span Task	0.01	.05	[-.10, .11]	-0.01	.20	.00
Sleep Duration ~ AUT Fluency	-0.07*	.03	[-.13, -.01]	-0.16	.23	.02

To evaluate the potential for bidirectionality, a symmetry check was performed. When the AUT fluency was modeled as a predictor of sleep duration, a significant negative association was observed again ($\beta = -.07$, $SE = .03$, 95% CI [-.13, -.01]). Although the unstandardized coefficient for the reverse model ($\beta = -.07$, Table 3) was weaker compared to the primary model (sleep ~ AUT fluency, $\beta = -.49$, Table 2), both R^2 values were similar ($R^2 = .23$ vs $R^2 = .24$, Table 2-3), suggesting a stronger association between sleep and cognition when sleep was modeled as the predictor. No other cognitive tasks significantly predicted sleep duration (all $p > .05$). Partial R^2 values indicated sleep duration explained no unique variance in Stroop performance, TOH, or DSMT scores (partial $R^2 = .00$), and accounted for a small proportion of variance in AUT fluency (partial $R^2 = .02$).

To explore potential curvilinear relationships, quadratic terms for sleep duration were tested in models both with and without covariates (race, gender, the type of device used for testing, and reported distraction level during the task). Across all cognitive outcomes, the quadratic terms were non-significant (all $p > .05$, Table 4).

Therefore, the current data did not find evidence for a curvilinear association between sleep duration and cognitive performance. Cook's distance values for all observations were below conventional thresholds ($D < 1$), suggesting no highly influential cases.

Table 4. Results for non-linear models for sleep duration predicting cognitive task scores

Model without covariates	Unstandardized Beta	SE	95% CI	Standardized Beta	R ²
Stroop ~ Sleep Duration ²	0.26	.19	[-.13, .64]	.05	.00
Tower of Hanoi ~ Sleep Duration ²	-0.01	.09	[-.19, .17]	0.00	.01
Digit Span Task ~ Sleep Duration ²	-0.01	.14	[-.11, .11]	-0.01	.00
AUT Fluency ~ Sleep Duration ²	0.02	.08	[-.15, .18]	0.01	.01
Model with covariates	Unstandardized Beta	SE	95% CI	Standardized Beta	R ²
Stroop ~ Sleep Duration ²	0.06	.20	[-.34, .46]	0.01	.08
Tower of Hanoi ~ Sleep Duration ²	-0.06	.10	[-.26, .13]	-0.03	.08
Digit Span Task ~ Sleep Duration ²	0.03	.16	[-.08, .14]	0.02	.12
AUT Fluency ~ Sleep Duration ²	0.05	.09	[-.12, .23]	0.02	.06

The first cognitive variable examined was inhibitory control. Although a negative trend was observed between sleep duration and performance in the Stroop task where participants with longer sleep durations tended to respond more slowly, these results were statistically insignificant. Longer time to respond relates to less inhibitory control as participants may struggle to reign in their instincts to answer the given word's meaning rather than the given word's font color. Figure 1

presents all data points and the linear slope of best fit between sleep duration and the incongruent Stroop task; higher y-values, or longer times on the incongruent Stroop task, refer to worse inhibitory control. On average, it took participants 25.10 (SD 7.70) seconds to complete the second word task (incongruent Stroop task). The incongruent Stroop task took participants 7.1 seconds longer on average than the congruent Stroop task. Researchers found the relationship between sleep duration and

Stroop response time was insignificant. Outliers ($n = 3$) that claimed response times exceeding 1000 seconds were deemed too excessive to be true and excluded from analysis. These latencies were attributed to typographical errors such as misplaced decimals.

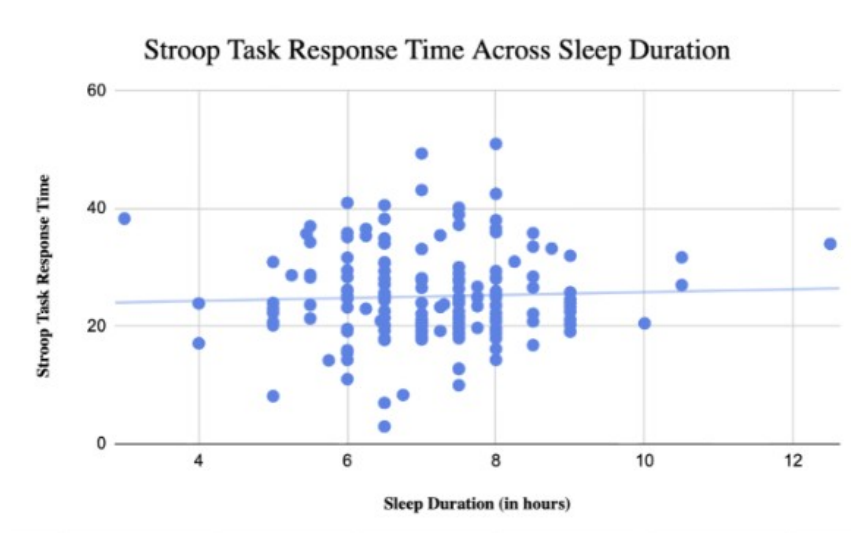


Figure 1. Association between sleep duration and response time to the incongruent Stroop task. Shorter times are associated with faster inhibitory control.

The second cognitive function examined was problem solving. Although a negative trend indicated that participants who slept longer took more moves to complete the problem-solving task, this trend was statistically insignificant. Figure 2 depicts the range of data and the linear line of best fit of the effect of sleep duration on problem solving capabilities where higher y-values, or more number of moves to complete the problem solving task, corresponds to poorer problem solving. On average, participants completed the task in 9.53 (SD 3.72) moves, with the minimum number of 7 moves.

The third cognitive variable studied was working memory through the DSMT. Figure 3 showcases all data points and the linear best fit line for the effect of sleep duration on the number of digits correctly recalled, or, working memory abilities. Participants who reported longer sleep durations showed a slight improvement in working memory performance, however, this trend was not statistically significant. The average score on the DSMT was 5.28 (SD 2.22) out of the maximum score 8.

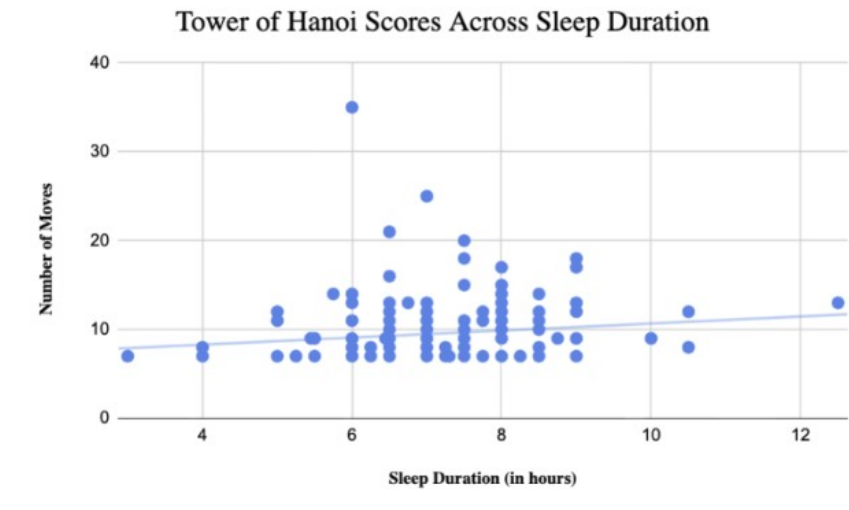


Figure 2. Association between sleep duration and the number of moves in which participants completed the Tower of Hanoi. Less moves are associated with more efficient problem solving performance.

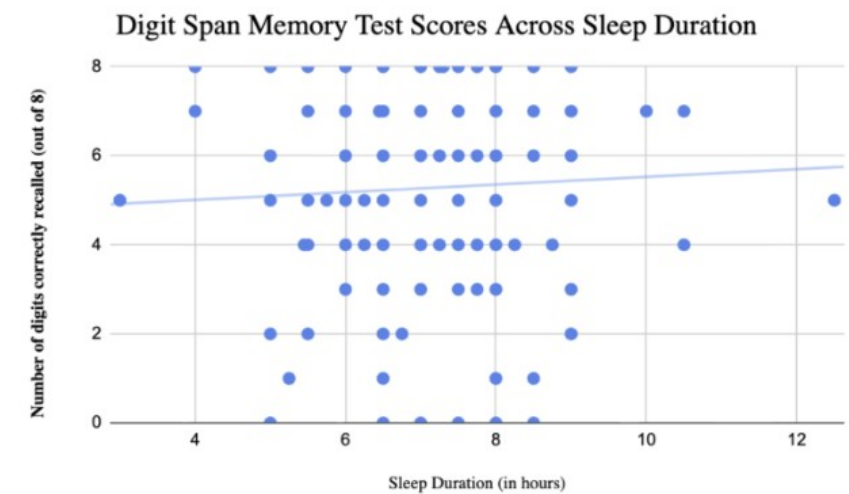


Figure 3. Association between sleep duration and the number of digits correctly recalled out of eight on the DSMT. A higher number of digits recalled is associated with better working memory performance.

Sleep duration was associated with fluency in the AUT. Figure 4 portrays the data of sleep duration's effect on the number of alternative uses for a water bottle participants were able to list in 120 seconds. Sleep duration had a significant negative association with fluency in the AUT, such that participants who slept less generated more ideas. This was the only statistically significant result between sleep duration and a cognitive task, indicating shorter sleep may be associated with higher idea generation in the short term. The average number of alternative uses generated among participants was 8.15 (SD 1.41).

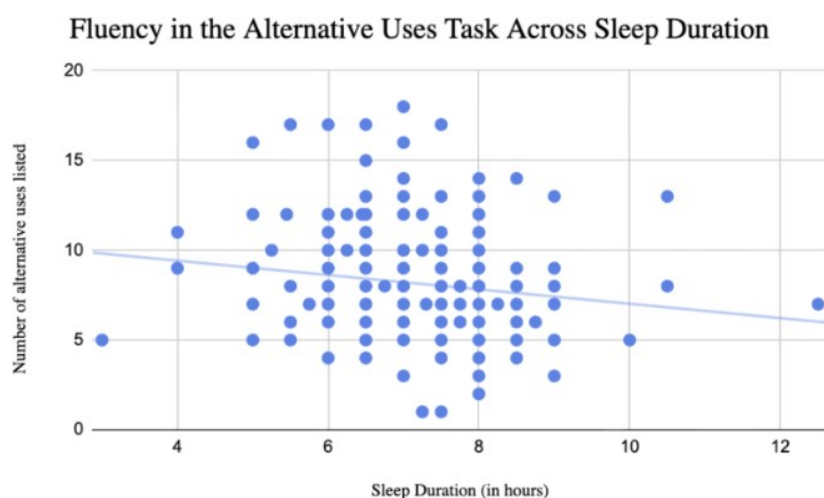


Figure 4. Association between sleep duration and the number of alternative uses listed for a water bottle. Larger numbers are associated with more efficient idea generation rate.

4. Discussion

The present findings in this study contribute to the debated findings in sleep and cognition literature; sleep duration patterns across two weeks were only significantly associated with idea generation rate, and no association was found between sleep duration and inhibitory control, problem solving, or working memory. These findings are aligned with broader mixed findings in the research on the relationships between sleep duration and cognitive performance, with questions regarding whether increased sleep duration alone directly correlates to stronger cognition (5, 15). The lack

of significant findings may reflect individual variability in sleep quality, circadian timing, or task engagement, as well as the short-term nature of the sleep measurement. Although sleep duration was not significantly associated with performance in most cognitive tasks, such as the Stroop task, TOH, and DSMT, there was a negative association between sleep duration and fluency in the AUT observed ($\beta = -.49$, $p < .05$, Table 2). This suggests that participants with lower average sleep durations in the two weeks prior to taking the survey had higher idea generation rates. Follow-up analyses examining the reverse direction were also significant ($\beta =$

-.07, $p < .05$, Table 3). The similarity in size of the standardized coefficients across both models ($\beta = -.18$, Table 2 versus $\beta = -.16$, Table 3) suggests the association between sleep duration and AUT fluency is comparable in both directions. However, sleep duration accounted for only a very small proportion of the observed variability in idea-generation fluency (partial $R^2 = .02$ in Table 2, 3). The partial R^2 value provides evidence of an observable but limited relationship between sleep duration and idea generation rate, rather than indicating sleep duration is a substantial determinant of idea generation rate. The small yet statistically significant preliminary association warrants replication before conclusions are considered regarding why statistical significance emerged for idea generation specifically. Given the modest effect size, it remains unclear if this is a domain-specific association or a sample-specific variability.

The negative correlation between Stroop response time and AUT fluency ($r = -.16$, Table 1) indicates that participants with better inhibitory control (i.e., shorter Stroop response times) tended to generate more ideas. This finding is consistent with the Dual Pathway Model of Creativity (42), which proposes that idea generation can emerge through either cognitive flexibility (broad associative thinking) or cognitive persistence (sustained, goal-directed exploration). One possible interpretation is that stronger inhibitory control supports the persistence pathway by helping individuals suppress competing responses and maintain focused exploration of ideas. However, because the present study was

correlational, these findings should not be interpreted as evidence that inhibitory control directly enhances idea generation. Contrary to these findings, the "disinhibition hypothesis" claims a lack of inhibitory control correlates with unusual associations in the brain which is a marker for higher idea generation rates. Disinhibition therefore may stimulate idea generation as it allows participants to connect ideas that may not appear to have direct correlation (43) and it facilitates fluency (44). Contrary to the disinhibition hypothesis but aligned with the dual pathway model of creativity, the current findings provide support for the positive association between inhibitory control and idea generation rate.

4.1 Limitations and perspective

Several limitations must be acknowledged. The nature of self-reported sleep and online test scores can result in potential recall biases (12, 13). Although questions regarding level of distraction and device used were captured and included in analyses, measures of cognitive tasks online may still result in questionable validity. Measures of cognitive outcomes for this study were also limited. The current study only explored the fluency of responses to the AUT, though future research should also examine other outcomes like originality (the proportion of unique responses), flexibility (the number of distinct conceptual categories represented in each response), and elaboration (the degree of detail in each response; 41, 45-48). In addition, because a large portion of recruitment occurred on a college campus, the current sample was skewed toward individuals aged 18–24, which limits the generalizability of

these findings to other age groups. Although the current study explored a two-week timeframe to explore short-term patterns of sleep behavior, future research should also investigate these associations for longer-term sleep behavior. Longer (6 months or more) or shorter (24-48 hours prior) observation periods may produce differences in these cognitive outcomes, which would focus on more general patterns or more acute associations.

Because the current data produced a significant association between sleep duration and fluency, future research should explore whether these findings are supported with more objective measures of sleep. Actigraphy data could provide more precise measures of sleep duration that can minimize the effect of recall bias in subjective reporting. Finally, other measures of fluency in the AUT, such as originality (i.e., the rarity of responses), flexibility (i.e., the range of different categories of responses), and elaboration (i.e., the amount of detail in responses) could reveal additional findings related to sleep duration.

5. Conclusion

These findings suggest that sleep duration alone may not be a strong predictor of overall

cognitive performance across multiple executive function domains. In this sample, sleep duration was not significantly associated with inhibitory control, problem solving, or working memory. Instead, a modest but statistically significant negative association was observed between sleep duration and idea generation rate, indicating that individuals reporting shorter sleep durations generated more ideas on a fluency-based task. Although the observed effect size was small and should not be interpreted as evidence that reduced sleep enhances cognition more broadly, the findings suggest that the relationship between sleep and cognition may differ across specific cognitive domains rather than being uniformly beneficial or detrimental. These results contribute to the growing literature demonstrating heterogeneous cognitive effects of sleep duration and underscore the importance of examining individual executive functions separately rather than as a single composite construct. Replication using larger, more diverse samples, objective sleep measures, and more comprehensive assessments of idea generation (e.g., originality, flexibility, and elaboration) will be important for determining the robustness and generalizability of these findings.

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