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RESEARCH ARTICLE

Effect of sleep deprivation on cognition in young Indian adults: A Color-Word Stroop task study

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ABSTRACT

Background: Sleep is a basic need for survival and restoration of body and mind. Human populations have undergone a steady constant decline in sleep hours attributable to changes in environmental and social circumstances. Sleep is an important determinant of cognitive performance in humans with sleep deprivation known to cause cognitive decline in susceptible individuals. **Aims and Objectives:** Our study aims to assess sleep duration as a determinant of cognitive function in young Indian adults. **Materials and Methods:** A total of 60 healthy young volunteers in the 18–25 years age group of both sexes were divided into two groups of 30 each, Group 1 – inadequate sleep duration (<7 h/day) and Group 2 – adequate sleep duration (≥7 h/day) on the basis of a sleep questionnaire. Color-word Stroop test was used to assess cognition in both groups. Data were expressed as Mean ± standard deviation and analyzed using SPSS Software Version 21. **Results:** Within the groups, the reaction time of incongruent trials was found to be significantly higher compared to the congruent trial in both groups ($P < 0.001$). Comparing the results of the Stroop test between the two groups, the reaction time of the incongruent trial was found to be significantly higher in Group 1 in comparison to Group 2 ($P = 0.02$). **Conclusion:** The reaction time during the incongruent trial was significantly higher in sleep-deprived subjects as compared to those getting adequate sleep/day signifying a decline in cognitive function with deprivation of sleep.

KEY WORDS: Cognition; Interference; Facilitation; Sleep Deprivation; Stroop Task

INTRODUCTION

Sleep is an ancestral and primitive behavior and an important determinant of cognitive performance in humans with research-based evidence for sleep deprivation known to cause cognitive decline in susceptible individuals. Sleep loss is a very important yet underestimated causative factorin disrupting the quality of life of a person.[1] Since the beginning of the century, populations have undergone a steady constant decline in the number of hours devoted to sleep attributable to changes in a variety of environmental and social circumstances mainly less dependence on daylight for most activities, extended shift work in professional life and 24/7 activities with an emphasis on active leisure.[2] Furthermore, people in cities tend to stretch their capacity for leisure and work compromising their nightly sleep, thus becoming chronically sleep deprived.[3]

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Color-word Stroop test was first described by John Ridley Stroop in the year 1935, which is a highly reliable and reproducible test for the assessment of selective attention in cognitive psychology. The subjects are required to name the color of the word printed in the same color (Stroop facilitation) and in different ink colors (Stroop interference, e.g., red printed in blue ink has to be read as blue). Interference between word meaning and ink color occurs, which prolongs reaction time.[4]

The study of the effect of sleep deprivation on cognitive performance as elicited by the Color-word Stroop task has been much studied with extensive research showing the detrimental effect on reaction time, executive function, and working memory of the subjects involved.[5-16] On the contrary, some studies recorded no correlation between sleep patterns of the subject and their cognitive performance[17,18] thus making research-based evidence regarding the effect of sleep deprivation on Stroop test conflicting.

With more people getting less sleep and given the growth rates of sleep disorders in the aging population globally,[19] it is vital that science advances our understanding of the effects of sleep loss on cognitive and emotional functioning. Keeping in mind the paucity of data on this subject in the Indian context, we undertook this study to examine how sleep duration is a determinant of cognitive function as assessed by the "Stroop test" in the adult Indian population.

MATERIALS AND METHODS

Study Design

It was a cross-sectional study. The study was conducted at the Department of Physiology of a Government Medical College located at Delhi/National Capital Region for 2 months between June and July 2019. The study was undertaken under the Short Term Studentship (STS) scheme of the Indian Council of Medical Research for MBBS students and the permission of the Institutional Ethics Committee of the college was sought and obtained.

Subject Selection

Sixty healthy medical student volunteers in the age group of 18–25 years of both sexes were recruited for the study after explaining the procedure and taking written informed consent. The essential criteria for the inclusion of subjects in the study were normal eyesight or corrected normal eyesight with normal color vision. The volunteers with a history of medical illness especially neurological diseases, chronic medical illness, color blindness, smoking, alcohol, any other drug consumption or any medications (within the past 7 days) were excluded from the study.

Sleep Duration

A standard sleep questionnaire mentioned below was used to obtain information about the sleep patterns of students.

Sleep questionnaire: Sleep time habits

1. What time do you usually go to bed?
   - Weekdays
   - Weekends

2. What time do you usually wake up?
   - Weekdays
   - Weekends

3. How many minutes did you sleep on any daytime naps?
   - Weekdays
   - Weekends

Average sleep duration was calculated (in h) as the difference between self-reported bedtime and wake up time for weekdays and weekends separately.

Average sleep duration = Weekday duration × 5/7 + Weekend duration × 2/7

The participants were divided into two groups of 30 each based on their average sleep duration:

Group 1 (Inadequate sleep duration) – Those having average sleep duration of <7 h/day ($n = 30$)

Group 2 (Adequate sleep duration) – Those having average sleep duration of ≥7 h/day ($n = 30$).

Stroop Test

Before conducting the Stroop test, the subject was asked to relax for 5 min. After a detailed history and physical examination, the subjects were familiarized with the test with a trial run before recording. The task was computer based wherein each subject was presented with a series of colored words (black, blue, green, red, etc.). These words appeared in different colors, sometimes matching the word (e.g., word blue written in blue-congruent/Stroop facilitation) and sometimes not matching the word (e.g., the word blue written in red color-incongruent/Stroop interference).[20] The task of the subject was to indicate as quickly as possible whether the color in which the word is written matches the word itself or not. Most people respond faster and more accurately to the congruent trial as compared to the incongruent trial. The correctness of response of the subject (in percentage) and average reaction time (in seconds) for the congruent and incongruent trial was recorded for the two groups.[21]

Statistical Analysis

All statistical analysis was analyzed using SPSS software version 21 for Windows. The results have been presented as a mean ± standard deviation and in percentages. Student "*t*-test" was used to compare the data between the two groups and within the group. The correlation was done between the average sleep duration and the parameters of the Stroop test using Pearson's correlation coefficient. "*P*" ≤ 0.05 was considered as significant whereas "*P*" ≤ 0.001 was taken as highly significant.

RESULTS

The present study evaluated the effect of sleep deprivation on cognition in young healthy Indian adults as evaluated by the Stroop test.

The age distribution of the subjects is shown in Table 1. No significant difference in the age distribution was seen in comparing between the two groups ("*P* > 0.05").

The sex distribution of the subjects is depicted in Table 2. The percentage distribution in Group 1 was 56.7% males and 43.3% females whereas in Group 2, 60% were males and 40% were females.

Table 3 depicts the mean sleep duration of the two groups. Group 1 had a mean sleep duration of 5.94 h/day whereas Group 2 had a mean sleep duration of 7.21 h/day. There was a statistically significant difference in the sleep duration on comparing between the two groups (*P* ≤ 0.05).

The results of the Stroop test conducted are shown in Table 4. On comparing the results within the groups, the percentage of the correctness of the response was comparable between the congruent and incongruent trials. The values were found to be statistically not significant (*P* > 0.05) on comparison within the two groups. However, the reaction time of the incongruent trial was significantly higher compared to the congruent trial in both the groups (*P* < 0.001).

On comparing the results of the Stroop test between the two study groups, it was observed that no significant difference was seen in terms of the percentage correctness of the response as well as in the reaction time of the congruent trial (*P* > 0.05), as shown in Table 5. However, the reaction time of the incongruent trial was seen to be significantly higher in Group 1 as compared to Group 2 (*P* ≤ 0.05).

Correlation studies were done between the average sleep duration and the different parameters of the Stroop test for the congruent as well as incongruent trials. However, no significant findings were seen (Table 6).

Table 1: Age distribution of the subjects

Groups	Age (years)	
	Mean±SD	*P*-value
Group 1 (*n*=30)	19.33±0.99	0.67
Group 2 (*n*=30)	19.27±0.79	
Total (*n*=60)	19.30±0.89	

P>0.05 – NS: Not significant

Table 2: Sex distribution of the subjects

Groups	Sex		Total
	Male	Female	
Group 1			
No. (%)	17 (56.7)	13 (43.3)	30 (100)
Group 2			
No. (%)	18 (60)	12 (40)	30 (100)
Total			
No. (%)	35 (58.3)	25 (41.67)	60 (100)

Table 3: Sleep duration

Groups	Sleep duration (h)	*P*-value
	Mean±SD	
Group 1 (*n*=30)	5.94±0.44	0.00*
Group 2 (*n*=30)	7.21±0.41	

**P*≤0.05 – significant

DISCUSSION

The current study was undertaken to see the association between sleep duration and cognition as tested by the Stroop test in young Indian adults. The two groups selected were matched for age (*P* = 0.67) to eliminate the bias due to age difference as previous studies have reported that age is a strong independent predictor of the Stroop performance with sleep disorders of elderly causing significant worsening of cognitive performance when compared to the young population.[22] The subjects selected belonged to the similar educational backgrounds as education too is an important and independent predictor of Stroop performance. In all age-dependent groups, less-educated healthy participants showed slower color-naming rates, needed more time to complete the color task, and presented a greater interference effect compared to those who were more educated.[23] In the present study, the reaction time of the incongruent trial was found to be higher in comparison to the congruent trial in both the groups. The reaction time of the incongruent trial was higher in those getting inadequate sleep as compared to those getting adequate sleep. No significant correlation was seen between sleep duration and results of the Stroop test.

Our findings concurred with those of El Hangouche *et al*.[24] who reported poor night sleep quality leading to cognitive decline and poor academic achievement in medical students. A cross-sectional study by Anderson *et al*. too claims decrements in selected executive function, which includes cognition as a result of decreased sleep duration.[25] The study conducted by Ghimire *et al*.[4] on 30 Nepalese medical students' records that the time taken to read the incongruent card in their study was longer as compared to the congruent card (*P* < 0.001), similar to ours. Our findings of variation in reaction time in congruent and incongruent trials are similar to those of Cain *et al*.[26] They have reported higher

Table 4: Results of the Stroop test in both the groups (intragroup comparison)

Groups	Type of trial	Correctness of response (%) Mean±SD	*P*-value	Reaction time (s) Mean±SD	*P*-value
Group 1	Congruent	99.35±3.65	0.79	25.95±8.46	<0.001**
	Incongruent	99.11±2.30		33.68±8.88	
Group 2	Congruent	99.33±365	0.45	23.67±7.07	<0.001**
	Incongruent	98.67±2.72		28.62±7.18	

**$P \leq 0.001$ – Highly significant. $P>0.05$ – NS: Not significant

Table 5: Comparison of the results of the Stroop test between the two groups

Parameter of the Stroop test	Type of trial	Groups	Mean±SD	*P*-value
Correctness of response (%)	Congruent trial	Group 1	99.33±3.65	1.00
		Group 2	99.33±3.65	
	Incongruent trial	Group 1	99.11±2.30	0.50
		Group 2	98.66±2.71	
Reaction time (s)	Congruent trial	Group 1	25.91±8.46	0.26
		Group 2	23.67±7.07	
	Incongruent trial	Group 1	33.68±8.88	0.02*
		Group 2	28.62±7.18	

$P>0.05$ – NS: Not significant. *$P \leq 0.05$- Significant

Table 6: Correlation between average sleep duration and various parameters of Stroop test

Average sleep duration (hours)	Correctness of response – congruent trial (%)		Correctness of response – incongruent trial (%)		Reaction time – congruent trial (s)		Reaction time – incongruent trial (s)	
	r-value	*P*-value	*r*-value	*P*-value	*r*-value	*P*-value	*r*-value	*P*-value
	−0.007	0.96	−0.63	0.63	−0.14	0.29	−0.24	0.063

$P>0.05$ NS: Not significant

reaction time in incongruent trials as compared to congruent trials following sleep loss. This indicates a global slowing of the mental processes following sleep deprivation. Similar findings have been reported by various other researchers using tests other than the Stroop task.[27,28] Mullins *et al*. in their study on the effect of efficiency and duration of sleep on college students' performance in the Stroop test have also reported a significant positive, moderate association between sleep deficiency and Stroop incongruent errors.[29] Another study conducted by Dixit and Mittal[30] on Indian medical students concluded that a significant increase in reaction time occurred after 12 and 24 h of sleep deprivation. Their findings have implications in professions such as medicine and armed forces wherein professionals put in long hours of duty at a stretch. A study by Aalasyam and Goothy found a positive correlation of sleep quality with the spatial and verbal memory suggesting an evidence for loss of sleep causing profound impairments in cognitive performance.[31] The reason for the positive correlation between sleep quality and cognition as detected by the Stroop task in the above studies can be explained on the basis of various functional models of the Color-word Stroop task. It belongs to a class of cognitive neuropsychological tests called interference/conflict tasks which are used extensively to elicit the phenomenon of cognitive interference, i.e., the slowing down of processing by competing the mental processes elicited by the new material with transfer effects of past learned behavior, memories, or thoughts that have a negative influence in comprehending the new attention, cognitive flexibility, and speed of processing.[32] One hypothesis for "Stroop Effect," is parallel processing of the information for word and color with a single response channel into which only one of the information can be admitted due to different speeds of processing.[20] This model suggests that the mechanism responsible for the strength of the processed stimulus strengthens the processing units through practice (practice effect), determines the strength of two competing processing units (interference or facilitation), and selectively attends to the stronger unit. Thus, in a situation of incongruency, the word information arrives earlier than the color information, resulting in confusion in decision-making, creates pressure on the subject to remain focused on the task at hand and complete the naming as quickly as possible.[29] Another hypothesis for the Stroop interference is automaticity specifically meaning that word reading is an automatic process whereas ink color naming requires controlled processing. Skilled readers automatically process word information because the association between a word and its name is stronger.[20,33] Another explanation for the observed interference in the Stroop task is the relative speed of processing or "horse race" model.[34] This model suggests that the competing processes of reading the word and naming the color occur in parallel and that word reading finishes more quickly and is likely to win the race, interfering with color naming when generating a response. This model is very similar to the parallel-distributed processing model.[35] Current neuroscientific evidence suggests two attentional systems to be involved in the Stroop task: The anterior attentional system located in the dorsolateral prefrontal cortex (DLPFC) and the anterior cingulate gyrus and the posterior attentional system in the parietal cortex, midbrain, and the pulvinar nucleus of the thalamus.[36-47] The anterior attentional system recruits activation from the DLPFC and the anterior cingulate to meet the demands of the Stroop task. The DLPFC is recruited for task-relevant information, for example, reading the word instead of naming the ink color which competes for priority in processing due to automaticity and the anterior cingulate is active on tasks that present incongruent stimuli in comparison to congruent and control/ neutral stimuli.[36-38,43-44] The posterior attentional system, on the other hand, is responsible for providing attentional restriction (orienting), spatial localization, and controlling attentional shifts.[36-46] When competing information (word reading vs. ink color) is presented in the Stroop task, the anterior attentional system is activated to provide control, reduce uncertainty and is heavily involved in conflict resolution. Sleep deprivation is specifically known to inhibit the functions of the anterior attentional system especially DLPFC.[48] However, not all studies on the effect of sleep deprivation on the Stroop task have documented findings similar to ours. The results of some studies are quite contradictory to ours. The Stroop test by Rosselli *et al*. showed no significant increase in time taken to complete or the number of mistakes made in each set following acute sleep deprivation.[49] Studies done by Sagaspe *et al*.[50] and Bratzke *et al*.[51] too have shown no significant variation in the results of the Stroop test following sleep deprivation. A small sample size leading to low power of these studies could explain the reason for them failing to establish any association between sleep pattern and cognition. However, we were not able to corroborate any findings in correlational analysis between the average sleep duration and the different parameters of the Stroop test for both the congruent as well as incongruent trials, which may be primarily due to insufficient power. Various studies, however, have been able to establish a correlation between sleep deprivation and cognitive decline[19,25,52-54] contradictory to our findings while some studies have not been able to do[9,29] like ours.

Theories and hypotheses regarding how sleep loss affects neurocognitive abilities are evolving rapidly as both the range of cognitive effects due to disordered sleep patterns and the neurobiology of sleep-wake regulation are better understood today. Our observations enable us to suggest early interventional programs for improving sleep hygiene like lifestyle intervention in the subjects suffering from inadequate sleep so as to reduce the chances of subsequent cognition related morbidity and mortality making our research highly clinically relevant, a strong point of our study. Although more studies are needed to validate our inference; nevertheless, our findings provide important guidance to navigate future research in this aspect of sleep health. The major limitation of the study was the small sample size (30 in each group). Hence, the broad generalization of the results to the larger population cannot be done. The sleep duration in the study is self-reported which cannot be assessed objectively. Subjects of both sexes have been included in this study which does not take into consideration the influence of hormones on cognition.

Our study concludes a definitive decline in cognitive function in sleep-deprived individuals indicating delayed selective attention and dysfunction of executive functions of the brain in them. Sleep deprivation, whether from a sleep disorder or altered lifestyle and whether acute or chronic, poses significant cognitive risks in the performance of many ordinary day-to-day tasks necessary for survival necessitating needful lifestyle intervention.

CONCLUSION

In our study, the reaction time during the incongruent trial was significantly higher in sleep-deprived subjects as compared to those getting adequate sleep per day. This signifies a decline in cognitive function in sleep-deprived individuals indicating delayed selective attention and dysfunction of executive functions of the brain in them underlying Stroop interference and facilitation. No significant correlation was however seen between the average sleep duration with different parameters of the Stroop test.

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