

Executive Functions are not Affected by 24 Hours of Sleep Deprivation: A Color-Word Stroop Task Study

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ABSTRACT

Background: Sleep is an important factor affecting cognitive performance. Sleep deprivation results in fatigue, lack of concentration, confusion and sleepiness along with anxiety, depression and irritability. Sleep deprivation can have serious consequences in professions like armed forces and medicine where quick decisions and actions need to be taken. Color-Word Stroop task is one of the reliable tests to assess attention and it analyzes the processing of information in two dimensions i.e., reading of words and naming of colour. The evidence regarding the effect of sleep deprivation on Stroop interference is conflicting. The present study evaluated the effect of 24 hours of sleep deprivation on reaction time and interference in Stroop task. **Materials and Methods:** The present study was done on 30 healthy male medical student volunteers in the age group of 18-25 years after taking their consent and clearance from Institute Ethics Committee. Recordings of Stroop task were at three times: baseline (between 7-9 am), after 12 hours (7-9 pm) and after 24 hours (7-9 am, next day). The subjects were allowed to perform normal daily activities. **Results:** The study revealed a significant increase in reaction time after 24 hours of sleep deprivation in comparison to baseline and after 12 hours of sleep deprivation. There was no significant change in interference and facilitation after sleep deprivation in comparison to baseline. The number of errors also did not show any significant change after sleep deprivation. **Conclusion:** The study indicated that there was slowing of responses without change in executive functions after 24 hours of sleep deprivation. It is probable that 24 hours of sleep deprivation does not bring about change in areas of brain affecting executive functions in healthy individuals who have normal sleep cycle. The present study indicated that in professions like armed forces and medicine working 24 hours at a stretch can lead to decrease in motor responses without affecting information processing and judgment ability.

Key words: *Cognition, interference, sleep deprivation, Stroop task*

INTRODUCTION

Sleep is a physiological mechanism that is important for cognitive functions. It is essential to have adequate sleep for good health. Modern day society has people

working 24 hours or more without proper sleep or breaks. This lack of sleep can lead to impairment of performance and fatigue. Such a decrease in vigilance and performance then leads to disastrous outcome in medical profession, long-distance driving, armed forces and air traffic monitoring.

Since the publication of first study on the effect of sleep deprivation on cognitive performance in 1896, a number of studies have been done to evaluate the behavioural, cognitive and psychomotor performance following sleep deprivation.^[1] Sleep deprivation results in fatigue and loss of vigour, confusion and sleepiness along with anxiety, depression and irritability.^[2]

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Dawson *et al.* reported that sustained wakefulness for 17 hours impaired hand eye coordination.^[3] Bartel *et al.* evaluated attention and working memory in resident doctors of anaesthesiology using reaction time tasks of increasing difficulty.^[4] They found that sleep deprivation led to psychomotor deficit in 52% of the doctors. They reported an increase in response time with increasing task complexity.

In the year 2007, Santhi *et al.* evaluated the effect of acute sleep deprivation on attention.^[5] They reported a slowing of response along with a decrease in accuracy of response. They hypothesised that there was impaired decision making that persisted on all night shifts.

The Stroop task was first described by John Ridley Stroop in 1935. The Stroop task is one of the best tests for assessment of attention.^[6] The Color-Word Stroop task assesses the interference in processing of word information and colour information. The task consists of words like “RED” etc. written in same ink colour i.e., Red (congruent condition) or different ink colour e.g. Blue (Incongruent condition). The subject has to respond to the ink colour and the response time is noted and analyzed. Interference in Stroop task in the response time difference between incongruent and neutral conditions was noted. The time taken to perform the task in the two conditions (incongruent and neutral) is recorded and the difference between the two represents interference.

The interference in Stroop task is based on the relative speed of processing view according to which reading of words is faster than naming of colours. There is parallel processing of the information for word and colour with a single response channel into which only one of the information can be admitted due to different speeds of processing.^[7] Another hypothesis for the Stroop interference is automaticity in which it is believed that naming of ink requires more attention than naming of word (as naming of words is automatic).^[8,9]

Studies on effect of sleep deprivation on Stroop task have revealed inconsistent results. In a study by Hartley and Shirley there was increase in interference in evening in comparison to morning and was attributed to diurnal variation in alertness.^[10]

Sagaspe *et al.* investigated the effect of 36 hours of wakefulness on Stroop task and reported no change in interference.^[11] Cain *et al.* in their study evaluated the effect of 40 hours of wakefulness on stroop task.^[12] They reported that the reaction time was slowest in incongruent condition and fastest in congruent condition. However, there was no change in interference or facilitation following sleep deprivation.

In a recent study, Bratzke *et al.* reported no significant variation in Stroop interference or facilitation following 40 hours of wakefulness.^[13]

A thorough literature search revealed inconsistent findings of the effect of sleep deprivation on Stroop task. The present study evaluated the effect of 24 hours of sleep deprivation on interference on Color-Word Stroop task.

MATERIALS AND METHODS

Thirty healthy male medical student volunteers in the age group of 18-25 years were recruited for the study after explaining the procedure and taking written consent. The study was approved by the Institute Ethics Committee. The subjects were asked to refrain from caffeine or any other stimulant intake for at least 12 hours prior to the study. The volunteers with history of medical illness especially neurological diseases, smoking, alcohol, any other drug consumption or any medications (within last 7 days) were excluded from the study.

The subjects were familiarized with the test procedure before recordings. The task was computer based wherein the incongruent stimulus consisted of words “Red”, “Blue”, “Green” and “Yellow” written in a colour other than the one implied by the word e.g. “Red” written in blue. The neutral condition consisted of “XXX” in the above colours. The congruent condition had the same words written in corresponding colour. The task consisted of three blocks one after another. Each block had 72 trials of congruent, neutral and incongruent task. The subjects responded to the colour of the text. The reaction time in performing the task was noted along with the error rates.

The testing was done following a restful overnight sleep on days when no stressful activity like exams was scheduled. There were three recordings — Baseline (between 7-9 am), after 12 hours (7-9 pm) and after 24 hours (7-9 am, next day). The subjects were allowed to perform normal daily activities. They were not allowed to consume any stimulant during the 24 hours of testing.

The mean reaction times and errors during the sessions were analyzed using repeated measures ANOVA by SPSS 17.

RESULTS AND DISCUSSION

The present study evaluated the effect of 24 hours of sleep deprivation on Stroop task. The results are summarized in Tables 1 and 2.

Table 1: Reaction time in ms (Mean ± SD)

Time of testing	Block 1			Block 2			Block 3		
	C1	C2	C3	C1	C2	C3	C1	C2	C3
Baseline	698.69±81.87	755.95*±89.19	658.14*±80.40	700.14±79.68	763.92*±94.64	669.68*±86.01	699.26±77.77	762.24*±89.27	665.46*±75.63
After 12 hours	709.66±87.32	756.23*±89.37	680.37*±88.65	725.08±97.85	781.92*±108.73	692.50*±101.61	727.85±95.41	787.89*±106.14	689.02*±94.84
After 24 hours	801.19*±92.41	882.74*±100.80	757.93*±93.65	886.78*±97.06	834.59*±87.26	722.71*±85.95	727.17*±75.12	794.72*±73.46	698.12*±74.46

* $P < 0.05$, C1: Neutral condition, C2: Incongruent condition, C3: Congruent condition

Table 2: Number of errors (Mean ± SD)

Time of testing	Block 1			Block 2			Block 3		
	C1	C2	C3	C1	C2	C3	C1	C2	C3
Baseline	4.6±2.6	4.9±3.6	3.9±2.4	4.4±2.3	4.7±3.2	4.2±2.4	4.8±2.7	4.7±3.2	4.1±2.6
After 12 hours	4.3±2.3	4.1±2.6	3.8±2.1	4.2±2.1	4.4±2.9	4.3±2.3	4.4±2.5	4.5±2.8	4.0±2.3
After 24 hours	5.6±3.7	4.6±3.2	3.8±2.3	4.9±3.2	4.9±3.4	4.4±2.5	4.8±3.2	4.7±3.1	4.1±2.4

C1: Neutral condition, C2: Incongruent condition, C3: Congruent condition

Table 1 shows the reaction times in milliseconds. The results revealed no significant difference in the reaction times between the three blocks thereby indicating no effect of practice. The reaction time was significantly different ($P < 0.05$) in incongruent and congruent condition when compared to neutral condition.

The reaction times were significantly increased after 24 hours of sleep deprivation when compared to the baseline ($P < 0.05$). A comparison of the reaction times after 12 hours and 24 hours also revealed a significant difference ($P < 0.05$).

However, there was no significant change in interference (difference in reaction times for neutral and incongruent condition) and facilitation (difference in reaction time for congruent and neutral condition). The mean value of interference changed from 61 ms at baseline to 64.4 ms after 12 hours and 75.3ms after 24 hours of sleep deprivation. The mean value of facilitation changed non-significantly from 36.3 ms at baseline to 34.3 ms after 12 hours and 33.2ms after 24 hours of sleep deprivation. The number of errors also did not show a significant change during the three conditions at three different times.

Our findings of change in reaction times in congruent and incongruent conditions are similar to those of Cain *et al.*^[12] Cain *et al.* also reported slowest reaction time in incongruent condition and fastest in congruent condition. Our findings of increase in reaction times are also similar to theirs, who reported an increase in reaction times in the three conditions till 24 hours with a plateau being achieved after that till 40 hours of sleep deprivation.^[7]

The present study revealed no change in interference and facilitation after 24 hours of sleep deprivation.

Similar findings have been reported in previous studies by Cain *et al.* and Bratzke *et al.*^[12,13] Both Cain *et al.* and Bratzke *et al.* evaluated the effect of 40 hours of sleep deprivation on Stroop interference and facilitation. Similar findings of no change in interference have been reported by Sagaspe *et al.* after 36 hours of sleep deprivation.^[11]

However, in contrast to our findings, Hartley and Shirley noted an increase in Stroop interference during a normal day from morning to evening.^[10]

The findings of an increase in reaction times in the present study indicate a global slowing of the mental processes. Similar findings have been reported by various authors using different test parameters.^[4,5,14] However, the finding of no change in interference and facilitation along with no significant difference in error rates indicates that the executive functions are less affected by 24 hours of sleep deprivation.

It is probable that the executive functions underlying interference and facilitation were insensitive to 24 hours of sleep deprivation. Studies have shown that one night sleep loss has little effect on executive functions.^[15,16]

One probable reason of our findings could have been that the volunteers were healthy young individuals who were having restful sleep before the study and hence 24 hours of sleep deprivation did not affect their cognitive processes to an extent so as to bring a change in their executive functions. This finding has implications in occupations like armed forces and medicine wherein these professionals put in more than 24 hours of service at a stretch. The fact that reaction times increased indicated that their responses can become slow but the fact that there was no change in executive functions suggests that decision making and judgment ability

is preserved even after 24 hours of sleep deprivation especially when sleep deprivation is preceded by restful overnight sleep.

CONCLUSIONS

The present study indicated that in professions like medicine and armed forces where people work for more than 24 hours at a stretch, there can be a decrease in motor response but the judgment ability and executive functions are not affected by 24 hours of sleep deprivation.

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