Effects of Partial Sleep Deprivation on Psychological Performance and Behaviour

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Abstract

Ten subjects were partially deprived of sleep for three nights and days. They were allowed only four hours of sleep each night. Their behaviour and performance on various psychomotor tasks were studied. These studies were undertaken with a view to assess the possible effects on aircrew from the point of view of operational efficiency and flight safety.

The performance showed deterioration under the effect of partial sleep deprivation and on sudden awakening. The deterioration was evident even on the morning following the first night of sleep deprivation. They reported various subjective complaints like increased desire to sleep, lack of concentration, increased appetite, etc. With recovery sleep for 8 hours at night supplemented with 2-3 hours of sleep next afternoon, the subjective complaints disappeared. The recovery in performance on various tasks after a night recovery sleep was variable depending upon the type of task.

Introduction

Aviation has been advancing very rapidly and modern aircraft are being designed for higher speeds, increased attacking power and automation to achieve better results in combat. However, in this man-machine complex, man still remains the vital factor whose psychophysiological limitations have to be catered for in aviation. In the modern supersonic aircraft, a pilot has to react with speed and precision which requires the peak performance of his psycho-physiological functions. Any decrement in performance could be potentially dangerous towards flight safety. There are many factors which have deleterious effects on one's performance in flying. Sleep deprivation is one of these factors which is important and is known to reduce performance.

Effects of sleep deprivation on performance for varying periods have been studied by many authors [2, 7, 9-12]. The results are not uniform. The difference in results could be due to differences in methodologies used, type of task and one's motivation towards the task. One may assume that sleep deprivation deteriorates human performance but it is not always easy to observe it in experimental subjects.

An average, 6–8 hours of sleep in 24 hours is recommended for an individual to keep him physically and mentally fit. In certain circumstances one is unable to get proper sleep at night and may have to carry out duties next day. Such conditions are not uncommon in the Air Force. The effect of partial sleep deprivation on performance assumes great importance in flying so that flight safety is not jeopardised. Therefore, it was decided to study the effects of partial sleep deprivation on task performance and behaviour. It is known that deprivation of rapid eye movement (REM) sleep produces more deleterious effects compared to the non-

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REM sleep. Therefore, in this study the subjects were deprived of sleep during second half of the night so that maximum of REM sleep deprivation could be produced, since most of the REM sleep occurs during the second half of the night. The subjects were allowed only 4 hours of sleep (10 pm to 2 am) every night for three consecutive nights and days. The effects of this partial sleep deprivation on task performance and behaviour have been studied.

Material and Methods

Ten healthy male volunteers in the age group of 21–29 years were taken up for the study. The programme of test schedule is given below :

Test Schedule for Subjects

No. of days	Day		Test schedule and sleep deprivation
1st–6th day	Monday to Saturday	...	Regular practice on tests employed in the study.
6th day	Saturday night	...	Subject slept in the sleep laboratory.
7th day	Sunday night	...	Subject slept in the sleep laboratory from 10 pm to 6 am with electrodes on, for recording EEG, EOG, EMG and EKG.
8th day	Monday	...	Morning-Basal performance on various tests was recorded. Night–Slept in sleep laboratory from 10 pm to 6 am. Whole night EEG recording with other parameters was carried out.
9th day	Tuesday	...	Night–Allowed to sleep from 10 pm to 2 am only. EEG and other parameters were recorded during this period. Performance on tests on sudden awakening was recorded. Not allowed to sleep till next night.
10th day	Wednesday	...	Morning–performance on tests was recorded. Night–same schedule as on Tuesday night
11th day	Thursday	...	– do –
12th day	Friday	...	Morning–performance of tests was recorded. Night–full night sleep from 10 pm to 6 am with whole night recording of EEG along with other parameters.
13th day	Saturday	...	Morning–performance on tests was recorded.

Their task performance was assessed on the following tests:

(i) Critical fusion frequency (CFF)
(ii) Stability of attention test (SAT)
(iii) Flight oriented psychomotor test (FOPT)
(iv) Choice reaction time test (CRTT)
(v) Spatial orientation test (SOT)
(vi) Pursuit rotor test (PRT)

Critical Fusion Frequency (CFF)

This test is taken as an index of the psychophysiological functioning of the body. The end point where flickers of light fused and the individual saw a steady point of light was taken for scoring and was expressed as flickers per second. C F F was ascertained by using the Flicker Fusion Apparatus made by Electronic Measurements, Bangalore. The apparatus consisted of two parts (i) Control Unit and (ii) Viewing Chamber. The subject looked at the flickering patch of light through 1 cm diameter viewing lenses. The flicker rate was controlled by the control unit.

Stability of Attention Test (SAT)

This is a visual pursuit test where the subject traces a series of zig-zag lines from their origin to the destination without using any pointer. The ratio of number of lines correctly traced over the total number of lines (12) within a stipulated time of two minutes formed the score. Higher the score better the performance.

Flight Oriented Psychomotor Test (FOPT) : Fig. 1

Subject had to fight up three points on a display with the help of stick and rudder pedals, according to the specified programme given to him. Twenty such specified programmes were given to the subject and the time taken to complete each task was recorded in seconds. The performance on this test involves comprehension, short term memory, reaction time and visual motor coordination. The average individual performance time was calculated by dividing the total time taken for completing each sub-task (each programme) correctly by the number of sub tasks completed correctly. Higher the score (seconds) poorer the performance.

Choice Reaction Time Test (CRTT)

In this test reaction time in milliseconds to randomly presented visual and auditory stimuli was measured. Higher the score (milliseconds) poorer the performance.

Spatial Orientation Test : Fig. 2

In this test the subject's ability to orientate in space was assessed. This test consists of a number of slides depicting an aircraft with coloured wing tips, in different attitudes. With the help of the colour code given in each slide the subject had to tell within three seconds the position of the colour ie, whether it was on left wing tip or the right wing tip. Sixteen such slides were projected for each subject. The ratio of the number of tasks correctly completed over the total number of tasks formed the score. Higher the score better the performance.

Pursuit Rotor Test (PRT)

This is a tracking task where a subject had to keep in touch a metal stylus with a metal disc mounted on a rotating turn table. Loss of contact at any time during the test was recorded as an error in the impulse counter included in the circuit. Average number of errors formed the score. Higher the score poorer the performance.

Subjects were instructed to abstain from alcohol and drugs during the period of study. Close contact was maintained with each subject. His subjective feelings and behaviour were noted.

The EEG records were subjected to visual

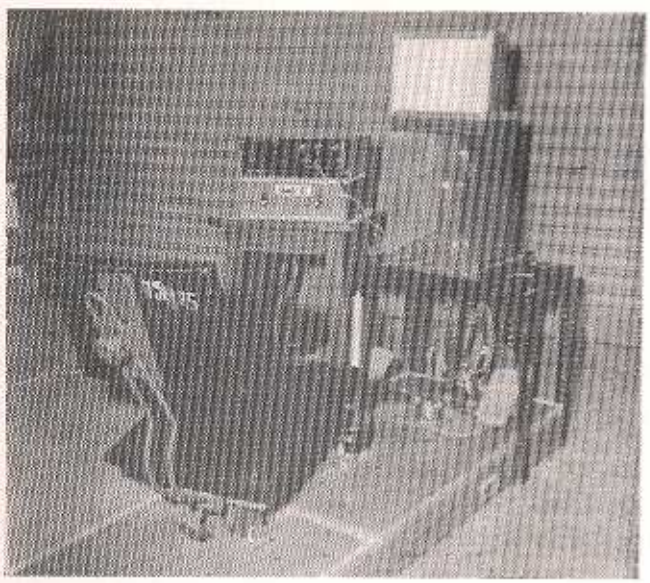

Fig. 1. Flight Oriented Psychomotor Test

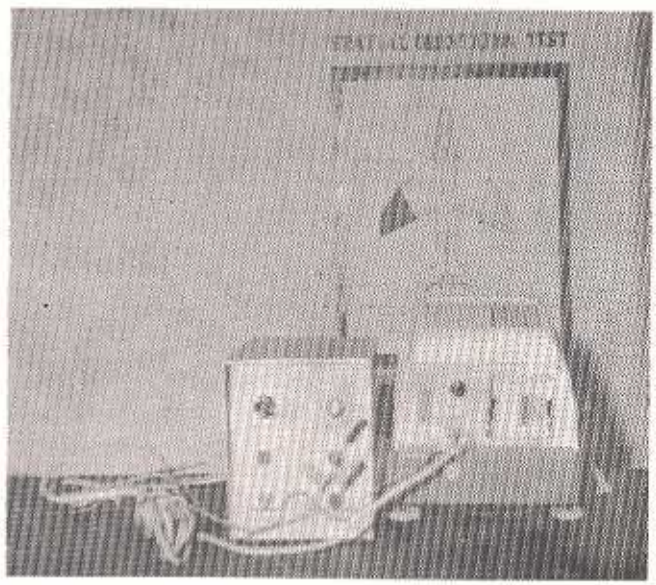

Fig. 2. Spatial Orientation Test

analysis by two persons. The Epoch scoring system recommended by the International Federation for Electrocncephalography and Clinical Neurophysiology was followed.

Results and Discussion

Table I shows the mean values of various basal performance test scores on three successive mornings and after sleep deprivation. It is seen that there is significant performance decrement after the first instalment of sleep deprivation. The deterioration in performance which is statistically significant is also observed on 2nd and 3rd mornings after partial sleep deprivation on all tests except CRTT. Results of this test on subsequent mornings showed a deterioration but not large enough to be statistically significant. Other workers [14] have also shown the adverse effects of one night partial sleep deprivation. Wilkinson [12] demonstrated the deleterious effects of sleep deprivation for one night on visual watch keeping.

TABLE I

Mean values of various performance tests before and after sleep deprivation (ASD) and the significance of their differences (n = 10)

Test	Mean values					Mean differences between			
	Basal (B)	I morning ASD	II morning ASD	III morning ASD	Post recovery with sleep	B & I morning	B & II morning	B & III morning	B & Post recovery sleep
Critical Flicker Fusion	33.6	32.3	31.4	31.4	33.3	1.3*	-2.2*	-2.2*	-0.3
Stability of Attention	0.96	0.83	0.82	0.89	0.89	0.13***	-0.14**	-0.07*	-0.07
Spatial Orientation	0.99	0.94	0.92	0.93	0.99	-0.05*	-0.07*	-0.06*	-0
Pursuit Rotor	0.65	1.75	1.98	2.30	1.0	1.10**	1.33**	1.65**	0.35
Flight Oriented Psychomotor Test	4.7	5.6	5.5	5.5	4.9	0.9**	0.8**	0.8**	0.2
Choice Reaction Time	233	265	246	273	227	32**	13	40	-6

CFF, SAT, SOT = Performance Score : − Deterioration ; + Improvement *** Significant at P = 0.001
PRT = Error Score : + Deterioration ; − Improvement ** ,, P = 0.01
FOPT, CRTT = Performance Time : + Deterioration ; − Improvement * ,, P = 0.05

Table II gives the mean values of 3 performance test scores/time at basal and on 3 successive nights of sudden awakening from sleep. It is seen that performance of the subjects on CFF, SAT and FOPT on sudden awakening on 1st, 2nd and 3rd night of partial sleep deprivation shows significant deterioration in all the three tests. The degree of deterioration is more on sudden awakening as compared to the scores on the 1st, 2nd and 3rd mornings after the nights of partial sleep deprivation. The decrement in performance on sudden awakening on the first night was due to sudden awakening only while on 2nd and 3rd nights it was due to combined effect of sudden awakening and partial sleep deprivation. The time taken for the performance on these three tests after sudden awakening varied from 7 to 10 minutes. Therefore, it can be concluded that the adverse effects of sudden awakening in our study lasted for a minimum period

of 7–10 minutes. This period of low performance varies in individuals depending upon motivation, interest in the particular task and the stage of sleep as indicated by EEG from which he was awoken. Fort and Mills[5] found that when subjects were awoken from stage 2 sleep there was no consistent variation in their performance whereas after awakening from stage 4, performance declined during the subsequent eight minutes.

Table III shows the percentage of basal NREM and REM and the incidence of loss of NREM and REM in percentage on three successive nights of sleep deprivation and an average of total loss of NREM and REM sleep (in percentage). It is seen from the table that the subjects had partial loss of NREM as well as REM sleep.

TABLE II

Mean values of various performance tests at basal and after sudden awakening from sleep (SAS) and the significance of their differences (n = 10)

Test	Mean values of				Mean differences between		
	Basal (B)	I SAS	II SAS	III SAS	B & I SAS	B & II SAS	B & III SAS
Critical Flicker Fusion	33.6	31.0	30.7	31.4	2.6***	-2.9***	-2.2**
Stability of Attention	0.96	0.66	0.72	0.67	-0.30***	-0.24**	0.29***
Flight Oriented Psychomotor Test	4.7	6.4	6.0	6.3	1.7***	1.3***	1.6**

CFF & SAT = Performance Score : – Deterioration ; + Improvement *** Significant at P = 0.001
FOPT = Performance Time : + Deterioration ; – Improvement ** ,, P = 0.01
* ,, P = 0.05

TABLE III

Basal and incidence of loss of NREM and REM sleep after sleep deprivation

Subject	Incidence of NREM and REM sleep in %		Incidence of loss of NREM and REM sleep in percentage of 3 successive nights of sleep deprivation as compared to Basal						Average of total loss of NREM & REM sleep in % as compared to Basal	
	Baseline		I Night		II Night		III Night			
	NREM	REM	NREM	REM	NREM	REM	NREM	REM	NREM	REM
1.	81.8	18.2	34.3	84.4	42.5	51.7	43.5	41.7	40.1	47.8
2.	78.4	21.6	51.9	72.6	61.4	30.6	52.5	73.6	55.3	58.8
3.	77.7	22.3	57.1	55.4	35.6	74.1	40.3	54.9	44.5	61.4
4.	79.9	20.1	51.4	60.0	52.0	50.0	48.7	58.5	50.7	35.1
5.	73.0	27.0	57.6	88.3	43.9	51.8	51.3	55.1	50.9	65.1
6.	73.5	26.5	40.3	73.3	33.2	74.2	38.0	76.4	37.1	74.6
7.	77.1	22.9	34.7	84.2	30.3	76.8	35.3	62.1	33.4	74.4
8.	79.4	20.6	46.3	59.7	43.9	64.8	44.7	58.3	45.0	60.9
9.	77.9	22.1	42.2	72.1	12.6	74.5	28.9	28.4	28.0	58.5
10.	76.9	23.1	55.0	57.7	40.3	45.5	56.5	52.9	51.1	52.0

On the whole the percentage loss of REM sleep was more than that of NREM sleep. So the effects of partial sleep deprivation on performance in this study are due to both NREM and REM deprivation but more of REM deprivation.

Table IV shows the percentage of basal NREM and REM sleep and the percentage of NREM and REM during the recovery night sleep. On recovery night sleep it is seen that out of NREM and REM sleep the incidence of REM sleep is more as compared to that of basal REM. It means that after partial sleep deprivation in which REM deprivation occurred to a greater degree as compared to NREM, REM sleep was more than his basal pattern. This finding is in agreement with the studies by Dement[3] and he labelled it as REM rebound. Other workers such as Kales et al,[6] Sampson,[8] Dement and Fisher[4] and Agnew et al[1] also reported similar build up.

TABLE IV

Incidence of NREM and REM sleep in percentage (Basal and Recovery with sleep)

Subject Number	Basal		Recovery	
	NREM %	REM %	NREM %	REM %
1	81.8	18.2	75.6	24.4
2	78.4	21.6	77.7	22.3
3	77.7	22.3	76.2	23.8
4	79.9	20.1	69.8	30.2
5	73.0	27.0	60.6	39.4
6	73.5	26.5	70.0	30.0
7	77.1	22.9	66.1	33.9
8	79.4	20.6	68.0	32.0
9	77.9	22.1	75.0	25.0
10	76.9	23.1	64.8	35.2

All subjects reported an increased desire to sleep and this desire increased with each night of sleep deprivation. Irritability, lack of concentration, memory lapses, thought blocks, headache, heaviness of head and fatigue were reported. Most of the subjects had an increase in appetite. In certain subjects amount of smoking also increased. The behavioural changes on sleep deprivation have been reported by other workers also. In a differential sleep deprivation of REM stage conducted by Williams et al[11] subjects consistently reported extreme desire to sleep, irritability, anxiety and increased appetite.

After one recovery night sleep and 2–3 hours of sleep next afternoon all of them became free of their subjective complaints. The performance on all the tests after the recovery night sleep showed improvement. On CFFT., SAT, PRT and FOPT the performance did not come back to basal level though deterioration which still persisted was minor and not statistically significant. On SOT the recovery was complete while the performance on CRTT showed little improvement which was not statistically significant.

Further it might be mentioned that at present we are studying the effects of partial sleep deprivation based on performance on NRC Stressalyser which has been obtained from Canada under the Commonwealth Advisory Research Committee programme. The performance on the Stressalyser consists of tracking task which has various components like reaction time, error correction time, acquisition time and overshoot correction time. The total response time is recorded in seconds and the performance is recorded on a tape which is decoded later with the help of a computer and data is obtained. In this study subjects were allowed to sleep for four hours during night (2 – 6 am) in twentyfour hours and their performance on the stressalyser recorded after the partial sleep deprivation. Basal performance scores were recorded before sleep deprivation and compared with the scores after sleep deprivation. It may be noted that sleep deprivation was produced during the non-REM phase during these studies as compared to the REM deprivation given in the earlier tests. So far no definite trend in the results has been noted in these preliminary studies. The studies are in progress.

Conclusion

Partial sleep deprivation even for one night where an individual slept for 3 – 4 hours only had its deleterious effects on performance on tests which involved attention, psychomotor coordination, reaction time, ability of orientation in space and tracking ability.

There was an increase in deterioration in performance on certain tests with further partial sleep deprivation on two successive nights.

The deterioration in performance on sudden awakening was significant. It lasted for a minimum period of about 7 – 10 minutes after sudden awakening.

The subjects developed subjective complaints like increased desire to sleep, lack of concentration, increased appetite etc. These subjective complaints disappeared with one night recovery sleep and 2 – 3 hours of sleep next afternoon.

The recovery in performance on the tests after one night of recovery sleep was variable. No significant deterioration persisted on any test.

The tests employed in this study were sensitive enough to measure decrement in performance under the effects of partial sleep deprivation and sudden awakening.

Recommendations

It is desirable that a flyer who has not been able to have proper sleep during night and does not feel fresh in the morning, does not undertake flying for the day.

Aircrew should be indoctrinated periodically to make them aware of the deleterious effects of partial sleep deprivation and sudden awakening.

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