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Original Article

Effects of a short afternoon nap on cognitive and psychomotor functions of non-sleep-deprived subjects

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ABSTRACT

Objectives: A short nap is a countermeasure against fatigue; however, the possibility of sleep inertia (SI) persists. Understanding its effects on piloting mental functions is crucial for the implementation of strategic naps.

Material and Methods: Fifty well-slept healthy male volunteers, aged 24–45 years (mean ± standard deviation: 33 ± 5.5 years), participated in this study. Psychomotor aspects, executive control functions, and higher-order cognitive functions were studied. Psychometry was conducted using simple reaction time test (SRTT), Stroop test (ST), and digit symbol substitution test (DSST). An afternoon nap of 30-min served as the intervention. Pre-nap data were collected at 0800 h and at 1330 hours (h). After 1400 h, participants were allowed to sleep for 30-min. Data were collected for 2 h post-nap, every 15-min during the 1st h and every 30-min during the 2nd h.

Results: SRTT response time was longer ($p < 0.0001$) in the post-nap period, and this effect persisted for 2-h. However, there was no post-nap change ($p = 0.0527$) in response accuracy. There was no significant change ($p = 0.379$) in the Stroop effect after the nap. The DSST, response time remained unchanged immediately post-nap ($p = 0.367$) but shortened and persisted after 30-min post-nap ($p = 0.0088$) for 2-h. The accuracy of responses in the DSST was unaffected.

Conclusion: An afternoon nap of 30 minutes is sufficient to produce SI, thus impairing the motor speed. However, the accuracy of psychomotor and cognitive functions was unaffected. Meanwhile, the speed of higher-order cognitive functions was improved. Although the findings caution about the policy of using short naps as a countermeasure against fatigue in aviation, it is recommended to further validate the research after addressing the limitations mentioned in the study.

Keywords: Short nap, Sleep inertia, Fatigue, Psychomotor, Cognitive functions

INTRODUCTION

Pilot fatigue, associated with circadian dysrhythmia, sleep loss, and long working hours, is a major flight safety concern.[1,2] Napping is used as an effective countermeasure against fatigue in several safety-critical occupations.[1,3,4] It is popular among civil and military aviators to maintain optimal performance when required to work beyond the usual duration.[1,5,6] Research showed that naps of 30-min or less are sufficient to reduce fatigue, improve performance, and lessen subjective sleepiness.[1,3,7] However, longer naps are often associated with sleep inertia (SI), a period of physical and mental impairment immediately after awakening.[3,8-12]

SI could be detrimental to aviators.[1,2] Documented psychomotor and cognitive deficits due to SI include increased simple and complex reaction times, reduced grip strength, and impaired steadiness and coordination.[3,9,12] It has been shown to lower scores in visual-perceptual tasks, memory, complex behaviors, and various cognitive tasks such as clock reversal, cancellation, and mental arithmetic.[8,9] The magnitude and duration of SI's impact depend on the complexity of the task performed, time from awakening to testing, sleep stage and depth, anxiety level, and circadian state.[8,9,12] In the absence of significant sleep deprivation, the duration of SI was found not to exceed 30 min.[1,3,9] However, SI may still adversely impact specific psychomotor and cognitive skills required in specialized professions with high mental workloads, such as aviation.[9,11-13] Severity of SI could be greater at the circadian trough compared to other times of the day.[1,8,9] Although SI significantly increases reaction time, reduces vigilance, and decreases the speed of information processing,[1,11,13] the magnitude and duration of its adverse effects are not well quantified for the aviation context.[3,8,9]

The possibility of sleep deprivation during flying duties is addressed by flight duty time limit regulations.[1] In addition, many international airlines allowed short-duration (30–40 min) cockpit naps to address fatigue during long-duration flights.[1] However, the effects of SI, especially following an afternoon nap, are a significant concern.[3] Therefore, this study was carried out to estimate the aftereffects of a short 30-minute afternoon nap on cognitive and psychomotor functions of non-sleep-deprived subjects as relevant to the aviation setting.

MATERIAL AND METHODS

Subjects

Subjects were aviation-naïve, healthy, and screened for any illnesses or medications that could influence the outcome. They were ensured to have adequate restful sleep for three consecutive nights before the test day. The sleep quality and pattern of the subjects were monitored for three nights before the test using actigraphy and sleep diary. The Groningen Sleep Quality Scale (GSQS)[14] was recorded on the morning of the test day. Subjects were given a standard lunch at 1245 h on the test day.

Materials

Wrist actigraphy[13] using M/s Philips Respironics Inc Actiwatch® Spectrum Plus™ and electroencephalogram (EEG) of standard sleep recordings using M/s Philips Respironics Inc Alice® PDX™ were undertaken.

The subjects' sleepiness state immediately before the nap was recorded using Karolinska sleepiness scale (KSS).[12-14] It comprises 9 levels, with users asked to encircle the number representing their sleepiness level.[14,15] Subjects' cognitive and psychomotor assessments were conducted using three tests: Simple reaction time test (SRTT),[16] Stroop test (ST),[17] and digit symbol substitution test (DSST).[18] An in-house developed and validated computerized test software known as IAM-psychometric evaluation designed for aviators or pSuMEDhA test battery was used.[19] The battery has five tests, with the SRTT, ST, and DSST being the first, third, and fourth tests, respectively.

The SRTT involved a yellow ball tracing a random path on the computer screen. From time to time, the ball changed color to red. The participant was required to react to this color change by pressing the space bar on the computer keyboard. The time taken from the color change to the key press was recorded as the response time. Pressing the space bar within 800 ms of the color change was considered a correct click. The test lasted 3-min, with 10 episodes of color change at random intervals during this period.

The ST was presented in two phases. In the first phase, the subject had to match the word, which names a color, presented in the box by clicking on the same square color presented on the screen. In the next phase, the subject had to match the color of the word to the color of the square given below. The ink color might or might not differ from the word. The colors used for the words and squares were red, green, yellow, and blue. Each word/colored word appeared 6 times, resulting in 24 words presented in random order in *phase-I* for 3-min. After that, *phase-II* began with changed instructions and continued for 3-min. The same word alphabet color had two successive presentations as two different words. The word appeared on the screen for 1 s, and the next word appeared with a beep immediately afterward. The participant had to identify the word as fast as possible and respond. The time difference between the phases was considered for analysis. This evaluated the reading ability with respect to the "color-word interference" effect.

The DSST consisted of a set of nine non-sense symbols, along with corresponding digits from 1 to 9 presented as a legend at top of the screen. One non-sense symbol randomly appeared on the screen, and the subject identified the corresponding digit from the legend and pressed that numerical key as fast as possible. The non-sense symbol was replaced by another if there was no response within 15-s, and the next random symbol appeared. In the case of immediate responses, the further random symbols kept appearing for the test duration of 3 min. The response time in milliseconds was recorded.

Experimental protocol

The study was carried out at the sleep and confinement facility at the Institute of Aerospace Medicine, Bengaluru. A repetitive measurement protocol to record changes in relevant cognitive and psychomotor functions before and after the intervention was used. It was approved by the Institute Ethics Committee, and written informed consent was obtained from all subjects.

A nap of 30 minutes started at about 1400 h and served as the intervention. Napping was undertaken on a comfortable bed in a large, temperature-controlled, and sound-attenuated room. Actigraphy and EEG were monitored from the time the lights were switched off. The subjects were instructed to nap and asked to wake up when the alarm bell (approximately 75 dB) rang, signaling the end of the nap. Subjects were not informed of the nap length, and no external cues indicated the time. The alarm was set for 30-min from the start of stage-N1 NREM sleep confirmed by EEG and corroborated with actigraphy.[13]

These tests were administered in the morning at 0800 h and in the afternoon from 1330 h to 1400 h to establish baseline data. Participants were allowed to sleep for 30-min under controlled conditions. The data were collected for 2 h post-nap, with tests administered every 15-min during 1st h and every 30-min during 2nd h.

Data analysis

The data included accuracy (correct clicks) and speed (response time) from the SRTT, the Stroop effect (difference in response time) from the ST, and accuracy (correct clicks) and speed (response time) from the DSST. The tabulated data from different instances for a particular parameter were combined and assessed for normality using D'Agostino and Pearson test. Parameters were compared using repeated measures analysis of variance or Friedman test, depending on the normality test results [Table 1].

RESULTS

Fifty healthy male volunteers, aged 24–45 years (mean ± standard deviation: 33 ± 5.5 years), participated. All subjects had GSQS scores of <2, confirming adequate restful sleep the night before the test.[14] The majority (78%, $n = 39$) of the participants had KSS scores of 3–5, while the remaining 22% ($n = 11$) had KSS scores of 1–2. This indicated that most subjects exhibited moderate levels of sleepiness[14,15] typical of the afternoon circadian trough. None showed excessive levels of sleepiness before the tests.

Table 1: Outcome of normality assessment of the study data using D'agostino Pearson test.

Name of the test	Parameter	Normality assessment	
		p-value	Result
SRTT	Correct clicks	0.6435	Passed
	Response time	0.0002	Not passed
Stroop test	Stroop effect	0.0001	Not passed
DSST	Correct response	<0.0001	Not passed
	Response time	0.031	Not passed

SRTT: Simple reaction time test, DSST: Digit symbol substitution test

The pre-nap data were not statistically different from morning recordings for all of the tests. As there was no evidence of circadian influence, the pre-nap data were considered as a baseline for analysis. All subjects fell asleep spontaneously within a few minutes of arriving at the sleep laboratory after the pre-nap recordings. The 30-min nap was monitored using EEG recordings and actigraphy, with the duration standardized by an alarm bell. The subjects began the post-nap tests immediately after awakening. EEG recordings were monitored throughout the 2-h post-nap period to rule out any recurrence of sleep.

Post-nap response time of SRTT was significantly higher ($p < 0.0001$) than baseline from the immediate post-nap to 2-h observation period. However, the frequency of correct clicks did not change ($p = 0.0527$) during the post-nap period [Tables 2 and 3]. It is inferred that motor speed was adversely affected by SI, while accuracy was unchanged.

In ST, the Stroop effect (measured as the difference in response time) did not change significantly ($p = 0.379$) after the nap [Table 4].

In DSST, response time was unchanged ($p = 0.367$) at 15th-min post-nap, but it significantly decreased ($p = 0.0088$) from 30th min onward. This lower response time was observed throughout the rest 2-h period. The accuracy of responses in the DSST did not change after the nap [Tables 5 and 6].

DISCUSSION

Available studies on SI had various conditions of sleep deprivation or sleep durations at night or during the day.[7-9,11,13,20,21] However, relevant data on the effects of SI after

Table 2: Number of correct clicks and response time measured in SRTT at different instances represented as mean±SD (*n*=50).

Time of measurement	Number of correct clicks (mean±SD)	Response time (milli sec) (Mean±SD)
Morning (0803 h)	6.22±1.89	454.6±31.76
Pre nap (1333 h)	6.50±2.02	458.2±45.53
03 min (Post-nap)	5.96±1.37	501.2±48.47
18 min (Post-nap)	6.34±1.41	484.8±44.63
33 min (Post-nap)	5.94±1.63	490.3±43.92
48 min (Post-nap)	5.70±1.37	484.8±41.78
78 min (Post-nap)	6.58±1.57	482.2±37.39
108 min (Post-nap)	6.44±1.22	490.2±44.63
Statistical test used for comparative assessment (using pre-nap as baseline)	Repeated measures ANOVA	Friedman test
Level of significance (*p*-value)	0.0527	<0.0001

SRTT: Simple reaction time test, SD: Standard deviation, ANOVA: Analysis of variance

Table 3: Comparison of and response time in SRTT at different instances with pre-nap values as baseline using Dunn's multiple comparison test (n=50).

Parameters of SRTT compared	Level of significance (p-value)
Pre-nap versus morning	>0.9999
Pre-nap versus 03 min post-nap	<0.0001
Pre-nap versus 18 min post-nap	0.0031
Pre-nap versus 33 min post-nap	0.0002
Pre-nap versus 48 min post-nap	0.0006
Pre-nap versus 78 min post-nap	0.0014
Pre-nap versus 108 min post-nap	<0.0001

SRTT: Simple reaction time test

Table 4: Difference in response time measured during Stroop test at different instances represented as mean±SD (n=50).

Time of measurement	Difference in response time (milli sec) (mean±SD)
Morning (0812 h)	−22.84±52.81
Pre-nap (1342 h)	−24.82±61.03
12 min (Post-nap)	−2.80±74.71
27 min (Post-nap)	−44.78±73.11
42 min (Post- nap)	−21.72±61.80
57 min (Post-nap)	−24.70±74.86
87 min (Post-nap)	−20.30±86.70
117 min (Post-nap)	−32.18±56.57
Statistical test used for comparative assessment (using pre-nap as baseline)	Friedman test
Level of significance (p-value)	0.379

SD: Standard deviation

"controlled rest" or "power naps" are limited.[3,9,22] The effects of such naps on cognition and psychomotor aspects in adequately rested individuals need to be well understood.[6,7,11,12,23-25]

In this study, none of the parameters differed significantly between the morning and pre-nap recordings, confirming that the parameters were not affected by circadian changes from morning to the pre-nap period (1330 h).

In SRTT, post-nap response time was significantly higher than pre-nap control and the effect was persisted for 2-h post-nap. However, there was no significant difference in the number of correct clicks after the nap. This indicated that the response speed was adversely affected due to SI; however, the accuracy was unaffected. The effect on response time was prolonged and remained for 2 h of the post-nap period. Similarly, Dinges *et al.* reported that about 60-min of rest/sleep in the afternoon resulted in significant performance decrement in simple reaction time and working memory-related tasks, which lasted for up to 35 min.[8] It has been hypothesized (arousal hypothesis) that the performance decrement observed in SI, without concomitant sleep deprivation, could be primarily due to decreased levels of arousal leading to a general slowing down of cognitive processes without remarkable impairment in accuracy, irrespective of the difficulty of the task.[5,13] Therefore, the effect on response time in SRTT could be purely based on delayed motor performance recovery, as stated by Ferrara and De Gennaro.[25] A study on similar setting by Bhatt *et al.* showed that the dual task response time was prolonged immediately after 30 min of afternoon nap; however, the effect was transient and did not last till 21-min.[19]

Table 5: Number of correct clicks and response time measured in DSST at different instances represented as mean±SD (n=50).

Time of measurement	Number of correct clicks (mean±SD)	Response time (milli sec) (mean±SD)
Morning (0815 h)	98.66±1.14	1603±245
Pre-nap (1345 h)	98.54±1.69	1471±210
15 min (Post-nap)	98.24±2.12	1516±238
30 min (Post-nap)	98.16±2.37	1390±227
45 min (Post-nap)	98.10±1.58	1329±232
60 min (Post-nap)	98.24±1.80	1301±220
90 min (Post-nap)	97.32±3.38	1271±190
120 min (Post-nap)	98.36±1.72	1254±208
Statistical test used for comparative assessment (using pre-nap as baseline)	Friedman test	Friedman test
Level of significance (p-value)	0.043	<0.0001

DSST: Digit symbol substitution test, SD: Standard deviation

Table 6: Comparison of correct clicks and response time in DSST at different instances with pre-nap values as baseline using Dunn's multiple comparison test (n=50).

Parameters of DSST compared	Level of significance (p-value)	
	Correct clicks	Response time
Pre-nap versus morning	>0.9999	0.3031
Pre-nap versus 15 min post-nap	>0.9999	0.3674
Pre-nap versus 30 min post-nap	>0.9999	0.0088
Pre-nap versus 45 min post-nap	0.7794	<0.0001
Pre-nap versus 60 min post-nap	>0.9999	<0.0001
Pre-nap versus 90 min post-nap	0.0796	<0.0001
Pre-nap versus 120 min post-nap	>0.9999	<0.0001

DSST: Digit symbol substitution test

The ST was one of the most widely used tests in cognitive assessment of executive functioning such as working memory, planning, focused attention, and problem-solving.[18] In literature, there are many varieties of STs and scoring systems, and they have been interpreted for cognitive, personality, and psychological facets. Here, the interference test scoring has been utilized, which was one of the most favored by many authors.[26,27] In the present study, the change in the response time in the ST was not statistically significant. Salamé *et al.* reported that SI post-1-h nap led to cognitive impairment, such as delay in response time of logical reasoning and spatial memory tasks, without affecting accuracy.[28] However, the study was done at night following a period of sleep deprivation.[28] Speed of cognition, and not accuracy, was affected with different levels of impairment under conditions of SI.[13,23,24] The lack of change in the Stroop effect in this study could be because the current paradigm may have produced only a relatively mild level of SI affecting the executive control functions.[29]

The DSST gave an insight into higher-order cognitive functions such as visuospatial processing, attention, processing speed, and mental tracking.[18,20] The current study showed that the response time of DSST did not change in the immediate post-nap period; however, the same was significantly faster after 30th min of the post-nap period, and the improvement persisted for the rest of 2 h. This evidence showed that the response time of DSST was not adversely affected due to SI, and the subsequent improvement in response time could be due to the beneficial effect of the short nap.[20] Moreover, the accuracy parameters were not affected by SI. These results were in disagreement with other studies wherein the SI adversely affected the capability of attention, vigilance, and tracking.[23,30-32] This could be because of the difference in the setting as experimented in this study in comparison to the experimental protocol of previous studies. A NASA/FAA study in Boeing 747s where crew members were allowed 40 min of rest during the low workload phase of the flight showed consistent and positive improvement in performance and alertness till the end of the flight in comparison to their counterparts who were not allowed the in-flight rest opportunity.[1,5,22]

Naps can counteract the effect of sleepiness by enhancing subjective and objective alertness, improving cognition, vigilance, and psychomotor ability.[1,4-7,9,19,22] Ferrara *et al.* suggested that cognitive performance recovery was greater and more rapid than motor performance recovery.[31] It could be possible that the cognitive recovery was rapid enough or not being affected at all by the level of SI induced by the short nap in this study.[12,21] Similarly, the beneficial effect of a short nap in the early afternoon on higher-order cognitive functions and attention functions has been well documented in the literature.[10,12,22,24]

There were certain limitations in methodology that could influence the outcome of this study. The subjects were non-aviators whose inherent cognitive and psychomotor skills could be distinctly different from aviators. Convenience sampling was used which reduces the strength of results. The nap was at a pre-scheduled time (1400 h) and was of fixed duration (30 min). It was not at a self-selected time or for a period as preferred by the subject. In practice, an individual is likely to take a nap when sleepiness becomes so intense that it interferes with ongoing activity and when opportunity or conditions arise. The cognition and psychomotor activity could be affected by circadian rhythm. Therefore, comparison with the same subjects or age and sex-matched controls would have been more objective to negate the effect of circadian influences.

Recommendations

The use of 30-minute afternoon nap as a potential countermeasure against fatigue of long-duration flying is to be exercised with adequate caution. However, considering the stated limitations of this study, the findings are recommended to be validated by randomized control trials in a simulator using Aviator subjects. Nevertheless, it is crucial to emphasize that the need for proper work-rest scheduling and adequate rest/sleep, which are essential for optimal functioning in aviation, should never be substituted with cockpit naps.

CONCLUSION

The study was undertaken to estimate the effect of SI on aviation-critical mental functions following a short afternoon nap akin to the one allowed as per policy in civil aviation to mitigate pilot fatigue. The short nap of 30 min was sufficient to produce SI, slowing down psychomotor activities. However, the accuracy component of psychomotor functions and executive control functions was unaffected. In addition, higher-order cognitive functions became faster. Therefore, it is concluded that while SI following a short nap slows down motor responses but benefits higher-order cognitive functions such as visuospatial processing, complex mental processes, and attention.

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Disclaimer

Views expressed in this paper are those of the authors and do not represent views or position of the Indian Armed Forces.

Ethical approval

The research/study was approved by the Institutional Review Board at the Ethics Committee Institute of Aerospace Medicine, number AFMRC 5138/2019, dated 30th August, 2018.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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