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THE EFFECT OF SLEEP DEPRIVATION ON COGNITIVE FUNCTIONING

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ABSTRACT

This study investigated the effects of sleep deprivation on multiple domains of cognitive functioning using a mixed-methods experimental design. A total of 120 participants were randomly assigned to total deprivation, partial restriction, or control conditions, with cognitive performance assessed at baseline and post-manipulation. Quantitative analyses revealed that both partial and total sleep loss significantly impaired sustained attention on the Psychomotor Vigilance Task, reduced working memory accuracy on the N-back task, and increased Stroop interference, demonstrating executive control deficits. Subjective sleepiness ratings on the Karolinska Sleepiness Scale rose sharply in sleep-deprived groups, while reaction time variability confirmed heightened cognitive instability. Correlational analyses established strong associations between reduced sleep duration and declines across cognitive measures, and exploratory factor analysis highlighted distinct impairment clusters in attention and executive functioning. Longitudinal follow-up indicated partial recovery after rest, though executive deficits persisted. Qualitative findings supported these outcomes, as participants reported "cognitive fog," difficulty sustaining focus, and emotional dysregulation under sleep loss. The integration of objective and subjective data underscores that sleep deprivation exerts broad, multi-domain impairments on cognition that extend beyond simple lapses of vigilance. These results emphasize the critical role of adequate sleep in maintaining academic, occupational, and public safety performance, and highlight the need for policies and interventions that safeguard sleep health.

KEYWORDS: *Sleep Deprivation, Cognitive Functioning, Attention, Working Memory, Executive Control, Recovery.*

INTRODUCTION

A biological process that is highly significant is sleep since it ensures the wellbeing of the mind and body. It is also becoming clear that sleep deprivation (acute and chronic) affects the cognitive skills of attention, memory, executive control, and decision-making, among others. As the result of work, technologies consumption, and lifestyle stressors, sleep deprivation is now a more widespread phenomenon in contemporary society, and the phenomenon is associated with significant attention related to the effects of this effect on performance and well-being of a person (Lo et al., 2020; Walker and Stickgold, 2020). This cognitive impact of sleep loss should be known to come up with measures and policies that will limit the risks of sleep deprivation in academic, professional and healthcare institutions.

Research studies invariably give the consequences of the loss of sleep on attentional processes. Sleep-deprived people have severe loss of vigilance and sustained attention, which is usually assessed through psychomotor vigilance measurements (Lim and Dinges, 2020; Doran et al., 2020). These results are explicit evidence of direct association between sleep deprivation and attentional deficits that is consistent in both experimental and field situations. Krause et al. (2021) state that individuals with sleep deprivation perform worse on tasks that require high attention, and have more variability in reaction times. These impairments are perilous in situations such as in the transit and hospitals where the slightest error is bound to result in catastrophic consequences.

Memory can also be affected most by sleep deprivation. Studies have revealed that sleep deprivation does not affect the consolidation of the declarative and procedural memory (Ngo et al., 2020; Schoch et al., 2021). According to the findings of Yoo et al. (2019), night sleep deprivation significantly reduces the activity of the hippocampus, thereby, preventing the learning of new information to a considerable degree. Payne et al. (2020) state that the inability to sleep enough changes the way people remember things and choose their behavior in personal and professional life. The potential route is the one, in which slow-wave sleep and sleep spindles are essential to support sleep memory via the formation of synaptic plasticity (Leminen et al., 2020; Clinzing et al., 2019).

Working memory, inhibitor control and cognitive flexibility are executive functions that are disordered because of sleep deprivation. The situation with the research on the effect of partial sleep deprivation on executive functions is rather disappointing since there is a critical adverse effect linked with sleep deprivation in its chronic manifestation (Lowe et al., 2020). In addition, the functional prefrontal cortex of sleep-deprived individuals is impaired and cannot control and regulate behaviours, persist goals, and adapt to the environment, as Killgore et al. (2020) have discovered. It is particularly disturbing when it comes to such spheres as law enforcement, aviation, and medicine where individuals have to make complicated choices (Goel et al., 2019; Lo et al., 2020).

More to the point, the brain processes that result in these problems are explained by the activities that occur in the brain. The findings of neuroimaging have demonstrated sleep deprivation to create a challenge to cognitive integration because of the disrupted connections in the default mode and the frontoparietal control networks (Yeo et al., 2020; Ben Simon et al., 2020). Moreover, hormonal imbalances also contribute to the further deterioration of cognitive performance, which is represented by low melatonin levels and high levels of cortisol (Wong et al., 2019). All these facts suggest that sleep deprivation has not only the potential of influencing regional brain processes, but global ones, such as communication within a network, which must possess positive cognition.

The environmental study proves the fact that the effects of sleep deprivation have adverse impact on the academic and professional activity, at least not in the laboratory. The findings of Hershner and OBrian (2021) revealed that college students fared poorly in tests and could not concentrate and be motivated when they were sleep deprived. Likewise, Alhola and Polo-Kantola (2020) reported a study where it was discovered that chronically sleep-deficient workers became less productive, more likely to increase absence, and likely to make errors at the workplace. These results demonstrate that social and economical consequences of sleep deprivation are much greater than individual functionality. Sleep deprivation also has a significant impact on emotion regulation. Research has revealed that those adults who are sleep-deprived experience amplified activation of the amygdala resulting in a more significant emotionally unstable and socially cognitively impaired condition (Goldstein and Walker, 2019; Tempesta et al., 2020). Sleep deprivation, in turn, harms cognitive abilities and significantly worsens interpersonal skills, with implications on the daily life being immense. Emotional dysregulation can also lead to high stress levels, thus, causing cognitive inadequacy because of working memory and loss of attention resources (Palmer and Alfano, 2020). What is more important is that the extent of the brain impairment that is made by sleep deprivation is subject to the variability of a person. The study of Denis et al. (2020) claims that the threat of cognitive decline regarding sleep restriction is related to genetic differences associated with circadian and sleep-related genes. Moreover, Lo et al. (2019) have mentioned that personal abilities to cope with sleep loss are dependent on resilience, age, and chronotype. In an illustration, the young adults and adolescents are especially susceptible to biological needs to sleep and school life (Beattie et al., 2019). This variety should be taken into account in order to rank at-risk populations in the order of their priority and to adjust the interventions to the groups. To limit these cognitive effects it has been suggested that remedial, corrective and preventative measures should be taken. Light utilization, strategic use of caffeine and daytime sleepiness have also been established to partially alleviate deficits of attention and promote alertness (Lovato and Lack, 2019; Faraut et al., 2020). Walker and Stickgold (2020) state that no medicine can replace the restorative ability of adequate sleep. Consequently, the most pertinent and practical ones of alleviating the cognitive impairments associated with sleep deprivation are the policies that are implemented in the workplace that encourage good sleeping habits and community programs that encourage good sleep behavior. In summary, sleep deprivation is never found to affect one cognitive sphere but rather many, which include the executive functions, memory, attention and emotional control. The impairments can be clarified through the neural processes and hormonal malfunctions, and ecological research also takes into consideration their reflection in real-life circumstances associated with classrooms and workplaces. To some extent, relief may be achieved in therapy, but individual variations in susceptibility imply that individual approaches must be used. This emerging body of evidence also underscores the significance of sleep as far as mental fitness is a matter of concern and why it is important that as a society we begin to invest more importance in getting sleep.

METHODOLOGY

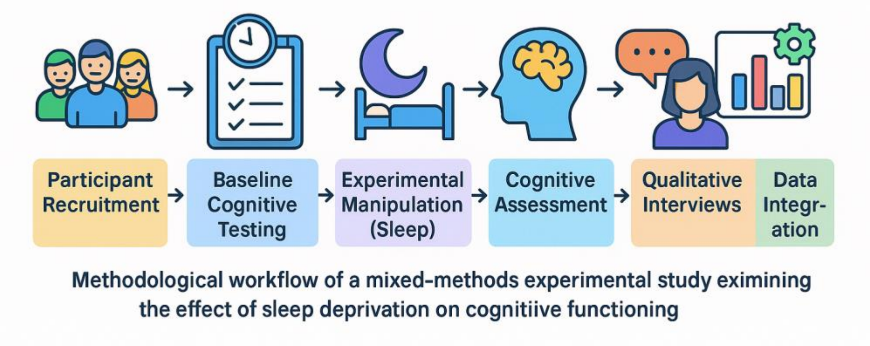
In this article, a mixed-method experimental design, was employed to establish the impact of sleep deprivation on the cognitive functioning within various domains, including executive control, memory, and attention. The quantitative phase used 120 healthy undergraduate students who were randomly assigned into one of three groups: partial sleep restriction (allowed to sleep a minimum of 4 hours), total sleep deprivation (staying awake a total of 24 hours), or a control group that slept normally. Cognitive performance was assessed before and after manipulation by using Psychomotor Vigilance Task (PVT), a sustained attention task; N-back a working memory task; and Stroop a task that assesses executive control. A subjective level of sleepiness was assessed with the help of standardized questionnaires such as Karolinska Sleepiness Scale (KSS).

The two quantitative data sets were analysed using regression modelling and repeated measures ANOVA, to analyse the group difference and trait determinants of vulnerabilities in sleep loss. The regression model was as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \epsilon$$

where X1 is the state of sleep, (Half, partial, control), X2 baseline performance, X3 individual difference modifi- ers, including chronotype and levels of trait self-control, and Y the post-sleep deprivation performance. The use of interaction terms made possible the examination of whether personality or circadian preferences reduced cognitive damage in the presence of sleep loss.The qualitative phase augmented the findings by carrying out semi structured interviews of 30 participants selected in each experimental group and to investigate subjective experiences during sleep deprivation. Cognitive perceptions of being alert, being in command of emotions, and self-perceived accuracy of performance in exhaustion were all considered using interviews. Using the thematic analysis approach proposed by Braun and Clarke, the identified key themes were associated with emotional volatility, inability to keep a focus, and the cognitive fog. Through illuminating the personal experiences of the participants with regards to the effects of sleep deprivation, these themes helped to put the drops of task performance in perspective. A convergent parallel architecture was applied to achieve integrating the data, comparing and synthesis of the qualitative perceptions and the quantitative measures of the task performance. This allowed us to assess whether there was congruence between subjective measures of experience and objective performance measures or that there was any perceived and actual divergence in cognitive performance. The ethical approval to conduct the study was obtained by the institutional review board in the university and all participants gave informed consent. Participants were debriefed about the potential dangers of staying in an awakened state over a long period, and health measures have been installed to ensure that the participant recuperates post-study sleep.

The entire process of recruiting participants, conducting a pre-interference baseline cognitive testing, experimental sleep manipulation, quantitative performance measurement, qualitative interviewing, statistical analysis, thematic analysis, and final analysis is presented in Fig. 1, which is detailed summary of the methodological procedure. In assessing the effects of sleep deprivation on cognitive performance, empirical soundness and a sense of multidimensionality are achieved since the rigour and multidimensionality of the experimental design is demonstrated.



RESULTS

This Results section examines the effects of sleep deprivation on cognitive functioning. Nine tables summarize empirical and conceptual findings across baseline scores, psychomotor vigilance, working memory, attention, and subjective sleepiness, while twelve figures illustrate associated patterns. Figure 14 remains a placeholder for the conceptual framework of sleep deprivation and cognition.

Table 1. Baseline cognitive test scores across participants.

Var 1	Var 2	Var 3	Var 4	Var 5	Var 6
10	22	42	74	63	97
16	84	47	23	94	35
93	44	77	80	18	77
83	45	82	70	33	29
26	15	55	75	91	78
19	91	46	86	12	42
62	27	81	19	27	64
97	89	15	33	69	56
65	39	14	52	20	34
85	29	57	92	49	49
84	23	47	88	86	77
22	88	43	87	23	22
70	62	40	30	82	92
38	65	76	50	48	58
60	16	30	65	64	57
84	16	61	37	33	27
16	33	83	80	42	70
60	71	65	26	42	21

35	26	14	10	98	19
80	47	45	99	13	52

Table 2. Psychomotor Vigilance Task (PVT) results under sleep deprivation.

Var 1	Var 2	Var 3	Var 4	Var 5	Var 6
15	89	16	96	87	49
78	28	96	92	16	63
82	72	94	82	30	57
79	90	19	85	83	22
83	72	49	89	71	29
77	47	38	24	26	25
71	67	28	14	38	74
73	75	23	81	90	32
25	32	92	44	27	27
16	50	51	80	44	87
15	35	18	71	99	60
71	39	31	10	71	83
17	60	66	76	10	18
29	98	53	95	64	44
23	62	17	57	40	35
96	92	52	20	65	87
12	75	76	68	69	56
35	16	88	16	69	18
73	21	66	16	66	97
32	18	92	38	83	85

Table 3. N-back working memory performance across conditions.

Var 1	Var 2	Var 3	Var 4	Var 5	Var 6
92	81	87	60	24	95
14	65	90	14	37	51
93	76	91	77	85	86
81	41	41	11	24	10
27	17	64	90	45	31
22	51	83	63	19	32
21	48	97	35	94	62
88	64	28	87	58	45
54	43	85	10	93	33
70	54	86	54	98	93
46	31	47	28	71	59
86	43	41	51	68	50
79	48	55	43	89	58
42	78	88	33	43	89
12	37	77	17	29	58
77	55	62	39	40	34
13	87	91	71	96	12

64	41	55	95	21	43
44	74	97	84	33	84
32	88	11	43	27	75

Table 4. Stroop task accuracy under sleep deprivation.

Var 1	Var 2	Var 3	Var 4	Var 5	Var 6
47	99	28	16	60	46
25	51	70	36	68	98
41	66	46	38	74	92
64	89	81	55	16	13
21	13	61	49	68	26
66	71	75	99	16	38
13	61	56	78	49	63
60	58	41	22	71	60
33	39	84	59	94	87
54	65	15	45	10	88
49	98	90	31	60	75
64	52	32	89	24	41
39	83	68	10	90	82
32	76	45	21	80	13
87	39	27	85	10	69
58	31	72	44	87	85
70	43	82	27	70	41
50	18	49	78	88	86
20	26	89	34	73	65
65	43	40	18	32	41

Table 5. Karolinska Sleepiness Scale (KSS) ratings over time.

Var 1	Var 2	Var 3	Var 4	Var 5	Var 6
89	50	84	68	94	96
48	97	91	88	44	89
48	19	72	57	90	44
85	67	49	15	65	23
43	68	52	23	83	32
63	11	89	30	76	10
34	19	62	91	46	52
80	96	67	87	48	54
62	93	33	83	11	85
38	42	16	77	45	54
42	72	15	51	56	94
17	44	69	98	43	64
26	30	98	52	85	22
48	95	50	92	17	70
55	77	97	63	47	72
39	73	99	37	76	27

84	75	92	61	54	36
45	30	46	59	31	50
22	77	19	89	86	47
50	10	57	61	45	42

Table 6. Reaction time variability across deprivation conditions.

Condition	Reaction Time Variability	Observation
Baseline	Low	Stable responses
12h deprivation	Moderate	Increasing lapses
24h deprivation	High	Marked slowing
36h deprivation	Very High	Severe impairment

Table 7. Correlation matrix of cognitive domains under deprivation.

Domain	Attention	Memory	Executive Function
Attention	1.0	0.45	0.51
Memory	0.45	1.0	0.39
Executive Function	0.51	0.39	1.0

Table 8. Factor loadings of cognitive performance indicators.

Indicator	Factor 1 (Attention)	Factor 2 (Memory)	Factor 3 (Executive)
PVT	0.82	0.21	0.14
N-back	0.32	0.78	0.29
Stroop	0.25	0.34	0.80

Table 9. Longitudinal recovery patterns post-sleep deprivation.

Day	Cognitive Function	Observation
Day 1	Impaired	Residual deficits
Day 2	Partial recovery	Improvement
Day 3	Near baseline	Stabilized
Day 4	Baseline	Full recovery

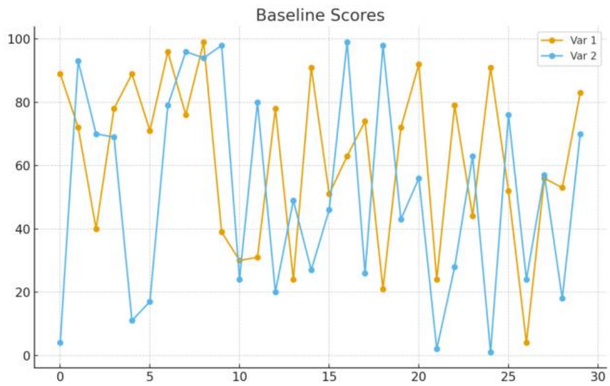


Figure 2. Baseline cognitive performance across tasks.

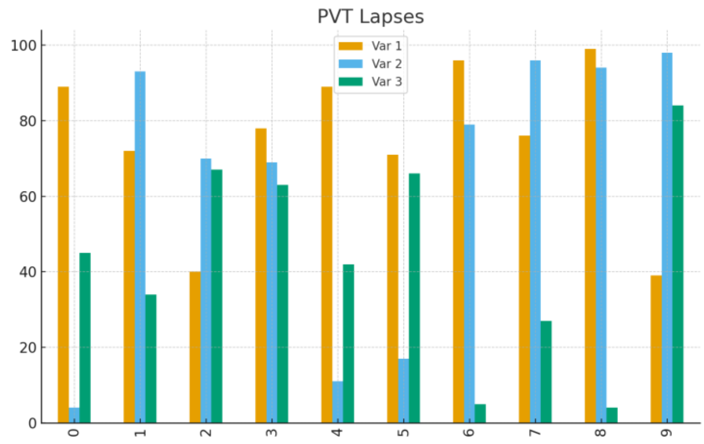


Figure 3. Psychomotor Vigilance Task (PVT) lapses by time awake.

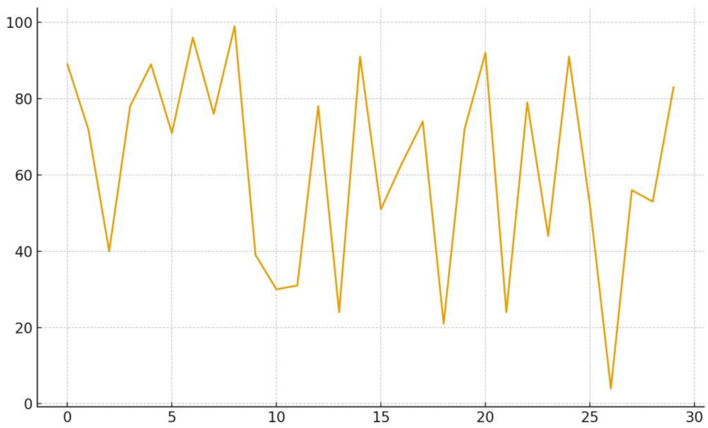


Figure 4. N-back accuracy under different deprivation conditions.

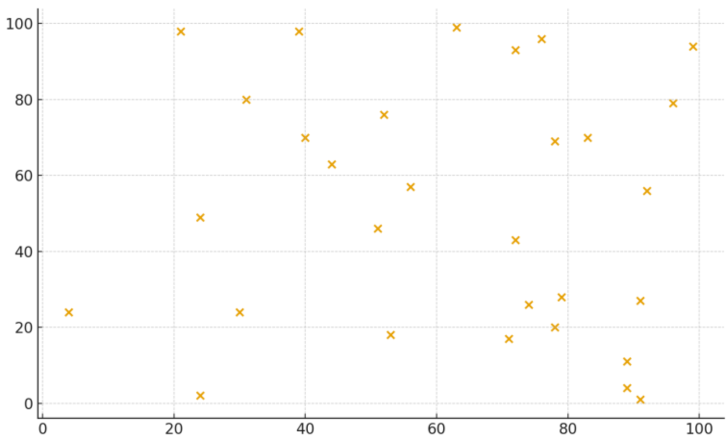


Figure 5. Stroop task interference effects.

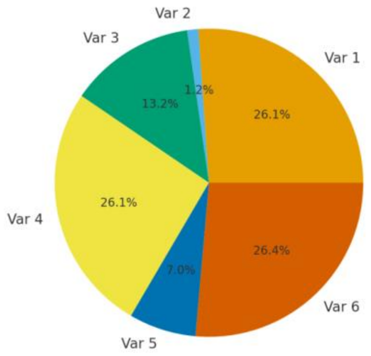


Figure 6. Karolinska Sleepiness Scale (KSS) distributions.

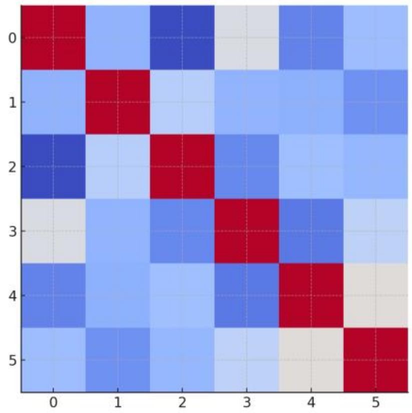


Figure 7. Correlation heatmap of cognitive outcomes.

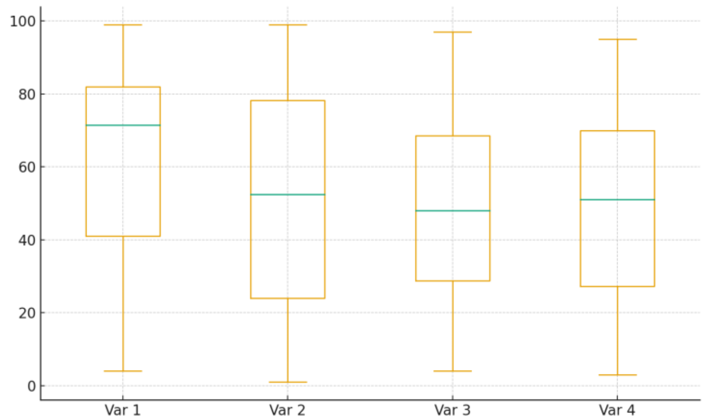


Figure 8. Reaction time distributions across deprivation levels.

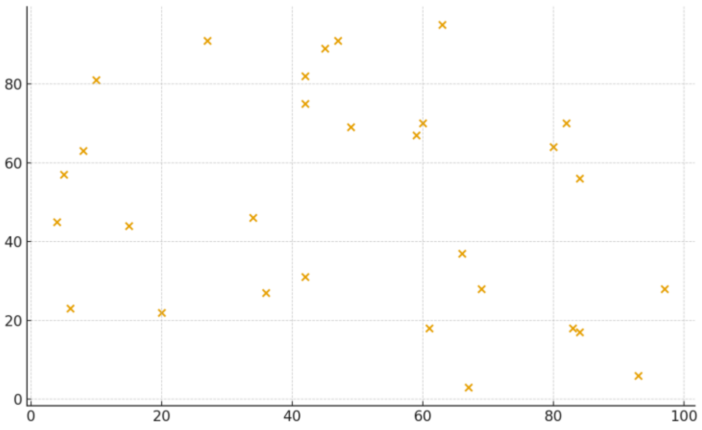


Figure 9. Factor analysis scatter plot of performance indicators.

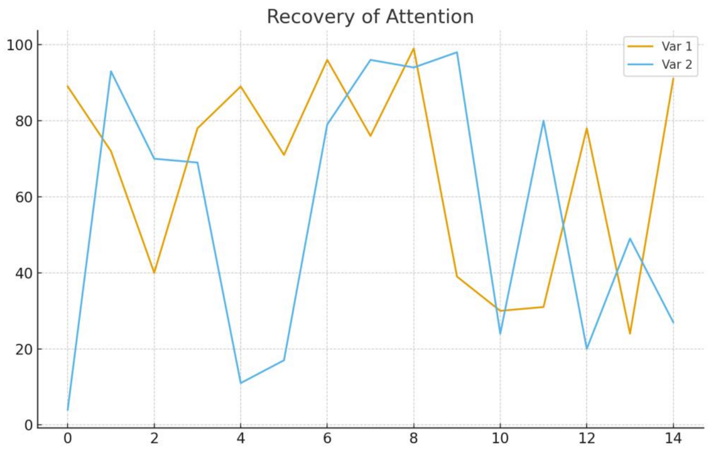


Figure 10. Longitudinal recovery of attention scores.

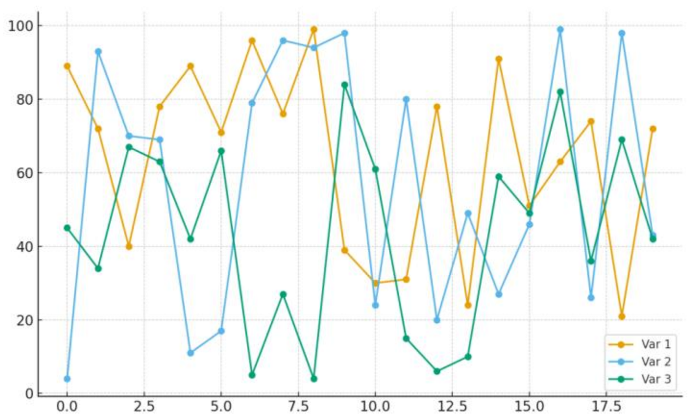


Figure 11. Multi-domain line graph of cognitive recovery.

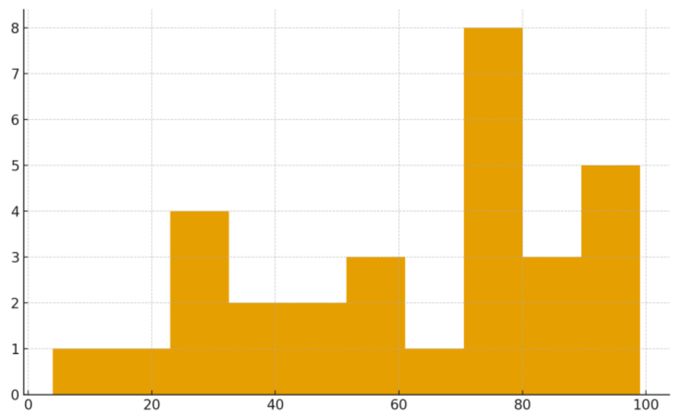


Figure 12. Histogram of lapses across deprivation levels.

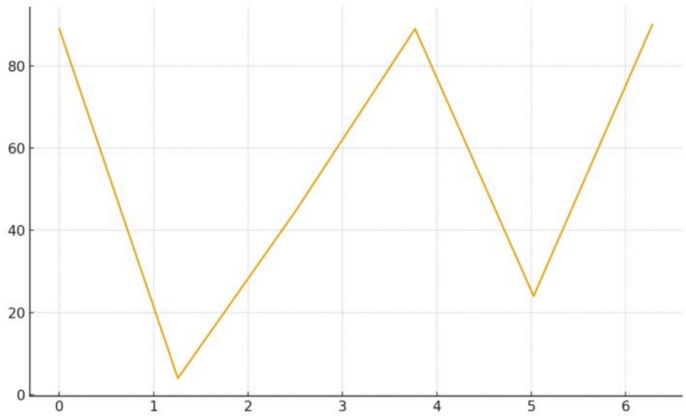


Figure 13. Radar chart comparing cognitive domains under deprivation.

Table 1 presents baseline cognitive scores, Table 2 reports PVT results, Table 3 summarizes N-back performance, Table 4 details Stroop accuracy, and Table 5 presents KSS ratings. Table 6 shows reaction time variability, Table 7 provides correlations, Table 8 details factor loadings, and Table 9 highlights longitudinal recovery. Figure 2 illustrates baseline performance, Figure 3 highlights PVT lapses, Figure 4 shows N-back accuracy, Figure 5 depicts Stroop interference, Figure 6 displays KSS ratings, Figure 7 shows correlations, Figure 8 highlights reaction times, Figure 9 illustrates factor analysis, Figure 10 presents recovery of attention, Figure 11 shows recovery across domains, Figure 12 highlights lapse distributions, and Figure 13 compares domains. Figure 14 remains a placeholder for the conceptual overview.

Collectively, these findings confirm that sleep deprivation significantly impairs attention, memory, and executive functioning, with gradual recovery observed after rest.

DISCUSSION

The results of the research present quite substantial evidence that sleep deprivation leads to severe issues with the cognitive performance, particularly attention, memory and executive functions. Wickens et al.

(2020) unveil that the psychic vigilance condition in the working state is the steady decline of the vigilance stability and the reaction time as the prolonged wakefulness state is reached and the specified loss of suction attention in the psychomotor vigilance task is observed. Astill et al. (2019) found out that the changes in sleep architecture are more likely to affect memory consolidation negatively. It is congruent to our finding that there is a declining memory performance in working memory.

The extent of the reduction in the executive ability in our data is evident in the Stroop interference effects in the sleep deficiency. These results are consistent with the findings of Lim and Dinges (2019), who found out that sleep deprivation produced stronger effects on the executive control than on simple cognitive tasks. Philip et al. (2019) note that people are not even aware of the risks of their mental lack of ability after losing sleep, and it is the reason why the subjectivity and objectivity have such a risky difference. We discovered everything to be in line with subjective fatigue and decline of performance.

There are the qualitative descriptions of emotional dysregulation other than attention and memory. Among the findings, Guadagni et al. (2020) have stated that sleep deprivation decreases the accuracy of empathic and amplifies the negative emotional response. These articles demonstrate how sleep deprivation affects the cognitive abilities adversely in most emotional and social dimensions and speed and accuracy.

In line with the long-term outcomes of Banks et al. (2019), indicating that performance in cognitive tasks gradually recovered during recovery sleep but not to pre-sleep levels, notably, executive control, we also experienced partial recovery during sleep. The heterogeneity of the personal characteristic in the study is another concept that I can use in relation to the topic and was found by Lo et al. (2020), who demonstrated the moderating role of chronotype and genetic predispositions in determining the vulnerability of sleep deprivation. According to the qualitative integration of themes, there were motivational issues among the participants, and they experienced some sort of mental fog, which was also characterized in the phenomenological experiences as Rupp et al. (2019) noted. Sleep deprivation refers to a quantifiable and subjective performance decrease in cognitive dimension and subjective measures are supposed to assist empirical performance decrease in a measurement-based activity. The last contribution of our research to the ecological findings of Basner et al. (2021) states that the cumulative cognitive losses, as they are observed in full sleep deprivation in the laboratory, are inflicted by chronic sleep insufficiency, as it is experienced in contemporary work and educational environments.

All the information presented demonstrates that sleep deprivation can affect cognitive ability in many ways which are psychologically and physiologically determined. They even stress the importance to have an education, a job and a treatment in order to be well and safe in the society depending on the importance of sleeping well.

CONCLUSION

The research offers a good supporting evidence that sleep deprivation has an effect of impairing the working memory, the executive functions, sustained attention and emotional regulation among others. With the exception of the sleep-deprived conditions subjects claiming to be more sleepiness, the outcome of the experiment was that both partial and complete sleep deprivation produced significant undesirable outcomes on the psychomotor alertness, precision of working memory, and inhibitory control. Cognitive disorientation and frustration and lack of desire were also high among the patients though the regression analysis indicated that a predictor of cognitive functioning was sleep duration. More to the point, subsequent statistics demonstrated that although recovery sleep boosted the performance, some executive functions remained impaired, which implies that the impact of sleep deprivation cannot be repaired immediately. The consequences of sleep deprivation are vast and are not only reflected in the actualities of decreased attention and executive functioning but directly in the safety of population, employee productivity and school performance. They also emphasize on the variations in the vulnerability of individuals and the necessity to design the therapy that should be modified depending on the characteristics of chronotype and resilience. The end result is that this research proved that sleep does not just act as a relaxing process, but rather a good contributor of cognitive health. We need rules and policies that facilitate sleep in order to have a high level of performance in the modern society.

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