Final Paper Research & Outline

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PSY1001-43

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August 1, 2024

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Contents

Thesis: Prolonged sleep deprivation and suboptimal sleep quality contribute to reduced performance on cognitive and memory-based tasks.

The consequences of sleep deprivation on cognitive performance (Khan & Al-Jahdali, 2023)

Supporting

1. Studies[1] show that prolonged partial sleep deprivation (SD) is more harmful in comparison to a single night of total SD.

2. Sleeping individuals experience three non-REM phases and one REM phase. A study[2] claims that REM SD "appears to have a notable effect on exciting neurons" and that NREM SD "reduces the normal release of specific neurotransmitters, which can affect the ability of the receptors to refresh and restore sensitivity." Khan and Al-Jahdali posit that the result of SD in regard to these four phases is reduced cognition.

3. Khan and Al-Jahdali posit that as SD increases, homeostatic functions associated with the brain are increasingly impaired.

4. A cited study[5] showed that a lack of sleep results in an increased amygdala hyperlimbic reaction, associated with negative emotional stimuli. This corresponds to a loss of medial prefontal cortex (mPFC) connectivity, and suggests a decrease in prefrontal inhibition signaling.

5. A cited study[7] examining moral judgment in individuals afflicted with SD found that there were accordingly higher response latencies, as SD "impairs the ability to integrate cognition and emotion to pass moral judgment"

6. "Sleep deprivation appears to disrupt memory consolidation in the hippocampus through long-term potentiation (LTP)." Similarly, a study[10] found that "The advancement of memory from an unstable to a more permanent form, requiring the NMDA receptor, is disrupted in SD."

7. A cited study[13] found that sleep deprivation alters glutamatergic signaling through modifications in AMPA and NDMA receptor structure, reducing molecular signaling

cascades due to an attenuated calcium influx, resulting in fewer permanent memories being consolidated in the brain (depicted in fig. 2A).

8. A cited study[14] found that the functional deficits in plasticity and behavior is produced by a molecular disruption attributed to SD.

9. A cited study[21] found that "A lack of sleep can result in the incapacity of the brain to process neural signals at optimal quantities, causing incoherent speech."

10. A cited study[23] found that SD "...results in a lack of enzymes that repair brain cell damage caused by free radicals, which affects memory and speech." Moreover, another cited study[24] found that "This can be worsened for people experiencing long-term SD because of the degeneration of neurons due to "relentless brain activity."

11. Clarify: A cited study[26] found that "equal inhibition means that there is consistent attentional performance in the brain."

12. A cited study[27] found that "In a sleep-deprived state, there is an imbalanced inhibition between the task-related DMN and FPM activity, and inconsistent increasing arousal activity that influences the thalamic activity." Khan and Al-Jahdali posit that this "leads to irregular disturbance of the DMN activity and a reduced FPN activity during external tasks." As a result, individuals are "unable to maintain attention to specific tasks," since "suppressing the DMN is vital to allow appropriate brain networks to achieve successful behavior towards tasks and goals."

13. In a cited study[29] conducted on objective attention, "Visual tasks given to participants showed that the difficulty of the tasks was related to parietal cortex activation, and inactivation of the insular cortices, visual cortices, and the cingulate gyrus." This activation pattern was considerably lower in the SD participants than the group with complete sleep. Khan and Al-Jahdali conclude that, based on a cited study[30], "These combined factors can

cause impairment in the attentional networks essential for accurate attention performance and can lead to higher vulnerability to risks and accidents in routine life."

14. A cited study[31] indicated that alertness and attention is "directly impacted by increased fatigue due to sleep loss."

15. Khan and Al-Jahdali posit that, in a SD state, an "unstable inhibition of task-related DMN and FPN activity as well as an inconsistent increasing arousal influencing activity in the thalamus" can cause "irregular signals of DMN activity and reduced FPN activity during tasks." This results in "a loss of attentiveness and working-memory functioning, improving with greater thalamic activity and less with reduced thalamic activity."

16. A cited study[40] showed that "The strength reduction of synapses can explain the benefits of sleep on memory acquisition and consolidation, as energy is saved when counteracting the network effects of synaptic excitation and increased neuronal activity following wake periods."

17. A cited study[45] concluded that "the coding of new images is compromised after a night of slight SD, which reduces the slow wave activity, exclusive of lessening total SD."

18. A cited study concludes that "sleep deprivation can diminish the active process of the glymphatic system, leading to toxin build-up which can negatively affect the cognitive performance, motor functions and behavioral patterns."

19. A study[51] measuring via a PET scan the amount of amyloid-beta in mice through standard sleep and sleep deprivation found that, in a one-night comparison, there was a "significant increase in the beta-amyloid levels in the thalamus and the hippocampus of the mice, demonstrating in vivo evidence of the effects of sleep deprivation on recognized neurodegenerative processes."

20. Khan and Al-Jahdali conclude that "The adverse consequences of SD are evident on overall behaviour and cognitive performance." More specifically, due to "fluctuations in the

thalamic activity, synaptic renormalization, glymphatic system roles, DMN activity, amygdala activity and hippocampal activity," unequal stimulation in the brain occurs, leading to irregular brain activity. As a result, "an impairment in attentiveness, working memory, consolidation of memories, alertness, judgment, decision-making, and many other diminished cognitive performances will follow."

21. Despite the lack of conclusive evidence regarding "the exact mechanisms and subsequent effects of SD," Khan and Al-Jahdali conclude that "evidence provide proof that regardless of health, receiving inadequate sleep daily or for multiple days causes the body's systems to gradually decline."

Contrasting

1. Study[7] "used a debatable single assessment procedure of moral judgment, which can limit the generalizability of the results." (Khan & Al-Jahdali, 2023)

2. A study claimed that "short-term SD does not selectively affect prefrontal functioning. However, all the tests carried out in this study were derived from a neuropsychological battery test created for clinical purposes, mostly to examine brain damage. The tests could have a ceiling effect, not influenced by short-term SD, and the participants were all university students."

3. While Khan and Al-Jahdali have concluded that SD can cause the decreased synthesis of certain proteins such as RbAp48, which can result in reduced memory, study[20] "did not observe the effects of SD in the mice to be able to conclude whether sleep is the main cause of reduced memory."

4. In contrast to studies[23,24], Cirelli et al found no apparent evidence of brain cell degeneration after long-term SD in rats. Khan and Al-Jahdali assert that this indicates that "more research is required to determine the cause of the neuron degeneration."

5. In contrast to study[31], Kuhnetal[32] found that glucose levels increase in SD individuals, indicating that "further research may be required to conform the effect of the glucose levels on attention and alertness in SD individuals."

6. In contrast to study[45], Gais et al[11] "concluded through fMRI studies that declarative memory is not affected with long term SD, and Voderholzer et a[46] that long term SD does not affect long term declarative memory in adolescents."

7. In contrast to study[51], the PET scan technique could not differentiate between soluble and insoluble beta-amyloid. This limitation could impact the results, as soluble beta-amyloid is more predictive of neurodegenerative disorders such as Alzheimer's disease than insoluble beta-amyloid (Khan & Al-Jahdali, 2023).

8. "...more research is required to conclude whether the increase of beta amyloid is indeed due to an impared glymphatic system, specifically due to sleep loss"

9. Khan and Al-Jahdali conclude that "Additional research is required to provide evidence of the validity of the exact mechanisms and subsequent effects of SD, which can be achieved with more resources, study and time."

Key Points

1. Prolonged partial sleep deprivation (SD) is more detrimental to cognitive performance than a single night of total SD (1).

2. SD affects both REM and non-REM sleep, leading to reduced cognitive function by impairing neuron excitation and neurotransmitter sensitivity (2).

3. Sleep deprivation impairs homeostatic brain functions, emotional regulation, and moral judgment, often causing increased response latencies and impaired cognition-emotion integration (5, 7).

4. Memory consolidation is disrupted during SD due to alterations in glutamatergic signaling and NMDA receptor function, impacting long-term memory storage (10, 13).

5. SD leads to inconsistent brain network activity, affecting attention and working memory, due to disruptions in the DMN and FPN, and irregular thalamic signals (27, 31).

6. Despite findings supporting the negative impact of SD on cognitive performance, several contrasting studies question the extent and mechanisms of these effects, indicating the need for further research (7, 23, 31).

7. Conflicting evidence regarding SD's effect on declarative memory, glucose levels, and neurodegenerative processes suggests the need for more comprehensive studies (45, 46, 51).

8. Overall, while there is substantial evidence of SD's adverse effects on cognitive and behavioral functions, further research is necessary to confirm the exact mechanisms and long-term consequences (1).

Sleep Duration and Executive Function in Adults (Sen & Tai, 2023)

Supporting

1. There is a quadratic relationship between sleep duration and executive function, suggesting that both short and long sleep durations are linked with poorer executive function (Sen & Tai, 2023, page 801, para. 2).

2. "A study of around 480,000 individuals, aged 38–73 years, showed that 7 h of sleep per day was associated with the highest executive function performance, using a measure derived from specific computer-based tasks of attention and working memory." (Sen & Tai, 2023, page 804, para. 6, fig. 1).

3. Sleep quality, rather than absolute duration, is crucial for maintaining executive function. Time spent in different sleep stages and sleep fragmentation correlates better with cognitive function (Sen & Tai, 2023, page 806, para. 1).

4. Poor sleep is associated with a reduced brain volume, affecting cognition. This reduction is partially reversible with interventions like CPAP therapy for sleep apnea (Sen & Tai, 2023, page 807, para. 1).

5. Diffusion tensor imaging studies show changes in brain connectivity after sleep deprivation, indicating the importance of sleep for maintaining functional brain connectivity (Sen & Tai, 2023, page 807, para. 2).

6. "A single night of sleep deprivation has been shown to affect several components of executive function such as sustained attention, reaction time, and working memory, as well as other cognitive domains of consolidation of episodic and procedural memory" (Sen & Tai, 2023, page 803, para. 3).

7. Sleep deprivation may lead to the accumulation of neurodegenerative proteins like beta-amyloid, which is linked to Alzheimer’s disease (Sen & Tai, 2023, page 807, para. 3).

8. The glymphatic system, responsible for clearing waste from the brain, is more active during sleep and may be disrupted by poor sleep (Sen & Tai, 2023, page 807, para. 4).

Contrasting

1. Some studies using actigraphy and EEG found no significant associations between total sleep time and executive function, suggesting that the quality of sleep might be a more important factor (Sen & Tai, 2023, page 805, para. 4).

2. Long sleep duration has been associated with an increased risk of dementia, but some studies did not find this link, likely because of focusing on mid-life sleep patterns (Sen & Tai, 2023, page 805, para. 2).

3. Objective sleep measures sometimes conflict with self-reported data, highlighting potential biases in self-assessment of sleep duration (Sen & Tai, 2023, page 806, para. 1).

Key Points

1. There is an optimal sleep duration for cognitive performance, with deviations in either direction leading to decreased executive function (Sen & Tai, 2023, page 804, fig. 1).

2. Sleep quality, characterized by sleep stages and fragmentation, is more indicative of cognitive health than sleep duration alone (Sen & Tai, 2023, page 806, para. 1).

3. Biological mechanisms linking sleep and cognition include brain volume changes, altered connectivity, protein accumulation, and disrupted glymphatic drainage (Sen & Tai, 2023, page 806, para. 8, fig. 2).

4. Both short and long sleep durations may predict cognitive decline and dementia, emphasizing the need for optimal sleep maintenance (Sen & Tai, 2023, page 805, para. 2).

5. Further research is needed to explore the causal relationships between sleep, cognition, with a focus on objective sleep measurements (Sen & Tai, 2023, page 808, para. 1, 3).

6. "There is consistent evidence for an optimal duration of sleep for cognitive function which is relevant to the personal health of every ageing individual." (Sen & Tai, 2023, page 808, para. 2)

The Relationship Between Cognitive Impairments and Sleep Quality Measures in Persistent Insomnia Disorder (Künstler et al., 2023)

Supporting

1. When compared to their healthy peers, "[patients with insomnia] not only had a lower overall cognitive status, but had particular difficulties in abstract thinking and clock drawing. When we compared the patients' performance to their objective sleep quality, we found that patients who fell asleep faster, spent less of the night awake, and spent longer in "dream sleep" showed better performance on the cognitive screening test."

2. Interestingly, the cognitive obstacles presented to patients with insomnia are "similar to this seen in mild cognitive impairment, a pre-stage of Alzheimer's. This supports the idea that poor sleep quality, if left untreated, can cause similar cognitive difficulties as those found in dementing diseases."

3. "Moreover, in a 22-year prospective study[30], verbal abstract reasoning was one of the strongest predictors for the development of Alzheimer's disease in the pre-clinical phase. Thus, this specific pattern of deficits observed here could be indicative of an incipient neurodegenerative process."

4. "Insomnia severity and the amount of REM-sleep are closely related to [neurocognitive deficits]" (Künstler et al., 2023)

Contrasting

1. In contrast to findings by Khan and Al-Jahdali, 2023, Smith et al., 2021 observed that "Sensorimotor speed, spatial learning and memory, working memory, abstraction and mental flexibility, emotion identification, abstract reasoning, cognitive throughput, and risk decision making were not significantly affected by sleep debt." However, Nasrini et al., 2020 reported different results, noting significant impairments due to sleep deprivation: fewer emotions were correctly identified, performance on the psychomotor vigilance test

(PVT) was slower and less accurate, and subjects exhibited increased ratings of tiredness, sleepiness, physical exhaustion, mental fatigue, poor sleep quality, and workload during sleep restriction phases in NASA's Human Exploration Research Analog (HERA).

2. Whether or not REM sleep is protective against neurodegeneration is the subject of further investigation.

Key Points

1. Healthy subjects unaffected by insomnia are statistically more proficient at a multitude of cognitive tasks, including abstract thinking, clock drawing, verbal abstract reasoning, emotion identification, psychomotor vigilance, and are likelier to report mental fatigue, poor sleep quality, workload, and tiredness.

Sleep for cognitive enhancement (Diekelmann, 2014)

Supporting

1. "Losing even a few hours of sleep can have detrimental effects on a wide variety of cognitive processes such as attention, language, reasoning, decision making, learning and memory" (Diekelmann, 2014).

2. "Sleep is known to facilitate the consolidation of memories learned before sleep as well as the acquisition of new memories to be learned after sleep" (Diekelmann, 2014).

3. "Memory processing during sleep can be boosted by (i) cueing memory reactivation during sleep; (ii) stimulating sleep-specific brain oscillations; and (iii) targeting specific neurotransmitter systems pharmacologically" (Diekelmann, 2014).

4. "Subjects who are allowed to sleep after learning typically perform better on a subsequent retrieval test than subjects who spend a comparable amount of time awake following learning" (Diekelmann, 2014).

5. "Olfactory and auditory cues can be used, for example, to increase reactivation of associated memories during post-learning sleep" (Diekelmann, 2014).

6. "Intensifying neocortical slow oscillations (the hallmark of slow wave sleep (SWS)) by electrical or auditory stimulation and modulating specific neurotransmitters such as noradrenaline and glutamate likewise facilitates memory processing during sleep" (Diekelmann, 2014).

Contrasting

1. "The practical significance of these effects [memory enhancement during sleep] is unclear... Even taking into account that [the percentage enhancement] might eventually turn out to be smaller, considering that effect sizes are typically overestimated in the first studies of a new field of research, the true effect size might still be high enough to warrant practical applications" (Diekelmann, 2014).

2. "Manipulating neurotransmitter systems to enhance memory during sleep has revealed inconsistent results... these findings should therefore be interpreted with caution" (Diekelmann, 2014).

3. "Sleep-specific manipulations have been found to effectively boost cognitive functions beyond the boundaries of the normal condition... Yet, these manipulations do not create new memories, but rather enhance the stability and resistance to forgetting of existing ones" (Diekelmann, 2014).

4. "Manipulations of memory processing during sleep can have side effects and unintended effects... It has been shown, for instance, that the reprocessing and integration of information during sleep can qualitatively change memories" (Diekelmann, 2014).

Key Points

1. "Sleep is essential for effective cognitive functioning" and its deprivation can impair various cognitive abilities, but it also has the potential to enhance cognitive performance beyond normal levels (Diekelmann, 2014).

2. Enhancing cognitive performance through sleep involves targeted manipulations such as "cueing memory reactivation during sleep," "stimulating sleep-specific brain oscillations," and "targeting specific neurotransmitter systems" (Diekelmann, 2014).

3. Ethical considerations in using sleep for cognitive enhancement are critical, as manipulations during sleep might happen without the individual’s awareness, raising concerns about autonomy and informed consent (Diekelmann, 2014).

4. "The neurochemical milieu of neurotransmitters and hormones during sleep" is intricately optimized for memory consolidation, suggesting caution in pharmacological interventions (Diekelmann, 2014).

Outline

Introduction

- Importance of sleep for cognitive functions and overall health.
- Overview of sleep stages and their roles in brain functioning.
- Thesis Statement: Examination of the impact of sleep deprivation and poor sleep quality on cognitive performance.

The Consequences of Sleep Deprivation on Cognitive Performance

Findings from Khan & Al-Jahdali (2023)

- Discussion on the effects of REM and non-REM sleep deprivation.
- Synthesis of studies showing the link between lack of sleep and reduced cognitive abilities including attention, memory, and decision-making.

Supportive Studies

- Detailed analysis of empirical data supporting the thesis.
- Impact of sleep deprivation on neurobiological functions and cognitive processes.

Contrasting Views

- Presentation of studies with differing viewpoints or results.
- Critical examination of the methodologies and conclusions of these studies.

Key Points Summary

- Summary of the main findings and their implications for cognitive health.

Sleep Duration and Executive Function in Adults (Sen & Tai, 2023)

Core Findings and Theoretical Implications

- Examination of the relationship between sleep duration and executive functioning.
- Analysis of optimal sleep durations for maintaining cognitive abilities.

Supportive and Contrasting Studies

- Review of supportive empirical evidence.
- Discussion on discrepancies and challenges in existing research.

Conclusion of Section

- Concluding remarks on how sleep duration affects executive function.

The Relationship Between Cognitive Impairments and Sleep Quality in Persistent Insomnia Disorder (Künstler et al., 2023)

Analysis of Study Findings

- Discussion on how chronic insomnia affects cognitive functions.
- Insights into the long-term cognitive impairments associated with poor sleep quality.

Sleep for Cognitive Enhancement (Diekelmann, 2014)

Overview of Cognitive Benefits of Sleep

- Review of how effective sleep enhances cognitive processes.
- Discussion on methods to enhance cognitive functions through better sleep.

Conclusion

Conclusion

- **Summary of Key Findings:** Recap the major insights derived from the study, including the critical role of sleep in cognitive function and memory consolidation. Highlight the specific impacts of REM and NREM sleep on cognitive abilities and the negative effects of sleep deprivation. Reiterate findings on the importance of sleep quality over mere duration in maintaining cognitive health.
- **Implications of Insomnia and Sleep Deprivation:** Summarize the consequences of chronic sleep deficiencies as demonstrated in insomnia patients, emphasizing the potential

for long-term cognitive decline. Discuss how these findings relate to broader concerns about public health, particularly the risks of developing neurodegenerative diseases.

- **Potential of Sleep Interventions:** Briefly revisit the discussion on enhancing memory and cognitive functions through targeted sleep interventions, such as pharmacological aids and sensory cues during sleep. Consider the implications of these interventions for both therapeutic and enhancement purposes in clinical and everyday settings.
- **Ethical Considerations:** Summarize the ethical concerns mentioned, including issues related to autonomy, informed consent, and the potential unintended consequences of manipulating sleep processes.
- **Future Research Directions:** Suggest areas for further study, such as refining sleep-based interventions for memory enhancement or exploring the long-term effects of these interventions on mental health. Emphasize the need for more comprehensive studies to understand the causal relationships between sleep patterns and cognitive functions.
- **Final Thoughts:** Stress the necessity of maintaining healthy sleep habits and the potential personal and societal benefits of improving sleep hygiene. Conclude with a call to action for both individuals and policymakers to prioritize sleep health based on the findings discussed in the paper.

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