Testing Non-Sleep Deep Rest (NSDR) protocol to counter the cognitive consequences of short sleep in young adult students

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Abstract

Traditional Eastern meditation practices have elicited profound interest in the scientific community, subjecting them to various systematic neuropsychological investigations. Western researchers have adapted meditation practices to infer causal explanations for probable psychotherapeutic benefits in both clinical and non-clinical cohorts experiencing any difficulties on the psychophysiological spectrum. Sleep deficiency is one variable which has been unequivocally established to disrupt normal human functioning by varying degrees. Student populations are especially vulnerable to the undesirable repercussions of curtailed sleep, making sleep-related problems another crucial area of inquiry. Because meditation-induced changes have been observed in the cognitive realms of attention and memory, this study evaluated the effects of the meditation-based Non-Sleep Deep Rest (NSDR) protocol, derived from the practice of Yoga Nidra, in ameliorating the cognitive consequences of short sleep in young adult students. Twenty-seven sleep-deprived university students, aged 18-25 years, were recruited to participate in an online experiment designed to understand the effect of the NSDR protocol on attention and working memory, measured using the Stroop and n-back tasks, respectively, against a Podcast listening control condition. Repeated-measured ANOVA revealed non-significant effects of the intervention on both attention (p = .092) and working memory (p = .116), rendering the results inconclusive yet instructive of respective theoretical and methodological limitations in meditation research.

Frontispiece

Note. Own work. Designed using Adobe Stock illustrations.

Dedication

To my father

and Boo Radley

and my little ones Thunder and Smookie

for all the love and pain

that I might not have endured otherwise.

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I sincerely want to thank my thesis director, Dr. Pace-Schott, for his endless support and encouragement, and my research advisor, Dr. Dante Spetter, for always keeping me on my toes and pushing me to produce the best possible work.

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Chapter I

Introduction

The prevalence of short sleep in young adults in association with its adverse physical, mental, cognitive, and academic consequences has been well documented. Biological delay in circadian rhythms combined with social factors and poor sleep habits expose university students to the risk of developing chronic sleep deprivation. However, despite a range of effective interventions aiming to improve sleep, this group continues to suffer sleep loss. While increasing total sleep time in these youth is crucial, it may be of value to assess time-efficient and accessible interventions to overcome the adverse cognitive outcomes of short sleep.

Existing Interventions for Short Sleep in Young Adults

Sleep is an indispensable, active, periodic, and reversible behavioral state that involves biological homeostatic and circadian processes critical to physical and mental health (Pace-Schott & Jones, 2015). Rest and restoration, cell repair and growth, hormone regulation, and memory consolidation are a few of the many hypothesized functions of sleep (Pace-Schott & Jones, 2015; Stickgold & Walker, 2007). Research has recognized the deleterious effect of sleep problems on people's lives, with college/university students noted as a particularly vulnerable population (Buboltz Jr et al., 2009). The recommended sleep duration for young adults, 18-25 years old, is 7-9 hours per night, but short sleep, defined as less than 6 hours per night, is prevalent among this group (Léger et al., 2011; Lu et al., 2021). In a university-based survey in Canada, 30.5% of students, aged ≤ 25 years, reported sleeping less than 6.5 hours (Brown et al., 2017). The National Sleep Foundation's poll categorized 59% of young adults as night owls who cannot fall asleep earlier and fail to compensate for their sleep deficit on the weekdays because of the requirement for an early start for classes. This suggests that short sleep is primarily due to scheduling demands and not to any underlying sleep disorders, as this group tends to sleep longer on the weekends in the absence of such demands (Gaultney, 2010). However, such compensatory behaviors worsen the problem the following week by delaying the endogenous circadian rhythm and reinforcing delayed sleep behavior which in some cases may contribute to clinical delayed sleep phase syndrome (Lack, 1986).

In discussing the high prevalence of sleep problems among young adults, Yang et al. (2003) voiced concerns about the lack of empirical studies identifying the coping strategies used by this population. Specifically, the authors explored correlations between coping strategies and subjective sleep quality using the Epworth Sleepiness Scale (ESS) and the Pittsburgh Sleep Quality Index (PSQI) in 1,922 Taiwanese college students with an average age of 18.52 years. About one-quarter of the studied sample reported having no strategy to ameliorate short sleep and daytime sleepiness. In contrast, the remaining sample reported napping as their most frequently used strategy, followed by adjusting sleep schedules, and sleep-promoting activities such as reading. Nevertheless, young adults continued to suffer from insufficient sleep and pathological daytime sleepiness, which was confirmed by the PSQI and ESS scores, suggesting the inefficacy of these strategies (Yang et al., 2003). These results highlight the need for interventions to effectively target the effects of short sleep in young adults.

The literature on sleep patterns of young adults suggests multiple factors that correlate with and contribute to short sleep. These include significant transitions that many young adults experience when starting their university lives – leaving home, independence from parental control, new peer groups and social situations, academic challenges, and relatively easy access to alcohol and other substances (Taylor et al., 2012). Among the 90% of university students who have roommates, as many as 41% are awoken at night by noise from their roommates (Schlarb et al., 2017). Adverse sleep outcomes, specifically delayed sleep onset and shortened sleep duration, are also associated with late-night screen usage, which is nearly ubiquitous whether students are working on school work or watching videos or playing games in the hour or so before attempting to sleep (Ban & Lee, 2001; Hale & Guan, 2014). These factors are compounded by poor sleep hygiene practices due to a lack of sleep knowledge and attitudes towards sleep (Semsarian et al., 2021).

Young adults getting insufficient sleep are increasingly susceptible to its physical, mental, and cognitive consequences (Gao et al., 2019; Gau et al., 2007; Guo et al., 2022). Research indicates an association between short sleep and several comorbidities, including feelings of fatigue, high perceived stress, depressive symptoms, and suicidal ideation among this group (Carpi et al., 2022; Léger et al., 2011; Li et al., 2020; Littlewood et al., 2019; Pilcher et al., 1997). However, despite these adverse outcomes, university students tend to sacrifice sleep in order to attain higher academic achievement, even though this negatively impacts their actual academic performance (Brown et al., 2017; Yang et al., 2003). For example, university students who experienced delayed sleep onset, potentially contributing to a mild form of delayed sleep phase syndrome, a circadian misalignment delaying sleep beyond the conventional bedtime, had difficulty with early rising, failed to get sufficient sleep, experienced excessive daytime sleepiness, and had lower academic performance as a consequence (Lack, 1986). Further, sleep deprivation degrades memory encoding and retention, the fundamental cognitive processes critical for learning (Stickgold & Walker, 2007). Sleep deficiency also affects academic tasks demanding sustained attention (Lack, 1986). Moreover, recent findings have shown an impairment in procedural and declarative memory following sleep deprivation (Curcio et al., 2006).

In recognizing sleep problems and the consequent cognitive impairments among young adults, Semsarian et al. (2021) evaluated the effectiveness of an online 10-week course on improving sleep-related problems in 379 undergraduate students at the University of Sydney. The course covered an introduction to sleep and circadian rhythms, sleep deprivation, jetlag, shift work, measurement of sleep and circadian rhythms, sleep hygiene and insomnia, and other common sleep and circadian disorders. Although sleep knowledge and habits improved, there was no meaningful change in the percentage of students considered to be getting insufficient sleep, as indicated by the total PSQI scores at a 6-month follow-up. Of the PSQI subcomponents, waketimes shifted earlier and 5% of the sample showed an improvement in sleep latency (<15 mins). However, the remaining subcomponents, including sleep duration and quality, remained unchanged (Semsarian et al., 2021). One implication of these findings is that despite having sleep knowledge, sleep loss continues to persist in young adults, which may result in impairments in neurocognitive variables crucial to academic performance, such as declarative learning, attention, and memory. Therefore, for the college student population, it is imperative to specifically target adverse cognitive outcomes of insufficient sleep in addition to continued efforts to deliver interventions to improve sleep quantity and quality.

Taking this approach, Fleckenstein et al. (2022) studied the effects of a single bout of exercise on the cognitive performance of young adults following sleep deprivation. Twenty-two university students, aged 18-36 years, in the field of sports sciences, wherein daily physical training of at least 2-3 hours is required, were recruited for participation in the research. To ensure sleep deprivation, the participants watched movies, engaged in conversations, and played cards and board games at the research center. The following morning, participants were randomly assigned to either the exercise group, which had to exercise for 20 minutes at the gym, or the control group, which had to remain seated. Cognitive measures included memory and attention. Memory was tested using 18 word lists, each containing 15 semantically related words, which the participants had to memorize prior to sleep deprivation and retrieve following the intervention. Attention was tested using the d2 attention task, which measures selective and sustained attention, and visual scanning speed (Brickenkamp, 1962). Results indicated no memory performance differences between the two groups. However, attention scores improved by 17.22 ± 15.21% on average in the exercise group compared to 3.53 ± 20.57% in the control group, suggesting a strong preventive effect ($d = 0.76$) of exercise on executive cognitive functions in young adults following sleep deprivation. Although the results could be considered clinically relevant, there are a number of caveats concerning the generalizability of the intervention. First, only sports sciences students were included in the sample and, given their consistent training regime, it cannot be established whether the measured cognitive benefits were due to the single exercise bout or to the cumulative effects of their regular training programs. Second, people with physical disabilities cannot benefit from such an exercise intervention. Third, cognitive variables were tested immediately after the intervention and it remains unknown how long the effects last following the intervention. Although these findings are intriguing, all young adults might not be ready to begin such a regime to counter the cognitive consequences of short sleep, suggesting the importance of testing and implementing interventions that do not require prior training or experience.

The last decade has seen a surge of interventions delivered through the internet as self-help tools, collectively referred to as internet-delivered Cognitive Behavior Therapy (iCBT). Such interventions attempt to replicate the classical technique of Cognitive Behavior Therapy in an online format to target various psychological/behavioral problems, of which sleep is one (Werner-Seidler et al., 2018). In a randomized controlled trial, Morris et al. (2016) tested the efficacy of 6-week long internet-delivered CBT (iCBT) interventions to improve sleep quality and anxiety in 91 healthy students, aged 20.5 years on average, compared to a waitlist control group. The iCBT module for sleep included psychoeducation, guided imagery, relaxation techniques, sleep hygiene, and progressive muscle relaxation. Post-intervention PSQI scores improved from 6.95 to 5.76, showing a moderate effect size. Although effective in improving sleep quality, the intervention did not test changes in sleep duration and concomitant cognitive impairments, which continue to be prevalent in young adults. Despite these limitations, research has proven CBT to be the most effective approach for sleep-related problems in healthy adult student populations with large effect sizes in all outcome sleep variables, especially short sleep (Friedrich & Schlarb, 2017).

In conclusion, empirical evidence confirms the existence of short sleep among college/university students. Though a relatively new area of inquiry, scientific investigations have progressed from merely understanding the coping strategies employed by students to testing various interventions, such as online training courses to enhance sleep knowledge, exercise to counter the effects of acute sleep deprivation, CBT to improve sleep quality, and mindfulness and relaxation therapies for sleep-related variables, with effect sizes varying from small to medium to large (Fleckenstein et al., 2022; Friedrich & Schlarb, 2017; Morris et al., 2016; Semsarian et al., 2021; Yang et al., 2003). While CBT proves to be the most effective treatment even for non-clinical sleep-related problems, owing to its large effect size, it still does not provide the means to counter the cognitive consequences of acute short sleep. Moreover, it is also important to consider inherent financial stipulations, the need for trained personnel, and time commitment, which render its utilization rather limited. Therefore, it is imperative to subject CBT to a comparative analysis with interventions that might overcome its aforementioned constraints and be prescribed as effective techniques to counter sleep-related problems, especially short sleep duration in young adults, which is the main focus of the proposed study. One such possibility underpins a recent line of research that applies the meditative practice of Yoga Nidra, the findings of which are analyzed below.

Yoga Nidra Intervention

Traditional literature defines Yoga Nidra as a meditative practice used by yogis to induce a sleep state while maintaining awareness of the environment (Datta et al., 2022;

Parker, 2017). It is performed in several steps that include preparation, focusing attention on various parts of the body, awareness of breath, feeling, visualization, and concluding the practice (Datta et al., 2022). Unlike standard yoga practices, Yoga Nidra does not require movement in difficult postures but can be performed in a supine position with closed eyes and by following guidelines delivered through an audio recording (Datta et al., 2021). Yoga Nidra has been a subject of empirical investigation since the 1970s when a yogi, Swami Rama, arrived in the United States to participate in an experiment in a psychiatric institute. While demonstrating control over various physiological processes, he also showed entrance into a delta wave state during Yoga Nidra meditation (Green & Green, 1977). Delta wave state is the physiological state of the brain at a frequency between 0.5-4.0 Hz, that becomes dominant in the EEG during deeper non-REM sleep (Pace-Schott, 2009; Parker, 2019). Surprisingly, Swami Rama simultaneously remained aware of his surroundings, which was verified when he recounted the lab technicians' conversation verbatim. These findings on Yoga Nidra were later replicated by experimentation on Swami Rama's disciple, Swami Veda (Parker, 2017, 2019).

Based on the initial empirical evidence, Yoga Nidra is described as conscious entry into non-REM sleep (Parker, 2017). Neurologically, it is characterized by four levels of depth or stages that correspond to various sleep stages (Parker et al., 2013). Stage one is evidenced by alpha waves (8-13 Hz) which indicate relaxation; stage two demonstrates theta waves (4-8 Hz) correlated with dreams, hypnogogic imagery, creativity, decision making, and problem solving; stage three corresponds to further slowing down of brain waves to delta rhythm (0.5-4.0 Hz) which parallels deep non-REM sleep but with an awareness of the environment; stage four is achieved upon mastery of the previous three levels during which the practitioner maintains sleep and conscious awareness simultaneously, and brain waves may alternate between theta and delta rhythms. Stages one and two are preliminary relaxation stages that are a precursor to Yoga Nidra, whereas stage three is a state of Yoga Nidra proper (Parker et al., 2013).

The research evidence discussed above is based on case studies that lacked matched control subjects; therefore, the results could not be generalized statistically and were never published in peer-reviewed journals, most likely due to prevailing skepticism and critique surrounding such spiritual practices (Parker, 2019). Going beyond the previous single-subject design, Lou et al. (1999) examined the neural correlates of Yoga Nidra compared to the normal resting state, using a within-subjects design, in nine experienced practitioners. Consistent brain activity was observed during meditation and relaxation which was measured using positron emission tomography (PET) and electroencephalography (EEG). However, the production of delta waves while retaining conscious awareness, which is a characteristic feature of Yoga Nidra proper, was not observed in the relaxation condition. Similarly, in another study, 40 trained Yoga Nidra students were subjected to an EEG and galvanic skin response analysis (Kumar & Joshi, 2009). During the practice, participants' brain waves gradually transitioned to an alpha rhythm, indicating a state of relaxation prior to the formation of slow delta waves. These findings imply that in the absence of delta waves the state referred to as Yoga Nidra in contemporary research is actually a level preliminary to it and cannot be characterized as a true Yoga Nidra state (Parker et al., 2013). However, since the initial findings were based on case studies, the subjects may have been atypical in their EEG brain activity, or the findings were possibly mistaken in detecting delta waves. These divergent results question the operational definition of Yoga Nidra and the experimental evidence based on imprecise assumptions. However, despite these hairsplitting arguments, several studies have utilized Yoga Nidra to establish its efficacy in relation to the abovementioned psychological variables, irrespective of the evidence of the type of brain waves.

Kohler et al. (2017) studied the effect of Yoga Nidra meditation in reducing attention deficits following sleep loss. Participants completed a 21-day training period after which they were sleep restricted for one night between 2-7 am, which was confirmed by actigraphy scores. Sleep restriction was ensured by phone calls from the research team at 1:45 am and 7:15 am. On awakening, they showed symptoms of sleepiness, fatigue, and attention impairment, which were measured in the laboratory as baseline parameters before their 30-minute Yoga Nidra session following the night of sleep deprivation. After the session, sustained attention scores on response speed (effect size = 0.54), reaction time (effect size = 0.46), and lapses (effect size = 0.45) improved compared to the baseline, concluding that this meditation can improve sleep loss related attention deficits. Similar improvements were not observed in the control group that listened to an audiobook (Kohler et al., 2017). However, there are several factors that may limit the generalizability of these results. These include the small sample of ten participants, limiting participation to those who reported no ongoing sleep problems, requiring a commitment to a rather lengthy training program, long meditation duration of 30 minutes, and a lack of estimation of the duration of the observed effects. Based on these limitations, it is unclear whether similar effects will be observed in a larger sample, or a sample already experiencing sleep problems, as noted in university students. It would also be helpful to investigate the effectiveness of a shorter meditation session without the extensive training requirement. These are some of the unanswered questions that the current research aims to examine.

Several studies address some of these limitations. Recent longitudinal research by Datta et al. (2021) investigated 41 participants, aged 25-60 years, suffering from chronic insomnia and tested the efficacy of Yoga Nidra meditation compared to conventional CBT for insomnia (CBT-I) using both subjective and objective measures. Self-report parameters included the use of a sleep diary, logging various sleep-related parameters, and retrospective self-report questionnaires – Pittsburg Sleep Quality Index (PSQI), Epsworth Sleepiness Scale (ESS), Insomnia Severity Index (ISI), Depression Anxiety Stress Scale (DASS), and Pre-Sleep Arousal Scale (PSAS). Objective sleep-related parameters were recorded during overnight polysomnography. Moreover, to determine the comparative effect of the interventions on stress, salivary cortisol samples were also examined. Polysomnography results indicated a mild improvement in total sleep time (Cohen's d = 0.28) and a reduction in total wake duration during the night (Cohen's d = 0.29) following both interventions. Yoga Nidra intervention also showed a moderate effect on total sleep time (Cohen's d = 0.69), sleep efficiency (Cohen's d = 1.16), and subjective sleep quality (Datta et al., 2021).

Drawing on these findings, the research was later extended to understand the neurophysiological correlates of Yoga Nidra in 30 healthy volunteers, aged 18-60 years, after two weeks of practice (Datta et al., 2022). Despite no electrophysiological evidence of sleep, marked alternations were still noted in the EEG during Yoga Nidra session compared to baseline in the central and parietal brain regions, dominated by slow-wave EEG, which is a marker of local sleep. The idea underlying local sleep is that small brain regions or networks can be locally asleep during behavioral wakefulness and localized brain regions or networks can show wake-like activity during behavioral sleep (Rattenborg et al., 2012). Local sleep has been studied in association with learning tasks such that local sleep in regions engaged by the task showed greater SWA following task performance, which in turn improves task performance after sleep (Huber et al., 2004). These findings on local sleep and the evidence of local sleep during Yoga Nidra have important implications for students, wherein their cognitive performance may be improved in tasks requiring attention and working memory.

Taken together, the results from Datta et al. (2021, 2022) have important implications. Yoga Nidra can be supplemented with CBT-I to improve sleep variables in persons getting insufficient sleep. Moreover, the evidence of local sleep during Yoga Nidra and its role in learning may establish it as a viable intervention, particularly for university/college students exhibiting delayed sleep behavior and experiencing reduced total sleep time. However, it is important to note that these studies recruited participants suffering from chronic insomnia; similar benefits of Yoga Nidra in a healthy sample with higher cognitive demands, for example, students, are yet to be established. These implications make Yoga Nidra an important area of inquiry in the student population to counter cognitive consequences of short sleep duration, which is the premise of the proposed research.

Conclusion

Putting it all together, sleep problems negatively impact university students who frequently fail to get recommended amounts of daily sleep. As discussed above, they get insufficient sleep for multiple reasons, including delayed sleep phase, academic demands which require staying up late to study and early starts to the day, sharing with roommates leading to more frequent mid-sleep awakening, daytime napping, and use of substances that interfere with sleep including alcohol and caffeine. Combined, these factors contribute to bringing about sleep problems associated with cognitive deficits affecting attention, memory, and learning ability, to name a few. CBT-I continues to show promising results in addressing these sleep problems. However, due to the requirements of trained personnel, time, and financial constraints, it remains underutilized. In light of these limitations, meditation-based interventions, such as Yoga Nidra, have started to emerge. Extant research on Yoga Nidra has focused on its comparative benefits in both clinical and non-clinical populations. While its benefits complementing CBT-I have been established, few attempts have been made to investigate its role in countering the adverse cognitive effects of short sleep.

Research Aim and Hypotheses

In light of existing literature on sleep problems and the consequent cognitive issues experienced by university students, this study is aimed at combining these findings with meditation-based studies that have utilized a shorter version of Yoga Nidra to analyze its effectiveness on psychological parameters (e.g. Moszeik et al., 2022). Specifically, this research explored the following hypotheses:

Hypothesis 1

A short, 10-minute, Yoga Nidra meditation will counter the effects of reduced total sleep time, defined as less than 6 hours per day, and lead to short-term positive cognitive outcomes in attention performance in healthy adult students.

Hypothesis 2

A short, 10-minute, Yoga Nidra meditation will counter the effects of reduced total sleep time, defined as less than 6 hours per day, and lead to short-term positive cognitive outcomes in working memory performance in healthy adult students.

Chapter II

Method

The study was conducted online using questionnaires, administered via Qualtrics, and cognitive experiments, administered via the PsyToolkit platform during the Zoom curated experiment sessions. An *a priori* power analysis was conducted using a statistical software, G*Power 3.1 (Faul et al., 2007, 2009). The input parameters for repeated measures, within-between interaction, ANOVA, were defined as the effect size of 0.25, power of 0.8, an alpha of 0.05, a correlation among repeated measures of 0.5, and non-sphericity correction (ε) of 1, using two groups and two measurements. The analysis yielded an output of the target sample size of 34. 54 participants took the pre-screening and 28 were qualified to participate in the study. Participants who were getting short sleep, defined as less than 6 hours per day, were enrolled in the study. Participants with experience in meditation-based practices within the last six months were excluded. Participants with a sleep disorder, history of smoking, use of sleeping pills, and substance use were also excluded from participation. Qualifying participants filled the consent form and the Pittsburgh Sleep Quality Index (PSQI). All study procedures were approved by the Harvard Committee on the Use of Human Subjects and performed according to the relevant guidelines and data safety protocol (see Appendix A).

Participants

A total of 27 participants – 26 females and 1 male – completed the research protocol. From the enrolled sample of 28 participants, one was excluded for repeatedly failing to attend the scheduled meetings and rescheduling requests. The average age of the included sample was 20.67 (SD = 1.57). All participants were enrolled in undergraduate degree programs (Psychology = 25, Economics = 1, Biosciences = 1).

Measures

The research protocol consisted of measures to record sleep patterns, audio recordings to administer the experimental and control conditions of Non-Sleep Deep Rest (NSDR) and Podcast, respectively, and cognitive assessments for attention and working memory performance.

Measures of Sleep Patterns

The following two instruments were used to measure various sleep parameters. Data for the Pittsburgh Sleep Quality Index (PSQI) was collected after obtaining consent from the participants. The Consensus Sleep Diary (CSD-M) was required to be completed for a period of two weeks by the participants enrolled in the study.

Pittsburgh Sleep Quality Index (PSQI). The Pittsburgh Sleep Quality Index (PSQI), developed by Buysse et al. (1989), is a 19-item self-report questionnaire that assesses sleep quality over a 1-month period. Its seven components include subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. It takes 5-10 minutes to complete and 5 minutes to score. The seven component scores range from 0-3 on a Likert-type scale and are combined to generate a global score ranging from 0-21 points (Buysse et al., 1989). The study did not use any component scores separately. A global score, summing up the seven component scores, with a cutoff > 5 for probable sleep disturbance, was calculated for the analyses. Also, questions regarding sleep pathologies, to be answered by a bed partner or roommate, were also excluded from the instrument since they did not include the variables of interest for the study. The PSQI is a reliable (Cronbach's $\alpha = 0.83$) and valid index with sensitivity of 89.6% and specificity of 86.5% in identifying patients and controls (Buysse et al., 1989).

Consensus Sleep Diary (CSD-M). The Consensus Sleep Diary (CSD) is a standardized instrument developed by insomnia experts to collect self-reported data on habitual sleep patterns over a period of time (Carney et al., 2012). The expanded version of the CSD to be filled upon awakening, within one hour of getting out of bed, in the morning (CSD-M) was used in the study. Sleep parameters in the CSD-M included 10 items: (a) bedtime, (b) time at which the participant tried to fall asleep, (c) sleep onset latency, (d) total number of awakenings during the night, (e) total duration of awakenings, (f) time of final awakening, (g) time spent in bed after final awakening, (h) premature awakening (yes or no), (i) final rise time, (j) total sleep time, (k) sleep quality (5-point Likert scale ranging 1 = Very good – 5 = Very poor), and (l) restedness (5-point Likert scale ranging (1 = Very well-rested – 5 = Not at all rested). Additional items regarding napping, alcohol/caffeine consumption, and medication use were not included. CSD-M was formatted as a fillable PDF form with general and item-specific instructions in the beginning, followed by a page to record one week of sleep data. Additionally, an optional "notes" page was provided at the end to let participants record any other subjective aspects of their sleep.

Although CSD is prevalent in various research and clinical settings, its validity and reliability remains to be established (Carney et al., 2012).

Intervention Audios

Audio recordings for the experimental and control conditions were uploaded on a YouTube channel specifically created to conduct the experiment (NSDR Research Experiment, n.d.). To eliminate possible distractions during both the conditions, pre-existing video content was deleted and a static visual displaying the image of the speaker and the title of the content was presented throughout the length of the audios.

Non-Sleep Deep Rest (NSDR) Protocol Audio. Non-Sleep Deep Rest (NSDR) protocol, introduced by Andrew Huberman, is a nervous system relaxation tool based on the traditional practice of Yoga Nidra (Huberman, 2023). An audio recording of a 10-minute guided NSDR protocol, developed by Huberman for Virtusan App (2022), was used as an intervention in this study. The audio starts with a brief introduction to the NSDR protocol and explains how specific forms of breathing bring the nervous system into a deep relaxation state by slowing down the heart rate. The subjects are instructed to adopt a seated or supine position with closed eyes, after which they are directed to focus their attention on various parts of the body. Throughout the practice, the subjects are expected to breathe normally unless instructed otherwise. The protocol ends by asking the subjects to open their eyes and observe their perceptions. The length of this NSDR protocol is in line with experiments that have studied the effects of brief meditation on attention and memory in non-experienced meditators (Basso et al., 2019; Moore et al., 2012).

Podcast Audio. An audio recording of a podcast was used as a control condition in this study. The podcast was taken from the Huberman Lab series and reduced to an approximate length of 10-minute section to match the time duration of the NSDR protocol audio (Huberman, 2021). This podcast series discusses science-based tools to optimize physical and mental health. Podcast listening has been used as a control in previous experiments to establish differences between meditators and non-meditators in their cognitive performance (Basso et al., 2019). It serves as an appropriate control because, as with guided meditation, it requires active engagement and attention to the audio content and does not require any prior training or supervision.

Cognitive Assessments

Psychological assessments – Stroop Color and Word Task (SCWT) and n-back – were conducted using an internet-based, open-access tool, PsyToolkit, developed by Gijsbert Stoet to conduct and analyze surveys and psychological experiments (Stoet, 2010, 2017). PsyToolkit was chosen to overcome any inherent financial constraints, administrative issues, scheduling limitations, and unavailability of a laboratory space. Notwithstanding these limitations, research has demonstrated online experimentation as having increased ecological validity wherein participants' behavior in an experiment closely resembles their natural behavior since they are in their familiar space, which may result in more authentic responses (Kim et al., 2019; Reips, 2002). Additional advantages of internet-based experimentation include a reduction in cost, time, inconvenience, demand characteristics and experimenter effects, and high statistical power owing to a convenient access to a large and diverse sample (Horton et al., 2011; Reips, 2002).

Using PsyToolkit for this study is supported by research that tested it in comparison to a commonly used laboratory-based tool, E-Prime 3.0, using complex response choice and reaction time experiments. The results indicated high replicability between PsyToolkit and E-Prime, establishing PsyToolkit as a practicable method for conducting psychological experiments involving reaction time tasks (Kim et al., 2019). Consistent with these findings, comparable results between lab- and internet-based studies have been documented in memory bias, Stroop effect, perceptual tasks, music cognition, and working memory capacity in relation to cannabidiol consumption (Armitage & Eerola, 2020; Germine et al., 2012; Giraudier et al., 2022; Jones & Vlachou, 2021; Linnman et al., 2006). PsyToolkit offers both a Linux-based local installation and a browser-based online version. Experimental data for this study was collected using a browser-based version for both the SCWT and n-Back. Since the online version fully loads the experiment into the participant's browser first, response times were not influenced by the internet speed (Stoet, 2010, 2017). Furthermore, both tasks, though available in the PsyToolkit experiment library, required modification to make instructions easily comprehensible, to eliminate detailed intermediate feedback after each block, and to change the number of trials and blocks to match the number defined for the study. Instruction modification and feedback elimination was achieved by designing new bitmaps for the study using graphics software, Adobe Photoshop, whereas the experiments were altered using the PsyToolkit scripting language. The experiment was designed to run in full screen resolution.

<u>Stroop Color and Word Task (SCWT).</u> The Stroop Color and Word Task (SCWT), originally introduced by Stroop (1935), is a neuropsychological test used experimentally to evaluate attention and the ability to inhibit cognitive interference. Research also suggests its use in assessing cognitive flexibility, processing speed, and working memory (Scarpina & Tagini, 2017). In the SCWT, stimuli words, for example, "RED,"

“GREEN,” “PURPLE,” or “YELLOW,” are sequentially presented to a subject in either congruent (for example, the word “YELLOW” presented in yellow ink) or incongruent (for example, the word “YELLOW” presented in green ink) trials. If there is incongruence, it creates a Stroop effect, which is the delay in reaction time resulting from inhibiting the automated response of reading the presented word instead of indicating its color (Scarpina & Tagini, 2017). Since several versions of the SCWT are available, validity and reliability indicators of this particular computerized version have not been adequately established.

The online version of the SCWT adapted from Moore et al. (2012) was used in the study to measure attention. The task consisted of a training block of 10 trials followed by 144 experimental trials split into three equal blocks of 48 trials, with 108 congruent and 36 incongruent conditions. Participants were supposed to press keys “r”, “g”, “b”, and “y” to indicate the color. The description of the task and the required keys were explained through the instructions embedded in the experiment. First, a fixation sign (+) was presented for 200ms; then, after a delay of 100ms, the color stimulus – “RED”, “GREEN”, “BLUE”, or “YELLOW” – was presented to which the participants needed to respond within 2000ms; lastly, feedback showing “RIGHT” or “WRONG” was presented and removed within 500ms, indicating the end of one trail. At the end of the block, participants were shown their Stroop Effect in milliseconds. Any additional intermediate feedback about the total accuracy score and the total reaction time in each condition was eliminated from the experimental design. Participants were supposed to proceed to the next block via key press. This SCWT version took approximately 5 minutes to complete, with 1.7 minutes per block. The final score in the SCWT, the Stroop Effect in milliseconds, was calculated by subtracting the mean difference in reaction time between incongruent and congruent conditions in correctly answered trials.

N-Back Task. The n-back task, developed by Kirchner (1958), is used in experiments to assess individual differences in working memory capacity. In the computerized n-back task, stimuli consisting of letters are presented to the subject sequentially for 500ms each. Then, the subject is given an additional 2500ms to indicate by pressing a key whether the target stimulus matches the one presented n spaces prior in the sequence. Some studies include several blocks of n-back trials, with n = 0, 1, 2, or 3, containing 30 + n random-letters stimuli, that are presented in random order. There is a short break of 10-20 seconds at the end of each block. The task increases in difficulty with increasing values of n and takes approximately 20 minutes to complete (e.g., Basso et al., 2019; Braver et al., 1997). Others have utilized an abbreviated version of the n-back task with approximately 75 trials split between 3 blocks (e.g., Hancevich et al., 2022; Jones & Vlachou, 2021; Riquelme et al., 2016; Wolff et al., 2023a, 2023b). Although the n-back task has sub-optimal validity and reliability, it remains useful in predicting inter-individual differences in working memory research. (Jaeggi et al., 2010; Kane et al., 2007).

In line with the shortened versions, an online implementation of the n = 2-back task with 75 trials, split equally between 3 blocks, was used in this study. The task started with a training block with 15 trials followed by 75 experimental trials. The stimuli consisting of 15 alphabet letters – A, B, C, D, E, H, I, K, L, M, O, P, R, S, and T – were presented randomly for 500ms followed by 2500ms of blank screen. Participants had 3000ms to respond using the “m” key in case the presented letter matched with the one presented two trials ago; no key press was required if the presented letter was a mismatch. Task description and instructions on how to respond to the stimuli were presented at the beginning of the training block. Correct responses were indicated with a green border around the letter and the incorrect responses, false alarm, and missed responses, were indicated with a red border around the letter. No intermediate feedback about accuracy or reaction time was provided upon block completion and the participants were simply instructed to proceed to the next block via keypress. This n-back version took approximately 8 minutes to complete, with 2.5 minutes per block. The trials were scored as 0 = incorrect or 1 = correct and the total score indicated the number of correct trials across all blocks.

Procedure

The study was completed in four phases – initial data collection, introductory sessions, experiment sessions, and data cleaning.

Initial Data Collection

The study was advertised to students enrolled in a degree program at COMSATS University Islamabad (CUI), Pakistan, through noticeboard announcements. The recruitment flyer mentioned study objective, inclusion and exclusion criteria, research activities, and information about participation compensation (see Appendix B). The pre-screening form, linked in the study advertisement through a Qualtrics QR code, briefly described the research purpose, a list of all the research activities and their duration, and the voluntary nature of participation (see Appendix C). Participants were screened according to the inclusion and exclusion criteria by embedding screening conditions in the pre-screening survey in Qualtrics. The only demographic question included was regarding age since the age range of the target sample of young adults was defined between 18-25 years. Interested participants who failed to meet the study criteria were informed about disqualification at the end of pre-screening and were not asked for any personally identifying information, whereas participants who met the criteria submitted their names, gender, contact number, and email address. Next, qualified participants were redirected to the consent form which included detailed study information and a sequential breakdown of all research activities along with the anticipated duration of those activities (see Appendix D). Lastly, they filled out the linked PSQI which recorded their sleep-related data (see Appendix E).

Introductory Sessions

Participants were contacted in order of their pre-screening completion and scheduled for the introductory session (S0). Consent and the PSQI data of all participants was checked for completion before S0 meetings. It appeared that several participants had closed the pre-screening survey after completion and did not proceed to consent or fill out the PSQI. Separate links were generated for the missed data and shared with those participants before their corresponding S0 meetings. S0 was scheduled for 30 minutes according to each participant's availability. During the session, the consent form was discussed and the participants were given opportunity to ask any study-related questions. All participants were given a detailed explanation of all the research activities and the required time commitment. Participants were also provided demo PsyToolkit links to the SCWT and n-back for familiarity and practice. Lastly, participants were shown the sleep diary via screenshare to demonstrate data entry and were emailed week 1 of the sleep diary tagged with their unique research participation number (see Appendix E).

Experiment Sessions

Participants who completed S0 meetings were sent available slots for experiment session 1 (S1). All experiment sessions were scheduled between 4:45 PM – 8:45 PM for the duration of one hour from Monday to Friday, with 45 minutes experiment duration and a 15-minute margin to accommodate any technical difficulties. One participant was unavailable during the weekdays and was accommodated on weekends. All participants were reminded about their sleep diary submission before S1. Reminders for S1 along with the technical requirements were also shared one day before their respective scheduled sessions (see Appendix G). Technical requirements included availability of a laptop/computer, since the designed tests were not supported by touchscreens, and optional headphones to listen to the intervention audios. Participants were also instructed to attend sessions preferably in a distraction-free environment. To facilitate maximum comfort, there was no requirement for turning the camera on during the sessions. Participants were shared a Zoom link and a final reminder one hour before their scheduled sessions.

During S1, participants were guided through the three-step process of the experiment session which included completing baseline assessments of attention and working memory using the SCWT and n-back, respectively, listening to the intervention audio, and repeating the cognitive assessments. A unique experiment link, tagged with the participation identification number, was generated for each participant. The experiment was setup in PsyToolkit in a way to first display research title, researcher information, brief IRB approval note, and a technical requirement for a real keyboard. Next, the participants had to click a button to start the experiment with the SCWT, followed by an optional 2-minute break, and then the n-back task. At the end of the n-back task, participants were required to click on a link to exit the experiment, which informed them about the completion of the assessments and to return to the Zoom session. Clicking the link generated a response in Qualtrics to inform the researcher of assessment completion and ensure compliance. Upon returning to Zoom, participants were provided a link to one of the experiment conditions and were instructed to listen to it in a comfortable seated or supine position with eyes closed. They were reminded of its 11-minute duration and to return to Zoom upon completion. Participants were alternately assigned to the NSDR and Podcast conditions to ensure a balanced sample in each condition. The third and last step was repeating the assessments for which the participants were provided a link again. At the end of all S1 activities, participants were asked about their experience to ascertain that they did not experience any discomfort. Lastly, the participants were emailed week 2 of CSD-M and were instructed to complete it before the final experiment session or session 2 (S2). The experiment and intervention audios were disabled after each session to prevent practice through link sharing and unwanted data recording.

A similar process was followed for S2. Participants were sent personalized updates about their completed and remaining research activities to retain their interest and participation (see Appendix H [identifiers removed]). Week 2 sleep diaries were collected before S2. Participants were counterbalanced to whichever condition – NSDR or Podcast – they hadn’t completed in S1 and the same experimental procedures were repeated. Participants who experienced any difficulties, technical or otherwise, were rescheduled at a later time. Upon completion of all research activities and confirmation of all data records, university department heads were contacted for credit compensation and acknowledgment notes were sent to the participants (see Appendix I).

The proposed protocol was modified for improvements and to accommodate for lab space limitations. The experimental design was changed from between-subjects to within-subjects to account for interindividual variability. Moreover, the initial procedure proposed to conduct experiment sessions in a university lab, at the same time of day, with a lapse of one week between S0, S1, and S2. However, the selected university did not approve the protocol requiring laboratory space and personnel, thus it was revised so that experimental sessions were conducted online via Zoom. Also, the Consensus Sleep Diary (CSD-M) was added to obtain a better assessment of participants' sleep patterns over a period of two weeks rather than an only one-time assessment using the Pittsburgh Sleep Quality Index (PSQI). The cognitive assessment, n-back, was proposed to have almost 375 trials split between 12 blocks with n = 0, 1, 2, or 3. The approximate completion time was 20 minutes, extending the entire experiment session to 1 hour 20 minutes, which was later curtailed to 3 blocks of 75 trials, with only the n = 2 condition, in light of the discussed literature and to reduce additional time demands on the participants. Lastly, a brief informal survey was conducted to glean insights about the impression of the term "Yoga Nidra" and what it entails. Based on the feedback expressive of its comprehension as either a religious practice or one involving physical movement in difficult postures, and a consequent reluctance to participate, led to change in the study title from "Yoga Nidra" to "Non-Sleep Deep Rest" protocol, the latter having a more scientific than religious connotation and thus invoking less reluctance to participation.

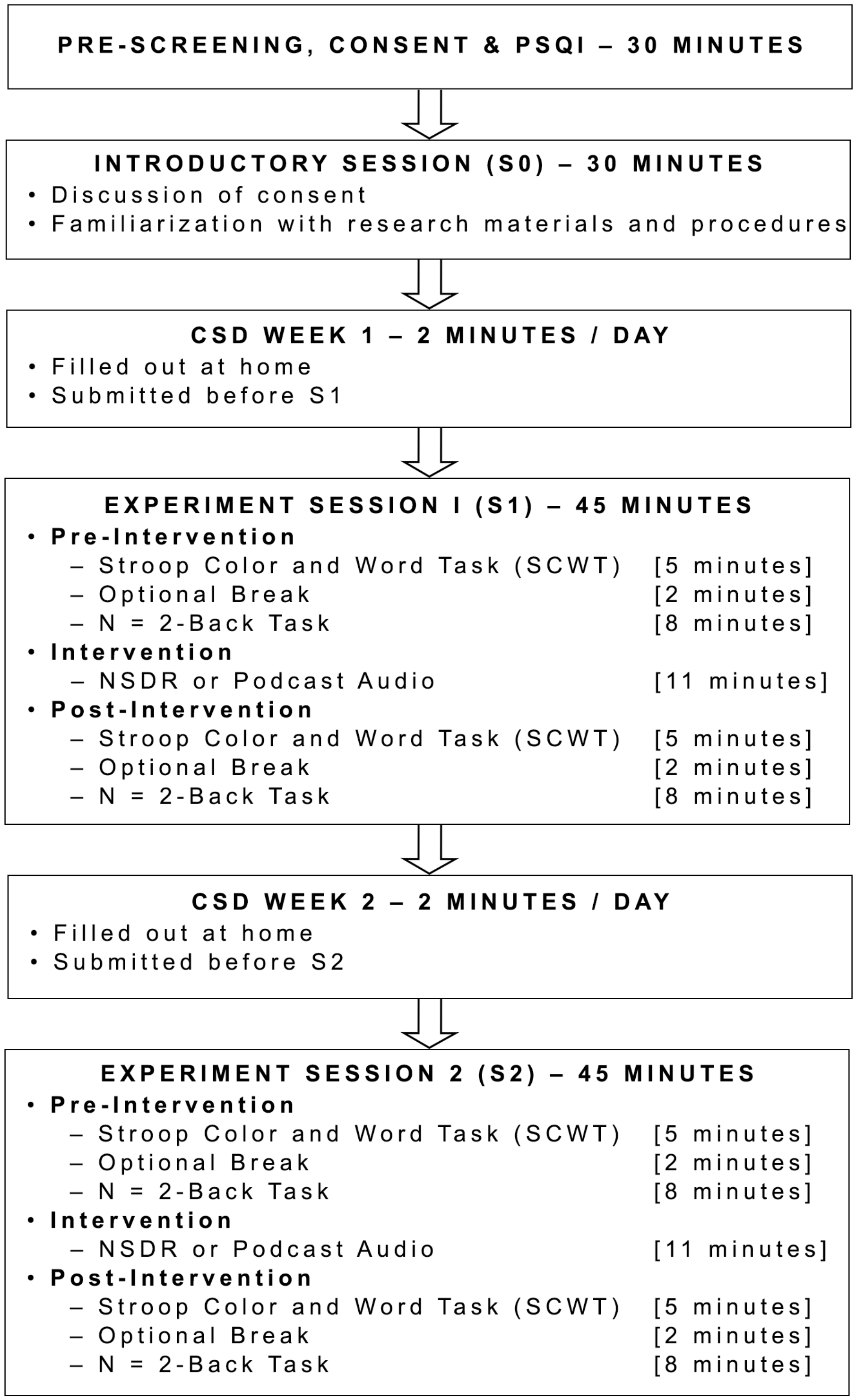

Figure 1. Research Schematic

Research protocol with temporal breakdown of research activities

Data Cleaning Protocol

The data cleaning protocol was initiated at the pre-screening stage. Security checks were embedded in Qualtrics to enable bot detection, prevent multiple submissions, and flag fraudulent responses. Such responses were excluded from the list of participants to be contacted. Missed responses on the consent form and the PSQI were identified and collected via link-share before the initiation of any research-related activities, i.e., before S0. The data from the sleep diaries was checked for completion upon submission. A close inspection of the sleep diaries at the data-entry stage revealed a few instances of duplicate responses in Likert-type questions, for example, sleep quality was rated as both poor and very poor. Such responses were flagged and were excluded at the preliminary analysis stage.

Data completion at the experiment stage was ensured by embedding a column in the output data file to indicate any missed responses. All SCWT and n-back data files were checked individually and did not reveal any incomplete responses. At the analysis stage, SCWT and n-back scores, pre- and post-intervention, were checked for outliers, defined as values outside 3 x standard deviation. One outlier in the SCWT score after the podcast condition was detected using z-scores and was replaced by the mean value of the SCWT scores.

Data Analysis

Data analysis was conducted in two stages – preliminary data analysis and main data analysis:

Preliminary Data Analysis

Preliminary data analysis involved calculation of scores for the PSQI, CSD-M, SCWT, and n-back. PSQI global score was generated by first coding and calculating the seven component scores individually and then summing them. For the CSD-M, total sleep time, sleep quality, and restedness were identified as important variables in detecting any sleep-related problems defined in the research hypothesis. Total sleep time was averaged across week 1 and week 2 separately. Sleep quality and restedness were coded and also averaged separately across week 1 and week 2. Then, the final score for these variables was calculated as a difference in mean values of week 1 and week 2, wherein positive or negative scores indicated a decrease or increase, respectively, in total sleep time, sleep quality and restedness.

Baseline and post-intervention scores for the SCWT and n-back, were calculated in RStudio embedded within the PsyToolkit platform. Training blocks for both the assessments were excluded from the analysis. For the SCWT, the Stroop effect, indicating reaction time in milliseconds, was calculated as a mean difference in reaction time between congruent and incongruent conditions across all correctly answered trials. For the n-back, score was calculated as a mean of correct responses across all trials.

Main Data Analysis

For the main analysis, global scores for the PSQI and total sleep time, sleep quality, and restedness scores for the CSD-M were defined as covariates. Separate data analyses were conducted for the two study hypotheses, followed by exploratory analyses to understand any significant effects.

Aim 1. To compare the effect of a 10-minute Yoga Nidra intervention to the Podcast control condition on attention performance in adult students, a 2 (before, after) x 2 (NSDR, podcast) within-subjects repeated-measures ANOVA, with condition order, i.e., NSDR first or podcast first, as a between-subjects factor, was conducted for the SCWT. Furthermore, to understand the effect of potentially co-varying variables – PSQI global score, CSD total sleep time, sleep quality, and restedness – on attention performance, additional analyses were conducted wherein these variables were included as covariates in the defined 2 x 2 ANOVA.

Aim 2. To compare the effect of a 10-minute Yoga Nidra intervention to the Podcast control condition on working memory performance in adult students, a 2 (before, after) x 2 (NSDR, podcast) within-subjects repeated-measures ANOVA, with condition order, i.e., NSDR first or podcast first, as a between-subjects factor, was conducted for the n-Back task. Furthermore, to understand the effect of potentially co-varying variables – PSQI global score, CSD total sleep time, sleep quality, and restedness – on working memory performance, additional analyses were conducted wherein these variables were included as covariates in the defined 2 x 2 ANOVA.

Chapter III

Results

The demographic characteristics of the final sample of 27 participants completing the study protocol are shown in Table 1. All participants reported getting less than 6 hours of sleep per day, consistent with the most crucial inclusion criteria for the study.

Table 2 shows individual component scores for the Pittsburgh Sleep Quality Index (PSQI) to illustrate the differences in various sleep parameters as reported by the study sample. Among the sample, the score ranged from 6 to 16, with a mode of 12. The frequency distribution of the Global PSQI scores is shown in Figure 2.

Table 3 shows the three components from the Consensus Sleep Diary (CSD) – total sleep time, sleep quality, and restedness – that were deemed essential to test the study hypotheses. Total sleep time was measured in hours, whereas sleep quality and restedness were rated on a 5-point Likert scale (see Chapter II Method). The three CSD sleep parameters were averaged separately for week 1 and week 2. Differences in the averaged scores across the two weeks were included in the analyses. Variation in mean total sleep time between the two weeks across the sample is illustrated in Figure 3.

After examining the sample characteristics, PSQI scores, and sleep parameters, the main study hypotheses were tested using a 2 x 2 repeated-measures ANOVA. Separate analyses were conducted to analyze the differences in the two experiment conditions, NSDR versus Podcast, on participants' attention and working memory performance.

Table 1. Sample Characteristics at Baseline

Baseline Characteristic	*n*	Age	
		M	*SD*
Gender			
Female	26	20.77	1.51
Male	1	18	
Enrollment status			
Undergraduate	27		
Graduate	0		
Other	0		
Department			
Psychology	25		
Economics	1		
Biosciences	1		
Other	0		

Note. N = 27 participants were on average 20.67 years old (SD = 1.57).

Table 2. Means and Standard Deviations of PSQI Scores

Component Scores (0 – 3)	*M*	*SD*
C1. Subjective Sleep Quality	1.63	0.63
C2. Sleep Latency	2.33	0.73
C3. Sleep Duration	2.37	0.88
C4. Habitual Sleep Efficiency	0.93	1.07
C5. Sleep Disturbances	1.67	0.55
C6. Use of Sleep Medication	0.19	0.48
C7. Daytime Dysfunction	1.81	0.83
PSQI Global [a] (0 – 21)	10.93	2.84

Note. In all cases of component scores, "0" indicates no difficulty, while "3" indicates severe difficulty.

[a] *Reflects the global PSQI score (cut-off > 5), indicating significant sleep disturbances across the sample.*

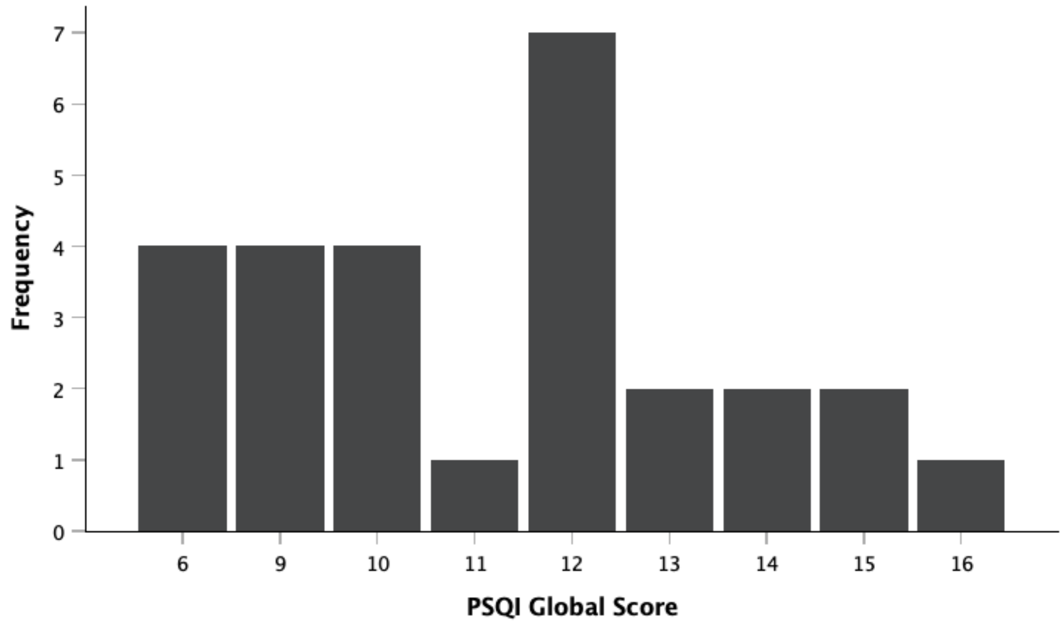

Figure 2. Distribution of the PSQI Global Scores

Table 3. Means and Standard Deviations of CSD Scores

	M	*SD*	Minimum	Maximum	Range
TST W1	5.86	1.43	3.86	8.96	5.10
TST W2	6.13	1.52	3.79	9.29	5.50
TST W1 - W2	-.27 [a]	.90	-2.02	1.23	3.25
SQ W1	2.89	.67	1.50	4.43	2.93
SQ W2	2.90	.72	1.14	4.43	3.29
SQ W1 - W2	-.01 [b]	.61	-1.12	1.14	2.26
Restedness W1	3.28	.78	1.86	4.50	2.64
Restedness W2	3.19	.71	1.57	4.57	3.00
Restedness W1 - W2	.08	.60	-1.29	1.14	2.43

Note. TST W1 = mean Week 1 Total Sleep Time, TST W2 = mean Week 2 Total Sleep Time, TST W1 - W2 = difference between TST W1 and TST W2, SQ W1 = mean Week 1 Sleep Quality score, SQ W2 = mean Week 2 Sleep Quality score, SQ W1 - W2 = difference between SQ W1 and SQ W2, Restedness W1 = mean Week 1 Restedness score, Restedness W2 = mean Week 2 Restedness score, Restedness W1 - W2 = difference between Restedness W1 and Restedness W2.

[a] *Increase in Total Sleep Time from Week 1 to Week 2.* [b] *Improvement in Sleep Quality from Week 1 to Week 2.*

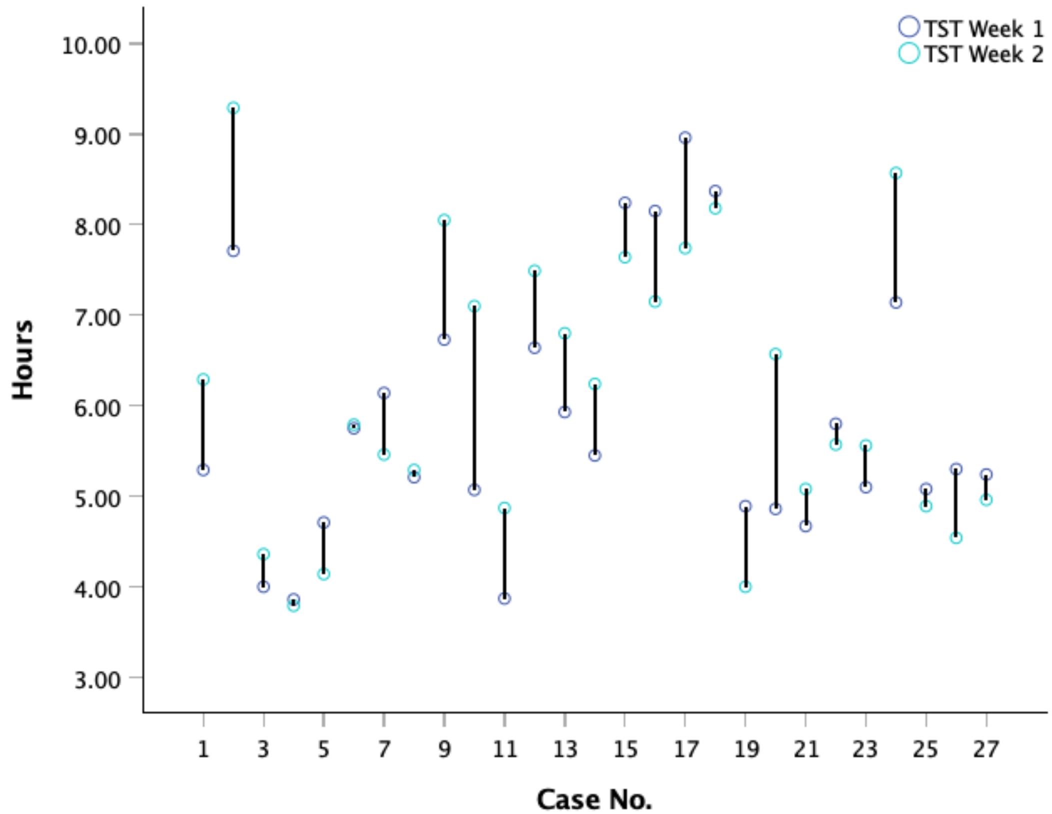

Figure 3. CSD Total Sleep Time Variation

Note. This figure demonstrates variation in mean total sleep time in hours across two weeks of the sleep diary for each participant during the study.

Effect of Interventions on Attention Performance

A 2 (NSDR, Podcast) x 2 (before, after) repeated-measures ANOVA, with intervention order (NSDR first, Podcast first) as a between-subjects factor, was conducted to examine the differences in mean attention scores, measured using the Stroop Color and Word Task, between the two interventions. Table 4 shows the within-subjects factors representing each level of the two factors. The means and standard deviations for the attention scores are represented in Table 5, wherein a higher Stroop effect indicates a reduction and a lower Stroop effect indicates an improvement in attention performance.

There was an improvement in attention performance after the NSDR intervention was administered (M = 105.31, SD = 89.40) compared to the baseline performance before the intervention (M = 115.26, SD = 71.53). Similarly, there was an improvement in attention performance after the Podcast control condition was administered (M = 118.28, SD = 60.19) compared to the baseline scores before the control condition (M = 136.04, SD = 74.96).

While there were no significant main effects of condition, $F(1, 25) = 3.07$, p = .092, partial η^2 = .11, order, $F(1, 26) = .22$, p = .647, partial η^2 = .01, and time, $F(1, 26)$ = 1.45, p = .239, partial η^2 = .05, there was a significant interaction effect of condition and order, $F(1, 25) = 4.88$, p = .037, partial η^2 = .16, on attention performance of participants getting insufficient sleep. ANOVA results are presented in Table 6. The bar graph presented in Figure 4 illustrates the mean differences in attention scores across the two experiment conditions.

Table 4. Within-Subjects Factors for Attention

Condition	Time	Dependent Variable
NSDR	Before	Stroop Effect BN
	After	Stroop Effect AN
Podcast	Before	Stroop Effect BP
	After	Stroop Effect AP

Note. Stroop Effect BN = mean attention score before NSDR; Stroop Effect AN = mean attention score after NSDR; Stroop Effect BP = mean attention score before Podcast; Stroop Effect AP = mean attention score after Podcast.

Table 5. Means and Standard Deviations for Attention Scores

Dependent Variable	Order	*M*	*SD*	*n*
Stroop Effect BN	Podcast	92.96	61.18	13
	NSDR	135.97	76.27	14
		115.26	71.53	27
Stroop Effect AN	Podcast	93.75	81.36	13
	NSDR	116.05	98.07	14
		105.31	89.40	27
Stroop Effect BP	Podcast	154.98	98.24	13
	NSDR	118.46	40.47	14
		136.04	74.96	27
Stroop Effect AP	Podcast	111.79	55.38	13
	NSDR	124.30	65.82	14
		118.28	60.19	27

Note. Stroop Effect BN = mean attention score before NSDR; Stroop Effect AN = mean attention score after NSDR; Stroop Effect BP = mean attention score before Podcast; Stroop Effect AP = mean attention score after Podcast.

Table 6. ANOVA Statistics for Attention

Variable	*df*	*F*	*p*	η^2
Condition	1	3.07	.092	.11
Order	1	.22	.647	.01
Condition * Order	1	4.88	.037**	.16
Error (Condition)	25			
Time	1	1.45	.239	.05
Time * Order	1	.37	.551	.01
Error (Time)	25			
Condition * Time	1	.23	.633	.01
Condition * Time * Order	1	3.42	.076	.12
Error (Condition * Time)	25			

Note. N = 27. η^2 *= partial eta squared (*$\eta^2 = 0.01$ *indicates a small effect,* $\eta^2 = 0.06$ *indicates a medium effect,* $\eta^2 = 0.14$ *indicates a large effect); Condition = NSDR or Podcast; Order = NSDR First or Podcast First; Time = Before Condition or After Condition.*

** $p < .05$.

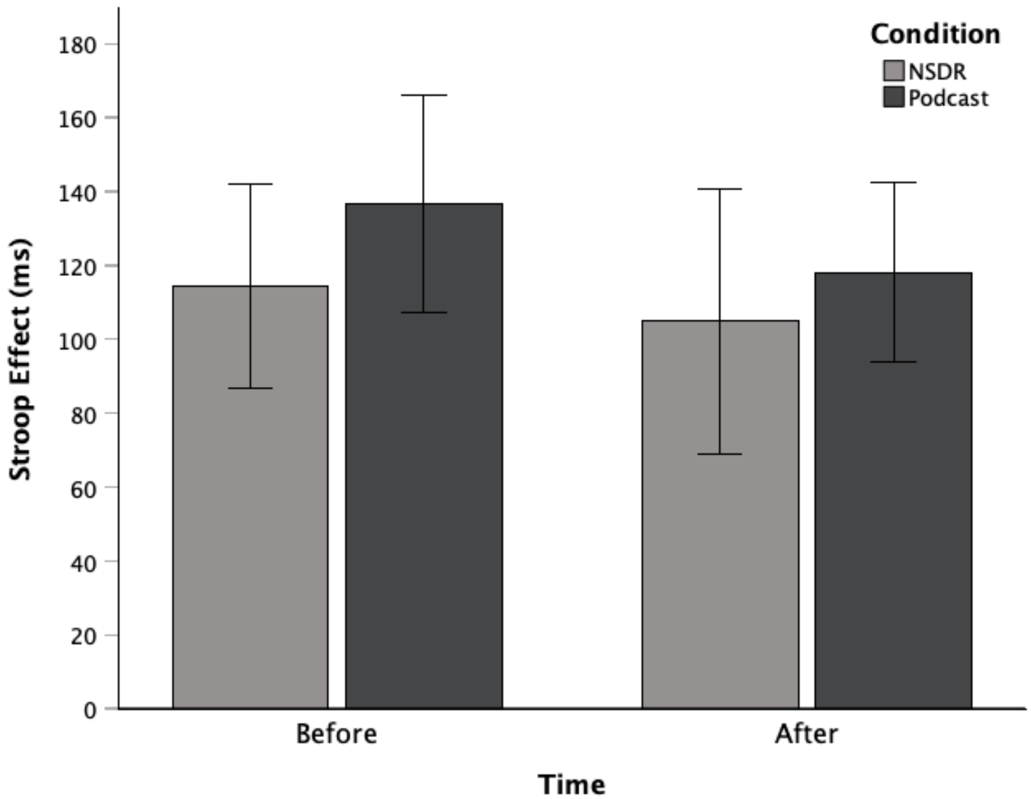

Figure 4. Mean Differences in Attention Scores across Interventions

Note. Stroop Effect indicates attention scores as mean reaction time in milliseconds on the SCWT across the NSDR and Podcast interventions. Error bars show standard errors.

To understand the condition * order interaction effect, post hoc pairwise comparisons after adjusting for multiple comparisons using Bonferroni correction were analyzed. Table 7 shows a breakdown of mean attention scores for all possible combinations of order, condition, and time.

Post hoc results revealed that after the NSDR intervention there was not a significant effect of order ($p = .257$), time ($p = .474$), and order * time interaction ($p = .439$) on attention performance. Changes in the mean attention scores for order * time interaction across the NSDR intervention are shown in Table 8 and Figure 5. Similarly, no significant effect of order ($p = .556$), time ($p = .274$), and order * time interaction ($p = .155$) on attention performance was found after the Podcast intervention. Changes in the mean attention scores for order * time interaction across the Podcast intervention are shown in Table 8 and Figure 6.

Post hoc analyses with respect to order showed that there was a non-significant effect of condition ($p = .697$), time ($p = .580$), and condition * time interaction ($p = .085$) on attention performance when NSDR was administered first (see Table 9). Changes in attention performance across the two conditions when NSDR was administered first are demonstrated in Figure 7. However, when Podcast was administered first, there was a significant effect of condition on attention performance, ($p = .035$), while the effects of time ($p = .318$) and condition * time interaction ($p = .249$) were non-significant (see Table 9). Changes in attention performance across the two conditions when Podcast was administered first are demonstrated in Figure 8.

Table 7. Post Hoc Descriptive Statistics for Attention

Order	Condition	Time	*M*	*SD*	*n*
NSDR First	NSDR	Before	135.97	76.27	14
		After	116.05	98.07	14
	Podcast	Before	118.46	40.47	14
		After	124.30	65.82	14
Podcast First	NSDR	Before	92.96	61.18	13
		After	93.75	81.36	13
	Podcast	Before	154.98	98.24	13
		After	111.79	55.38	13

Note. N = 27.

Table 8. Post Hoc Results for Attention with respect to Condition

Condition	Variable	*df*	*F*	p^a
	Order	1	1.35	.257
	Error (Order)	25		
NSDR	Time	1	.53	.474
	Order * Time	1	.62	.439
	Error (Order * Time)	25		
	Order	1	.36	.556
	Error (Order)	25		
Podcast	Time	1	1.25	.274
	Order * Time	1	2.15	.155
	Error (Order * Time)	25		

Note. N = 27. Order = NSDR First or Podcast First; Time = Before Condition or After Condition.

[a] *Adjustment for multiple comparisons: Bonferroni.*

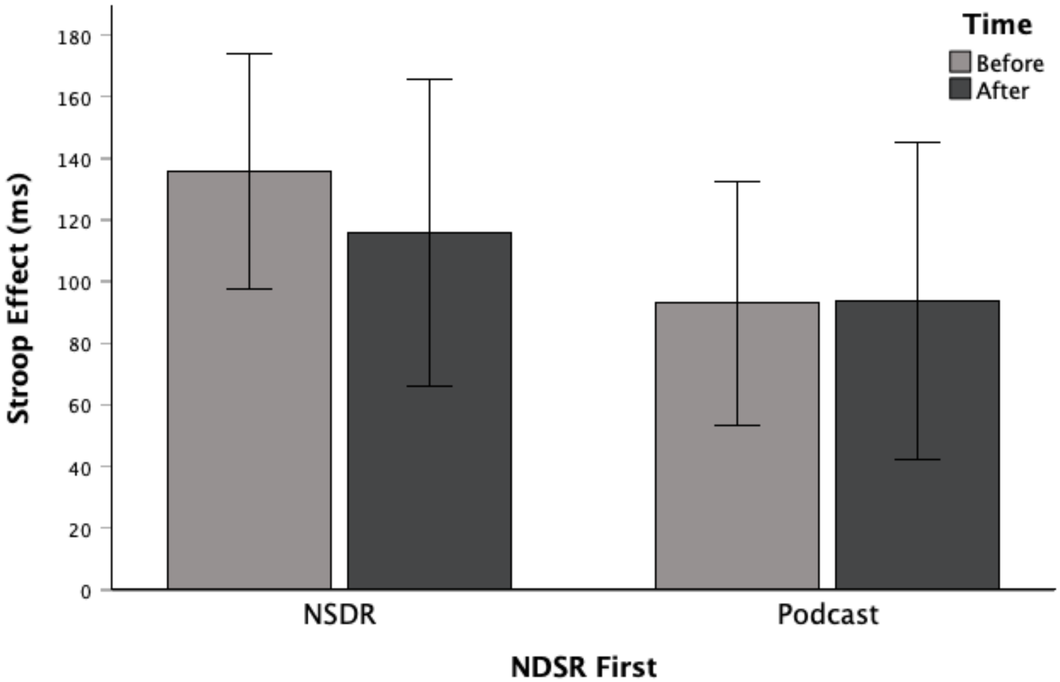

Figure 5. Mean Differences in Attention Scores for NSDR Condition

*Note. Stroop Effect indicates attention scores as mean reaction time in milliseconds on the SCWT across the NSDR and Podcast interventions for order * time interaction. Error bars show standard errors.*

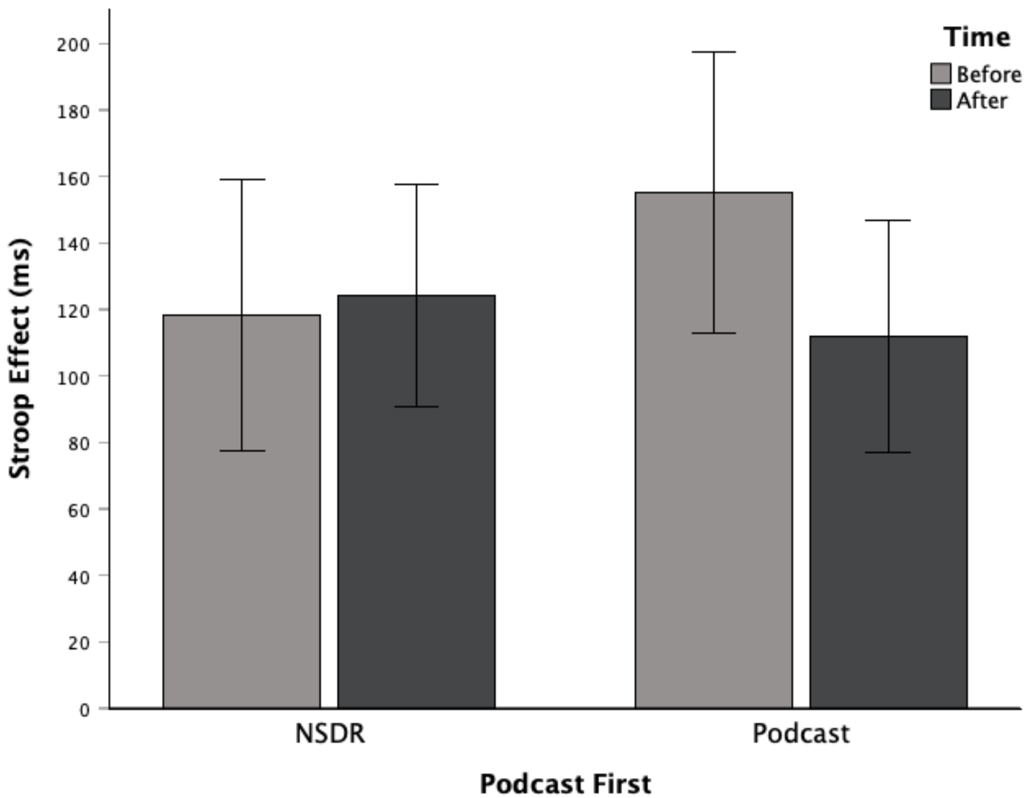

Figure 6. Mean Differences in Attention Scores for Podcast Condition

*Note. Stroop Effect indicates attention scores as mean reaction time in milliseconds on the SCWT across the NSDR and Podcast interventions for order * time interaction. Error bars show standard errors.*

Table 9. Post Hoc Results for Attention with respect to Order

Order	Variable	*df*	*F*	p^a
NSDR first	Condition	1	.16	.697
	Error (Condition)	13		
	Time	1	.32	.580
	Error (Time)	13		
	Condition * Time	1	3.49	.085
	Error (Condition * Time)	13		
Podcast first	Condition	1	5.65	.035**
	Error (Condition)	12		
	Time	1	1.09	.318
	Error (Time)	12		
	Condition * Time	1	1.47	.249
	Error (Condition * Time)	12		

Note. N = 27. Condition = NSDR or Podcast; Time = Before Condition or After Condition.

[a] *Adjustment for multiple comparisons: Bonferroni.*

** *p < .05.*

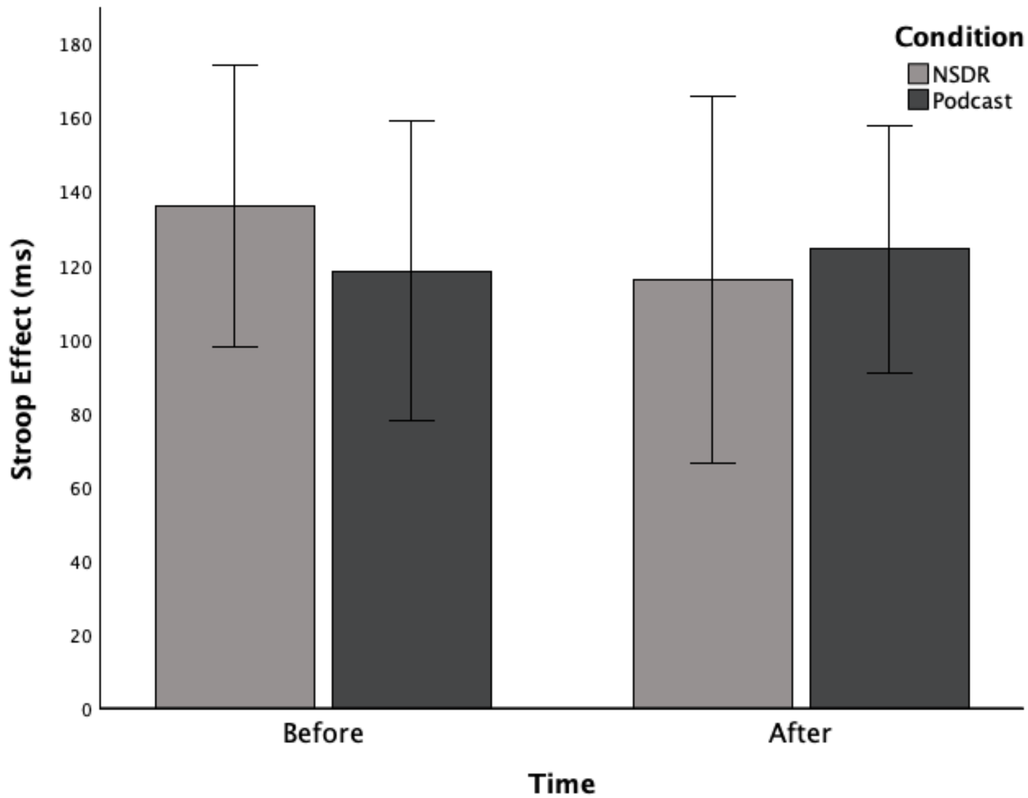

Figure 7. Mean Differences in Attention Scores for NSDR First

*Note. Stroop Effect indicates attention scores as mean reaction time in milliseconds on the SCWT across the NSDR and Podcast interventions for condition * time interaction when participants were exposed to the NSDR condition first. Error bars show standard errors.*

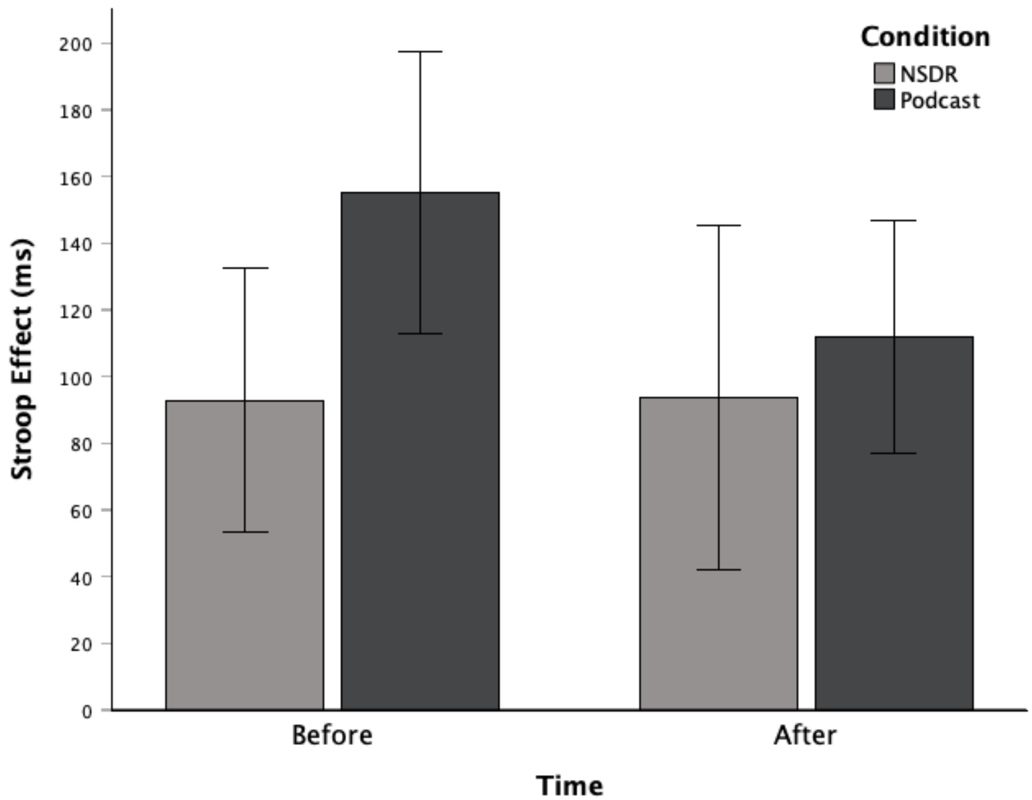

Figure 8. Mean Differences in Attention Scores for Podcast First

*Note. Stroop Effect indicates attention scores as mean reaction time in milliseconds on the SCWT across the NSDR and Podcast interventions for condition * time interaction when participants were exposed to the Podcast condition first. Error bars show standard errors.*

Next, the differences in attention scores across the NSDR and Podcast conditions were analyzed by including the sleep parameters – PSQI global score and CSD total sleep time, sleep quality, and restedness – as covariates in the ANOVA analysis defined above.

PSQI was not related to participants' attention performance across the two conditions, $F(1, 24) = 2.89$, $p = .102$, partial $\eta^2 = .11$. However, there remained a significant condition * order interaction effect, $F(1, 24) = 6.39$, $p = .018$, partial $\eta^2 = .21$, after accounting for sleep disturbances indicated by the mean PSQI scores (see Table 10).

The covariate, CSD total sleep time, was not related to participants' attention performance across the two conditions, $F(1, 24) = 3.85$, $p = .062$, partial $\eta^2 = .14$. Table 11 shows the effect of total sleep time on attention performance across the two conditions.

The covariate, sleep quality, was not related to participants' attention performance across the two interventions, $F(1, 24) = 2.95$, $p = .099$, partial $\eta^2 = .11$. However, there was a significant interaction between condition and order, $F(1, 24) = 4.77$, $p = .039$, partial $\eta^2 = .17$, after controlling for sleep quality (see Table 12).

Attention performance was not related to the two experiment conditions, $F(1, 24) = 3.00$, $p = .096$, partial $\eta^2 = .11$, after controlling for participants' restedness score. However, there was a significant interaction effect of condition and order, $F(1, 24) = 4.47$, $p = .045$, partial $\eta^2 = .16$, when restedness was accounted for (see Table 13).

PSQI Global Score

Table 10. ANOVA Statistics for Attention with PSQI Score

Variable	*df*	*F*	*p*	η^2
PSQI	1	.02	.902	.00
Condition	1	2.89	.102	.11
Order	1	.22	.642	.01
Condition * PSQI	1	1.73	.201	.07
Condition * Order	1	6.39	.018**	.21
Error (Condition)	24			
Time	1	1.76	.197	.07
Time * PSQI	1	1.15	.295	.05
Time * Order	1	.80	.381	.03
Error (Time)	24			
Condition * Time	1	.65	.428	.03
Condition * Time * PSQI	1	.51	.483	.02
Condition * Time * Order	1	3.83	.062	.14
Error (Condition * Time)	24			

Note. N = 27. η^2 *= partial eta squared (*$\eta^2 = 0.01$ *indicates a small effect,* $\eta^2 = 0.06$ *indicates a medium effect,* $\eta^2 = 0.14$ *indicates a large effect); Condition = NSDR or Podcast; Order = NSDR First or Podcast First; Time = Before Condition or After Condition; PSQI = Global PSQI Score.*

** $p < .05$.

CSD Total Sleep Time

Table 11. ANOVA Statistics for Attention with CSD Total Sleep Time

Variable	*df*	*F*	*p*	η^2
TST	1	.05	.827	.00
Condition	1	3.85	.062	.14
Order	1	.25	.619	.01
Condition * TST	1	.96	.336	.04
Condition * Order	1	2.89	.102	.11
Error (Condition)	24			
Time	1	1.61	.216	.06
Time * TST	1	.21	.648	.01
Time * Order	1	.15	.702	.01
Error (Time)	24			
Condition * Time	1	.18	.671	.01
Condition * Time * TST	1	.01	.941	.00
Condition * Time * Order	1	2.94	.099	.11
Error (Condition * Time)	24			

Note. N = 27. η^2 *= partial eta squared (*$\eta^2 = 0.01$ *indicates a small effect,* $\eta^2 = 0.06$ *indicates a medium effect,* $\eta^2 = 0.14$ *indicates a large effect); Condition = NSDR or Podcast; Order = NSDR First or Podcast First; Time = Before Condition or After Condition; TST = Difference in mean total sleep time across week 1 and week 2.*

CSD Sleep Quality

Table 12. ANOVA Statistics for Attention with CSD Sleep Quality

Variable	*df*	*F*	*p*	η^2
SQ	1	.00	.99	.00
Condition	1	2.95	.099	.11
Order	1	.18	.677	.01
Condition * SQ	1	.23	.637	.01
Condition * Order	1	4.77	.039**	.17
Error (Condition)	24			
Time	1	1.41	.247	.06
Time * SQ	1	.08	.782	.00
Time * Order	1	.19	.670	.01
Error (Time)	24			
Condition * Time	1	.22	.642	.01
Condition * Time * SQ	1	.17	.687	.01
Condition * Time * Order	1	3.34	.080	.12
Error (Condition * Time)	24			

Note. N = 27. η^2 *= partial eta squared (*$\eta^2 = 0.01$ *indicates a small effect,* $\eta^2 = 0.06$ *indicates a medium effect,* $\eta^2 = 0.14$ *indicates a large effect); Condition = NSDR or Podcast; Order = NSDR First or Podcast First; Time = Before Condition or After Condition; SQ = Difference in mean sleep quality across week 1 and week 2.*

** $p < .05$.

CSD Restedness

Table 13. ANOVA Statistics for Attention with CSD Restedness

Variable	*df*	*F*	*p*	η^2
Restedness	1	.21	.650	.01
Condition	1	3.00	.096	.11
Order	1	.34	.563	.01
Condition * Restedness	1	.05	.821	.00
Condition * Order	1	4.47	.045**	.16
Error (Condition)	24			
Time	1	1.31	.264	.05
Time * Restedness	1	.02	.888	.00
Time * Order	1	.26	.616	.01
Error (Time)	24			
Condition * Time	1	.20	.662	.01
Condition * Time * Restedness	1	.02	.881	.00
Condition * Time * Order	1	2.73	.112	.10
Error (Condition * Time)	24			

Note. N = 27. η^2 *= partial eta squared (*η^2 *= 0.01 indicates a small effect,* η^2 *= 0.06 indicates a medium effect,* η^2*= 0.14 indicates a large effect); Condition = NSDR or Podcast; Order = NSDR First or Podcast First; Time = Before Condition or After Condition; Restedness = difference in mean restedness across week 1 and week 2.*

** $p < .05$.

Effect of Interventions on Working Memory Performance

The same 2 x 2 repeated measures analysis of variance model was used to evaluate the differences in the mean working memory scores, measured using the n = 2-back task, between the two interventions. Experiment condition (NSDR and Podcast) and time (before and after) were within-subject factors and intervention order (NSDR first and Podcast first) was a between-subjects factor. Table 14 shows the within-subjects factors representing each level of the two factors. The means and standard deviations for the working memory scores are represented in Table 15.

The first main effect involved experiment condition, $F(1, 25) = 2.66$, $p = .116$, partial $\eta^2 = .10$. Mean accuracy score indicating working memory performance after the NSDR intervention ($M = 80.78$, $SD = 7.38$) was improved compared to the baseline performance ($M = 78.70$, $SD = 7.12$). Similarly, after the Podcast control condition, mean working memory score improved ($M = 79.37$, $SD = 7.22$) compared to baseline ($M = 77.36$, $SD = 9.36$). These results indicate a non-significant main effect of the intervention on working memory performance. The second main effect, time, was statistically significant, $F(1, 25) = 5.34$, $p = .029$, partial $\eta^2 = .18$. However, the condition * time interaction failed to reach statistical significance, $F(1, 25) = .04$, $p = .840$, partial $\eta^2 = .00$. These results suggest that the change in working memory performance was significant with respect to time, i.e., before and after the administration of both the interventions, regardless of the experimental or control condition. ANOVA results are shown in Table 16. Mean differences in working memory scores before and after the two experimental conditions are demonstrated in Figure 9.

Table 14. Within-Subjects Factors for Working Memory

Condition	Time	Dependent Variable
NSDR	Before	n-Back BN
	After	n-Back AN
Podcast	Before	n-Back BP
	After	n-Back AP

Note. n-Back BN = mean working memory score before NSDR; n-Back AN = mean working memory score after NSDR; n-Back BP = mean working memory score before Podcast; n-Back AP = mean working memory score after Podcast.

Table 15. Means and Standard Deviations for Working Memory Scores

Dependent Variable	Order	*M*	*SD*	*n*
n-Back BN	Podcast	79.38	7.78	13
	NSDR	78.07	6.67	14
		78.70	7.12	27
n-Back AN	Podcast	81.31	6.96	13
	NSDR	80.29	7.98	14
		80.78	7.38	27
n-Back BP	Podcast	77.46	9.28	13
	NSDR	77.79	9.78	14
		77.63	9.36	27
n-Back AP	Podcast	79.85	6.93	13
	NSDR	78.93	7.72	14
		79.37	7.22	27

Note. n-Back BN = mean working memory score before NSDR; n-Back AN = mean working memory score after NSDR; n-Back BP = mean working memory score before Podcast; n-Back AP = mean working memory score after Podcast.

Table 16. ANOVA Statistics for Working Memory

Variable	*df*	*F*	*p*	η^2
Condition	1	2.66	.116	.10
Order	1	.07	.792	.00
Condition * Order	1	.32	.577	.01
Error (Condition)	25			
Time	1	5.34	.029**	.18
Time * Order	1	.08	.777	.00
Error (Time)	25			
Condition * Time	1	.04	.840	.00
Condition * Time * Order	1	.26	.613	.01
Error (Condition * Time)	25			

Note. N = 27. η^2 *= partial eta squared (*η^2 *= 0.01 indicates a small effect,* η^2 *= 0.06 indicates a medium effect,* η^2*= 0.14 indicates a large effect); Condition = NSDR or Podcast; Order = NSDR First or Podcast First; Time = Before Condition or After Condition.*

** $p < .05$.

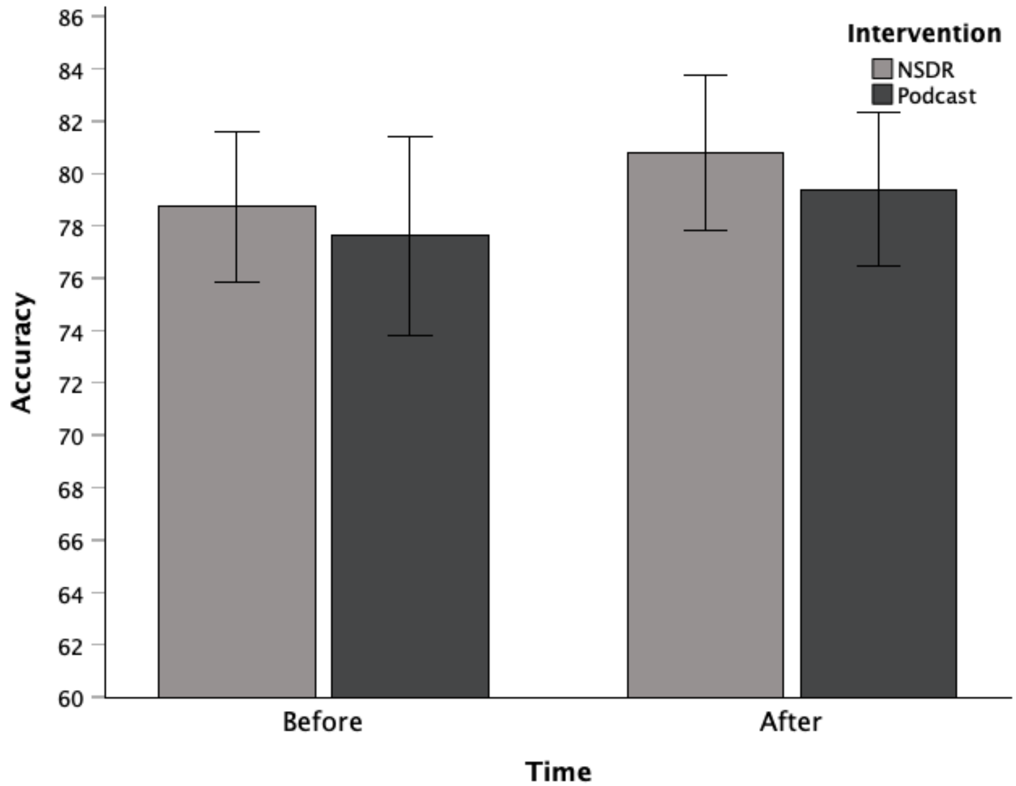

Figure 9. Mean Differences in Working Memory Scores across Interventions

Note. Accuracy indicates working memory scores as mean correct responses on n = 2-Back Task across the NSDR and Podcast interventions. Error bars show standard errors.

Next, the differences in working memory scores across the two interventions were analyzed by including the sleep parameters – PSQI global score and CSD total sleep time, sleep quality, and restedness – as covariates in the ANOVA analysis defined above.

PSQI Global Score

There was a significant main effect of the covariate, PSQI global score, (p = 0.20), on working memory performance. However, after adding PSQI to the analysis, the main effect of condition, $F(1, 24) = .02$, $p = .884$, partial $\eta^2 = .00$, remained non-significant and the resulting main effect of time failed to reach statistical significance, $F(1, 24) = 1.36$, $p = .255$, partial $\eta^2 = .05$ (see Table 17).

As shown in Table 18, simple linear regression analysis was conducted to evaluate the extent to which PSQI global scores could predict working memory performance. The linear regression analysis revealed a statistically significant model, $F(1, 25) = 5.29$, $p = .030$, with an R^2 of .18. This finding suggests that PSQI scores accounted for approximately 18% of the variance in working memory performance among the sampled students. Further, the regression coefficient for PSQI was found to be -1.03, with a standard error of .45. This indicates that for each additional point in PSQI, there is an average decrease of 1.03 in working memory scores. This negative relationship between PSQI and working memory was statistically significant, $t(25)$ = 17.87, $p < .001$, affirming the predictive power of PSQI on working memory performance irrespective of the experiment condition. Figure 10 shows a scatterplot with the fitted regression line to demonstrate PSQI scores in predicting working memory scores of the sample.

Table 17. ANOVA Statistics for Working Memory with PSQI Score

Variable	*df*	*F*	*p*	η^2
PSQI	1	6.22	.020**	.21
Condition	1	.02	.884	.00
Order	1	1.01	.324	.04
Condition * PSQI	1	.06	.814	.00
Condition * Order	1	.21	.649	.01
Error (Condition)	24			
Time	1	1.36	.255	.05
Time * PSQI	1	.42	.526	.02
Time * Order	1	.21	.651	.01
Error (Time)	24			
Condition * Time	1	.76	.391	.03
Condition * Time * PSQI	1	.90	.352	.04
Condition * Time * Order	1	.59	.451	.02
Error (Condition * Time)	24			

Note. N = 27. η^2 *= partial eta squared (*η^2 *= 0.01 indicates a small effect,* η^2 *= 0.06 indicates a medium effect,* η^2*= 0.14 indicates a large effect); Condition = NSDR or Podcast; Order = NSDR First or Podcast First; Time = Before Condition or After Condition; PSQI = Global PSQI Score.*

** *p < .05.*

Table 18. Linear Regression Analysis for PSQI Predicting Working Memory

Variable	*B*	β	*SE*	*t*	*p*
Constant	90.39		5.06	17.87	<.001
PSQI	-1.03	-.418	.45	-2.30	.030**

Note. $N = 27$. $R^2 = .18$; $R^2_{adjusted} = .14$. *The effect of PSQI scores on working memory performance was examined by averaging n-Back scores across the two experiment conditions. Averaged n-Back was added as a predictor.*

** $p < .05$.

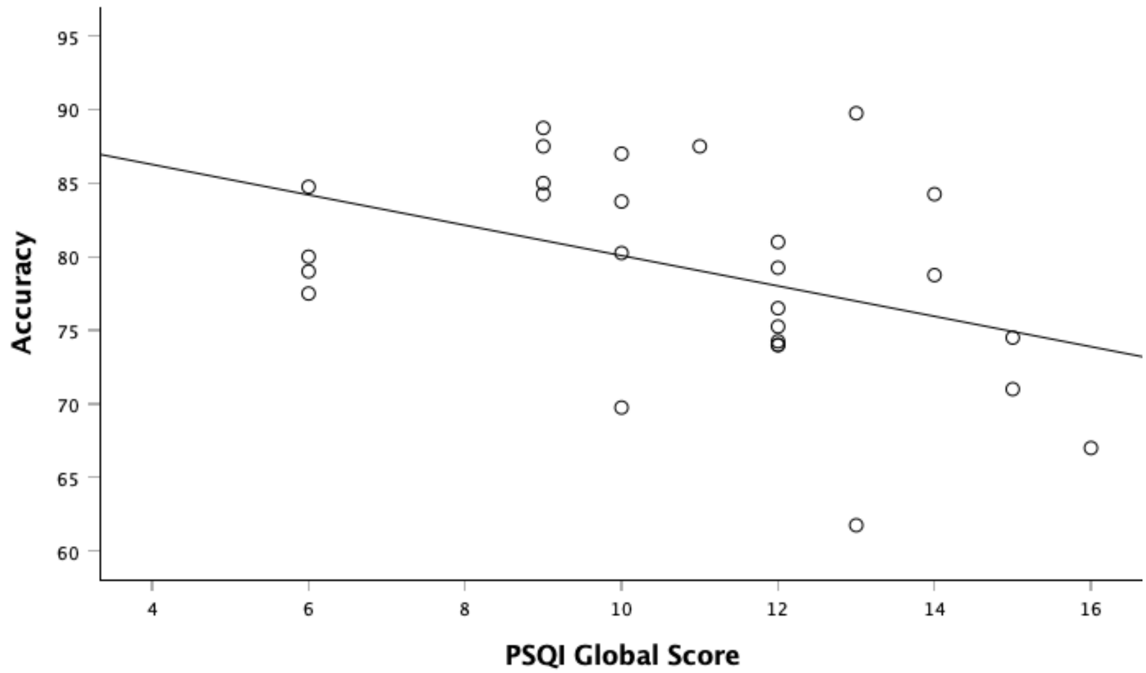

Figure 10. Relationship Between PSQI and Working Memory Scores

Note. Accuracy indicates working memory scores as mean correct responses on n = 2-Back Task averaged across the NSDR and Podcast interventions. Each dot represents an individual participant. Lower PSQI scores were associated with higher accuracy in n-Back Task.

CSD Total Sleep Time

Table 19. ANOVA Statistics for Working Memory with CSD Total Sleep Time

Variable	*df*	*F*	*p*	η^2
TST	1	.84	.368	.03
Condition	1	2.64	.117	.10
Order	1	.34	.567	.01
Condition * TST	1	.11	.746	.00
Condition * Order	1	.16	.694	.01
Error (Condition)	24			
Time	1	4.37	$.047^{**}$	.15
Time * TST	1	.07	.799	.00
Time * Order	1	.13	.725	.01
Error (Time)	24			
Condition * Time	1	.07	.787	.00
Condition * Time * TST	1	.08	.783	.00
Condition * Time * Order	1	.32	.574	.01
Error (Condition * Time)	24			

Note. N = 27. η^2 *= partial eta squared (*η^2 *= 0.01 indicates a small effect,* η^2 *= 0.06 indicates a medium effect,* η^2*= 0.14 indicates a large effect); Condition = NSDR or Podcast; Order = NSDR First or Podcast First; Time = Before Condition or After Condition; TST W1 - W2 = difference in mean total sleep time across week 1 and week 2.*

$^{**}p < .05$.

CSD Sleep Quality

Table 20. ANOVA Statistics for Working Memory with CSD Sleep Quality

Variable	*df*	*F*	*p*	η^2
SQ	1	.21	.649	.01
Condition	1	2.72	.112	.10
Order	1	.18	.674	.01
Condition * SQ	1	1.21	.282	.05
Condition * Order	1	.01	.940	.00
Error (Condition)	24			
Time	1	5.25	.031**	.18
Time * SQ	1	.43	.517	.02
Time * Order	1	.00	.996	.00
Error (Time)	24			
Condition * Time	1	.04	.848	.00
Condition * Time * SQ	1	1.31	.263	.05
Condition * Time * Order	1	.00	.991	.00
Error (Condition * Time)	24			

Note. N = 27. η^2 *= partial eta squared (*$\eta^2 = 0.01$ *indicates a small effect,* $\eta^2 = 0.06$ *indicates a medium effect,* $\eta^2 = 0.14$ *indicates a large effect); Condition = NSDR or Podcast; Order = NSDR First or Podcast First; Time = Before Condition or After Condition; SQ = difference in mean sleep quality across week 1 and week 2.*

** $p < .05$.

CSD Restedness

Table 21. ANOVA Statistics for Working Memory with CSD Restedness

Variable	*df*	*F*	*p*	η^2
Restedness	1	.13	.723	.01
Condition	1	2.79	.108	.10
Order	1	.14	.716	.01
Condition * Restedness	1	.28	.603	.01
Condition * Order	1	.49	.489	.02
Error (Condition)	24			
Time	1	4.95	$.036^{**}$	.17
Time * Restedness	1	.00	.952	.00
Time * Order	1	.06	.810	.00
Error (Time)	24			
Condition * Time	1	.08	.779	.00
Condition * Time * Restedness	1	.28	.602	.01
Condition * Time * Order	1	.09	.771	.00
Error (Condition * Time)	24	2.79	.108	.10

Note. N = 27. η^2 = partial eta squared (η^2 = 0.01 indicates a small effect, η^2 = 0.06 indicates a medium effect, η^2= 0.14 indicates a large effect); Condition = NSDR or Podcast; Order = NSDR First or Podcast First; Time = Before Condition or After Condition; Restedness = difference in mean restedness across week 1 and week 2.

$^{**}p < .05$.

The covariate, CSD total sleep time, was not related to the participants' working memory performance across the two interventions, $F(1, 24) = 2.64$, $p = .117$, partial $\eta^2 = .10$. There was a significant effect of time, $F(1, 24) = 4.37$, $p = .047$, partial $\eta^2 = .15$, when the total sleep time was accounted for (see Table 19).

The covariate, sleep quality, was not related to the participants' working memory scores across the two conditions, $F(1, 24) = 2.72$, $p = .112$, partial $\eta^2 = .10$. However, there was a significant effect of time, $F(1, 24) = 5.25$, $p = .031$, partial $\eta^2 = .18$, after controlling for sleep quality (see Table 20).

Working memory performance was not related to the experiment conditions, $F(1, 24) = 2.79$, $p = .108$, partial $\eta^2 = .10$, after controlling for participants' restedness score. However, there was a significant effect of time, $F(1, 24) = 4.95$, $p = .036$, partial $\eta^2 = .17$, when restedness was accounted for (see Table 21).

Chapter IV

Discussion

The purpose of this experimental study was to understand the effect of the Non-Sleep Deep-Rest protocol on working memory and attention performance of students consistently getting insufficient sleep. It was hypothesized that a short, 10-minute, Yoga Nidra meditation will counter the effects of reduced total sleep time, defined as less than 6 hours per day, and lead to short-term positive cognitive outcomes in attention performance in healthy adult students. The results of the experiment do not support the hypothesis. It was also hypothesized that a short, 10-minute, Yoga Nidra meditation will counter the effects of reduced total sleep time, defined as less than 6 hours per day, and lead to short-term positive cognitive outcomes in working memory performance in healthy adult students. The research findings do not support the hypothesis.

The study first analyzed the differences in attention performance, measured using the SCWT, between the two groups exposed to both experiment conditions – NSDR versus Podcast. Any effect of the intervention was also expected to depend on participants' sleep disturbances, represented by the global PSQI scores; and total sleep time, sleep quality, and restedness, evaluated using the mean sleep diary scores over a period of two weeks. Likewise, differences in working memory performance, measured using the n-back task, based on the intervention, were also analyzed in relation to the same sleep variables. It is interesting to note that poor PSQI scores, indicating sleep disturbances across the sample, significantly predicted working memory performance despite the experiment condition. However, the difference between the effects of the two interventions on the cognitive domains of attention and working memory failed to reach statistical significance. However, a conclusive statement invalidating the effect of the NSDR protocol in improving cognitive performance in students getting insufficient sleep would be erroneous in the light of advised caution against such binary interpretation of the p-value, indicating the statistical significance of .05, which may or may not support the null hypothesis (Ciapponi et al., 2021; Visentin et al., 2020). Moreover, the small sample size and large unexplained variance in the sample may also have contributed a higher probability of Type II error (Visentin et al., 2020). Therefore, apropos of these caveats, possible alternative interpretation of the results, also highlighting the inherent limitations of the study, methodological or otherwise, need to be discussed.

Insufficient Statistical Power

The smallest sample size to detect the effect was calculated to be 34 (see Chapter II Method). Sufficiently-powered meditation-based interventions, ascertaining its cognitive benefits in non-clinical populations, have reported only small to medium effect sizes. The lack of any effect in the study could, therefore, be attributed to its insufficient power due to a small sample size of 27. Moreover, several possible confounding variables may have increased the probability of unexplained variance in the sample, which has been meticulously controlled in studies reporting any cognitive benefits of meditation (see, e.g., Basso et al., 2019; Fu et al., 2022; Kohler et al., 2017; Moore et al., 2012). Although the study was conducted using the within-subjects design to reduce interindividual variability, several other factors might have led to a further reduction in the statistical power. These factors include inconsistent experiment scheduling based on participants' availability or its lack thereof; absence from university due to public holidays or personal reasons, adding on the total sleep time – the most crucial variable for the study; and background noise during the experiment sessions.

Motivational Factors

One potential factor that may also have affected the study outcomes is participant motivation. Research has explored several motivational factors that lead to participation in online experimental research and impact the validity of findings. Participants are motivated to participate in order to learn about themselves, to compare themselves to others, or to contribute to science. Other motivational factors include boredom and the desire to have fun (Jun et al., 2017). Additionally, in testing the effectiveness of a mindfulness-based intervention in university students with sleep problems, Fu et al. (2022) worked closely with the screened participants, who also showed a willingness to make a change, thus indirectly establishing it as another conceivable motivational factor, which the participants seemed to be lacking in the NSDR study. Although the study was advertised in all university departments, 25 out of 27 participants who completed the protocol were psychology students. Correspondingly, despite the screening checks for short sleep duration, it seems plausible that most participants may have been eager to participate in the research out of curiosity rather than any serious concern about alleviating the problems associated with their short sleep duration since the cumulative sleep diary data revealed a maximum total sleep time of 7 or more hours for some participants (see Table 3). Moreover, despite the voluntary nature of the study, participation motivation might also have been dominated by credit compensation since the influx of interested participants increased after the notion of course credit was explained during the initial introductory sessions. These factors may have induced undesirable sampling bias and elicited behavioral ramifications manifested as plausible careless responses in sleep measures and inattention during the experiment conditions, resulting in non-significant results.

Practice Effects

Practice effects, defined as test-takers' ability to learn and adapt through repeated cognitive testing, reflected in improved performance in the tasks irrespective of exposure to any interventions, may embody a nuisance to complicate the result interpretation further. Practice effects have been attributed to diverse yet interconnected reasons, including familiarity and comfort with the experimental environment, regression to the mean, improved test-taking strategies, test complexity, and intertrial interval, to name a few (Bartels et al., 2010; Benedict & Zgaljardic, 1998). Results of the current study under scrutiny indicated an improvement in the mean working memory scores across interventions notwithstanding the experiment conditions, implying that the change in performance could be ascribed to practice effects. Since literature supports the validated use of the longer and shorter versions of the n-back task, the study utilized the latter, cognizant of any additional time demands that the former may impose. However, test-retest reliability coefficients for cognitive instruments have not been established for more than two repetitions of the tests, discounting systematic integration of the Reliable Change Index – a psychometric method to evaluate statistical significance based on actual change vis-à-vis measurement error – accounting for practice effects (Benedict & Zgaljardic, 1998; Blampied, 2022; Jacobson et al., 1984; Temkin et al., 1999). Since the SCWT and n-back tasks were administered five times, including the demonstration, then, based on the discussed literature and the inherent shortcomings of psychometric testing, the evidence seems to converge towards practice effects as a likely explanation of non-significant effect of the experiment condition on attention and working memory performance. However, such elucidation continues to render the effect of the NSDR protocol inconclusive in improving sleep-induced cognitive impairments in students, which also begs the question of whether or not the study participants were truly chronically sleep-deprived.

True Sleep Deprivation

Inducing sleep deprivation is a common methodological practice in sleep research to facilitate causal inferences from randomized controlled trials investigating healthy cohorts. Sleep restriction in such experiments is ensured either by retaining participants in the laboratory and manipulating environmental stimuli or by instructing participants to wear an actigraph and systematically alter their sleep patterns in their natural environment (Baum et al., 2014; Beebe et al., 2008; Fleckenstein et al., 2022). Where experimental conditions cannot be feasibly manipulated, experimenters rely on subjective reporting of sleep parameters through other validated instruments such as the ones utilized by this study (Ahrberg et al., 2012; Carpi et al., 2022; Claßen et al., 2022; Taylor et al., 2012). In this study, interested participants were screened for short sleep and several additional sleep parameters were recorded using the PSQI. Though the PSQI scores were all in the range of clinical sleep disturbance (cutoff score > 5), corroborating the initial reporting, CSD scores did not indicate consistently curtailed total sleep time across the two weeks of reporting (see Table 3 and Figure 3). Such variability in sleep duration, while not discerning true short sleepers across the sample, may also have been a crucial factor confounding the results. Therefore, the generalizability of the effects of the NSDR intervention on cognition cannot be categorically stated as the acceptance or rejection of the null hypothesis.

Meditation Duration

Failure to detect any effects in the study also warrants doubt as to the duration of the NSDR practice being merely 11 minutes. Considering literature on mindfulness-based interventions, substantial variation based on specific form, practice period, and differences in psychological effects in experienced versus non-experienced meditators and clinical versus non-clinical populations have been observed. For example, in attempting to stipulate the minimum possible meditation dose in student populations, Kumar and Joshi (2009) detected significant neurophysiological changes after Yoga Nidra meditation was practiced for 30 minutes over a period of 40 days. On the other hand, integrated mind-body meditation practice, focusing on posture, breath, relaxation, and attention, for just 20 minutes over 5 days has shown significant improvements in attention and stress responses in students (Tang et al., 2007). In a similar vein, Moszeik et al. (2022) established the effectiveness of Yoga Nidra meditation, curtailed to 11 minutes of practice for 30 days, in improving the sleep and stress parameters of a large sample. Based on these findings, it is likely that the 10-minute duration of the NSDR protocol was too short to elicit improvements in attention and working memory.

Conversely, it is also intriguing to comment on the human brain's sensitivity to transitory experiences, as has been demonstrated by Naccache et al. (2005), who recorded protracted cerebral processes when emotional words were subliminally presented to epileptic patients. Additionally, attention-related brain networks showed activation in both expert meditators with 10 to 54 thousand hours of meditation practice and novices with an exposure of only 1 hour per day to meditation (Brefczynski-Lewis et al., 2007). Although the NSDR study did not use such objective measures, there is still reason to believe that 11 minutes of practice may lead to improvements in the cognitive domains of attention and working memory in meticulously controlled experiment conditions, which had not entirely been possible due to the several methodological restraints elaborated above, thereby tempering the research findings.

Collectively, these divergent findings point to a lack of theoretical consensus and operational definitions in translating Eastern enlightenment approaches to Western psychotherapeutic experiments. However, such methodological pitfalls are inevitable given that meditation research is in its infancy and still traversing stages of trial and error, which also puts the results of the current study in perspective. Therefore, the findings of this research are better conceived as a contribution to experimental methodology in follow-up meditation research studies to facilitate convergence to more systematic approaches that may eventually profit both science and humanity in the future.

Appendix A.

IRB Approval Letter

HARVARD
Human Research Protection Program

Harvard University-Area
Committee on the Use of Human Subjects
44-R Brattle, Suite 200 (2nd floor)
Cambridge, MA 02138
IRB Registration - IRB00000109
Federal Wide Assurance - FWA00004837

Notification of Initial Study Approval

September 27, 2023

Ghalia Akram
gha798@g.harvard.edu

Protocol Title:	Testing Non-Sleep Deep Rest (NSDR) protocol to counter the cognitive consequences of short sleep in young adult students
Principal Investigator:	Ghalia Akram
Protocol #:	IRB23-0919
Funding Source:	None
Review Date:	9/27/2023
STUDY Effective Date:	9/27/2023
IRB Review Type:	Expedited
IRB Review Action:	Approved

The Institutional Review Board (IRB) of the Harvard University-Area approved this Initial Study. This approval does not expire and you will not be required to submit an annual renewal application. However, you are responsible for submitting the following to the IRB, as applicable. Any change or update to the research must be submitted in ESTR via a Modification. Once the study is eligible for closure, a closure request must be submitted in ESTR via the Close Study activity. All reports of new information must be submitted in ESTR via the Report New Information activity. If you are unsure what to submit, contact the Harvard University-Area IRB office for further assistance.

The documents that were finalized for this submission may be accessed through the IRB electronic submission management system at the following link: IRB23-0919

The IRB made the following determinations:

- Waivers: Waiver of consent documentation-online
- Risk Determination: No greater than minimal risk
- Research Information Security Level (based on Harvard Research Data Security Policy): Sensitive

Please contact me at 617-495-9204 or kathryn_bean@harvard.edu with any questions.

Sincerely,

University Area IRB http://cuhs.harvard.edu
Harvard Longwood Campus IRB http://www.hsph.harvard.edu/orarc

HRP-510: Template v5/15/2020

HARVARD
Human Research Protection Program

Kathryn Bean
IRB Administrator/Team Lead

Appendix B.

Study Advertisement

PARTICIPATE

PSYCHOLOGY RESEARCH

Are you a student not getting sufficient sleep?

We invite you to get involved in experimental research to understand the effects of Non-Sleep Deep Rest (NSDR) protocol on your cognition.

You may qualify if you are:

- Between 18-25 years of age
- Enrolled in a degree program

You may not qualify if you:

- Smoke, take drugs or sleep meds
- Meditate

Participation includes:

- 2 research meetings each lasting 1 hour
- Listening to 10-minute NSDR/Podcast audios
- Taking cognitive tests before and after the audios

Participation compensation:

- Course credit

INTERESTED PARTICIPANTS WILL BE SCREENED FOR ELIGIBILITY

Please contact the researcher at:

gha798@g.harvard.edu OR Scan the QR code

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Appendix C.

Consent Form

Study Title:	Testing Non-Sleep Deep Rest (NSDR) protocol to counter the cognitive consequences of short sleep in young adult students
Researcher:	Ghalia Akram
Faculty Advisor:	Dr. Edward Franz Pace-Schott

Key Information

The following is a short summary of this study to help you decide whether to be a part of this study. More detailed information is listed later in this form.

Why am I being invited to take part in a research study?

We invite you to take part in a research study as a young adult aged 18-25 years who is enrolled in an undergraduate or graduate degree program at a university, and may be getting less than 6 hours of sleep every night. We want to test the effect of a meditation intervention called Non-Sleep Deep Rest (NSDR) based on the practice of Yoga Nidra in potentially improving working memory and attention following sleep loss.

What should I know about a research study?

- Someone will explain this research study to you.
- Whether or not you take part is up to you.
- Your participation is completely voluntary.
- You can choose not to take part.
- You can agree to take part and later change your mind.
- Your decision will not be held against you.
- Your refusal to participate will not result in any consequences or any loss of benefits that you are otherwise entitled to receive.
- You can ask all the questions you want before you decide.

Why is this research being done?

The literature on sleep patterns of young adults, aged 18-25 years, suggests that short sleep, defined as less than 6 hours per night, is prevalent in this population. Short sleep results in impaired attention and memory which impact learning and academic performance. However, existing interventions are not enough to specifically target these negative effects of short sleep in student populations.

Research has shown meditation techniques to be effective in restoring cognitive functions, such as attention and short-term memory, following sleep deprivation. Therefore, this research is an opportunity to examine the potential effectiveness of a 10-minute meditation intervention called Non-Sleep Deep Rest (NSDR), in overcoming the cognitive consequences of short sleep in adult student populations.

How long will the research last and what will I need to do?

We expect that you will be in this research study for a period of three weeks which involve three Zoom meetings with the researcher. The meetings will consist of a familiarization with the study procedures, an initial experimental session, and a final experimental session. The Zoom meetings will be one-to-one which will be scheduled according to your availability. During these sessions you will be asked to listen to two audio files, Non-Sleep Deep Rest (NSDR) and podcast, for 10 minutes, and you will perform two tasks, the Stroop Color and Word Test (SCWT) and the n-Back Task, to test for attention and working memory, respectively. Please refer to the ***Detailed Information*** section below for a detailed explanation of all research procedures.

Is there any way being in this study could be bad for me?

The study involves collecting information about you including identifiers and sensitive information about use of sleep medications. Potential risks include breach of confidentiality if the information obtained by the researcher is disclosed outside the research setting. This could adversely affect you psychological, social, or economic status. The researcher will take necessary steps to minimize any risks. Your data will be coded for identifiers and code lists and data files will be encrypted and stored separately in a password protected computer. At the conclusion of the final research meeting, all identifiers will be permanently discarded and aggregate reporting will be used in the research manuscript.

Will being in this study help me in any way?

We cannot promise any benefits to you or others from your taking part in this research. However, possible benefits include improvement in cognitive functions, such as working memory and attention, following sleep loss and may result in improvements in learning and academic performance. However, these benefits possibly depend on performing the intervention and may not continue after the research has ended.

What happens if I do not want to be in this research?
Participation in research is completely voluntary. You can decide to participate, not participate, or discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled.

Your alternative to participating in this research study is to not participate.

Detailed Information

The following is more detailed information about this study in addition to the information listed above.

What is the purpose of this research?
The prevalence of short sleep in young adults in association with its adverse physical, mental, cognitive, and academic consequences has been well documented. Biological delay in circadian rhythms combined with social factors and poor sleep habits exposes university students to the risk of developing chronic sleep deprivation. However, despite a range of effective interventions aiming to improve sleep, this group continues to suffer sleep loss. While increasing total sleep time in these youth is crucial, it may be of value to assess time-efficient and accessible interventions to overcome the adverse cognitive outcomes of short sleep. The purpose of this research is to test a short Non-Sleep Deep Rest (NSDR) intervention to counter cognitive consequences of short sleep duration, including working memory and attention. Unlike standard yoga practices, NSDR does not require movement in difficult postures but can be performed in a seated or lying down position with closed eyes and by following guidelines delivered through an audio recording. Specifically, the research hopes to answer whether a brief, 10-minute NSDR protocol could counter the cognitive effects of reduced total sleep time and lead to short-term positive outcomes in working memory and attention in healthy adult students.

How long will I take part in this research?
You will take part in this research for a period of 3 weeks which will include 3 online meetings on Zoom. Each visit will last approximately 1 hour and 20 minutes. The research will include the following surveys, psychometric tests, and audios:

- **Pittsburg Sleep Quality Index (PSQI):**
  The PSQI is a 19-item self-report questionnaire that assesses your sleep quality. Its seven components include subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction.
  The PSQI is to be completed once for screening and takes 10 minutes to complete.

- **Consensus Sleep Diary (CSD):**
  The CSD gathers information about your daily sleep pattern which includes bedtime, sleep time, nighttime awakenings and their duration, wake time, sleep duration, and sleep quality, etc.
  The CSD is to be completed daily for two weeks within one hour of getting out of bed in the morning. It takes 2 minutes/day, 30 minutes total.

- **Stroop Color and Word Test (SCWT):**
  The SCWT is a psychological test used to evaluate attention. In this test, you will see colored words (like GREEN, or BLUE). You will need to respond to the color of the words (not the meaning) by pressing the corresponding key (r, g, b, y for red, green, blue, and yellow stimuli).
  The SCWT is to be administered twice per session, pre- and post-intervention. It takes 10 minutes/session, 20 minutes total.

- **N-back (2-back) Task:**
  The n-back task is used to assess working memory capacity. In the n-back (2-back) task, you will see letters. Each letter is shown for a few seconds. You will need to decide if you saw the same letter 2 letters ago. If you saw the same letter 2 letters ago, you press the “m” key.
  The n-back (2-back) task is to be administered twice per session, pre- and post-intervention. It takes 20 minutes/session, 40 minutes total.

- **Non-Sleep Deep Rest (NSDR) Audio:**
  Non-Sleep Deep Rest (NSDR) is a nervous system relaxation tool based on the traditional practice of Yoga Nidra. You will be required to listen to an audio recording of a guided NSDR protocol developed by Dr. Andrew Huberman for Virtusan App. The audio starts with a brief introduction to the NSDR protocol and explains how specific forms of breathing bring the nervous system into a deep relaxation state by slowing down the heart rate. You will be instructed to adopt a seated or supine position with closed eyes, after which you will be directed to focus your attention on various parts of the body. Throughout the practice, you are expected to breathe normally unless instructed otherwise. The protocol will end by asking you to open your eyes and observe your perceptions. The NSDR audio is to be listened to once with 10 minutes listening time.

- **Podcast Audio:**
  You will be required to listen to a podcast taken from the Huberman Lab series that discusses science-based tools to optimize physical and mental health. The podcast audio is to be listened to once with 10 minutes listening time.

What happens if I say yes, I want to be in this research?

In the first Zoom meeting you will be introduced to the research procedures and your questions regarding the study will be discussed. You will be given a sleep diary to fill out every morning for 2 weeks, 1 hour after waking up, which takes about 2 minutes to complete. The research involves listening to a guided meditation called Non-Sleep Deep Rest (NSDR) and a podcast audio, each lasting 10 minutes. You will listen to these audios for familiarization. Following this, you will be given two tasks, the Stroop Color and Word Test (SCWT) and the n-Back Task, for familiarization. One week after the introductory meeting you will be invited to the Zoom meeting for the first experimental session. You will be asked to complete both the abovementioned tasks, which take about 30 minutes to complete. After that you will be assigned to either a NSDR group or a podcast group where you will listen to the audio for 10 minutes through a headphone in a seated position. Then, both the SCWT and n-back will be repeated 5 minutes after the completion of the audio. Similar procedures will be repeated in the third and final meeting except that you will be assigned to a podcast group if you were in the NSDR group in the previous session and vice versa. This will conclude your participation in the research and you will be compensated with course credit. Please refer to the schematic below for research procedures and time description. Throughout the duration of the research, you will interact with the researcher only. All study procedures will be performed online on Zoom at 11:00 am. You will receive reminders via email at least 48 hours prior to each meeting.

What happens if I say yes, but I change my mind later?

You can leave the research at any time; it will not be held against you. Any data collected to the point of withdrawal will be discarded. There will be no follow-up procedures or data collection after your withdrawal from the research.

If I take part in this research, how will my privacy be protected? What happens to the information you collect?

Efforts will be made to limit the use and disclosure of your Personal Information, including your name, contact, email, age, and research data, to people who have a need to review this information. We cannot promise complete secrecy. Organizations that may inspect and copy your information include the IRB and other representatives of this organization.

If identifiers are removed from your identifiable private information or identifiable samples that are collected during this research, that information or those samples could be used for future research studies or distributed to another investigator for future research studies without your additional informed consent. All identifiable private information will be removed from the data and discarded after the final research meeting and the data without any identifiers will be retained by the researcher for an indefinite period of time.

Can I be removed from the research without my OK?

The person in charge of the research study or the sponsor can remove you from the research study without your approval. Possible reasons for removal include any discomfort or distress from research-related activities and failure to comply with the research procedures.

Who can I talk to?

If you have questions, concerns, or complaints, or think the research has hurt you, talk to the research team at gha798@g.harvard.edu.

This research has been reviewed and approved by the Harvard University Area Institutional Review Board ("IRB"). You may talk to them at +1 (617) 496-2847 or cuhs@harvard.edu if:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team.
- You want to talk to someone besides the research team.
- You have questions about your rights as a research subject.
- You want to get information or provide input about this research.

☐ By clicking this box, I declare that I have read and understood the consent form and I agree to take part in this research.

Appendix D.

Pre-Screening Form

Research Description:
The purpose of this research is to test the effect of a meditation intervention called Yoga Nidra in improving working memory and attention following sleep loss in adult students. This study consists of filling out an online screening test called the Pittsburg Sleep Quality Index which has questions about your regular sleep habits in the past month only. After filling this out you will be invited for an introductory session on Zoom if you meet the inclusion criteria. This session will help you familiarize with all the research material and procedures including the Yoga Nidra and Podcast audios and Stroop Color and Word Task and n-back tasks. You will also have a chance to ask any questions about the research.

Next, you will complete a sleep diary within an hour after waking up for a period of one week. Then, you will be invited for the first research meeting on Zoom at 11:00 am and take complete cognitive tasks. There will be a 5-minute break after which you will listen to either the Yoga Nidra audio or the Podcast audio. This will be followed by another 5-minute break and lastly you will complete the two cognitive tasks again. This whole session will last for about 1 hour and 20 mins.

You will then have to complete the sleep diary within an hour after waking up for another week. After one week, you will be invited for the second and last research meeting on Zoom at 11:00 am to complete the same study procedures.

Does this sound interesting to you? If so, there are certain questions you must answer to see if you qualify. You are free to withdraw at any time.

Responses to the following questions are both confidential and voluntary. There are no right or wrong answers. You can elect not to answer any questions you do not feel comfortable answering. Please note, however, that questions that are not answered may cause you to be ineligible to complete the experimental portion of the study.

1. What is your age? __________
2. Are you currently a student at a university? __________
   Undergraduate or graduate? __________
3. How much sleep do you usually get per night? __________
4. Do you currently practice meditation? Yes / No

5. Are you currently a smoker? Yes / No
6. Are you currently taking any psychiatric or sleep medications? Yes / No
7. Do you use any other drugs (marijuana, etc.)? Yes / No
8. Have you ever had any problems with alcohol or drug abuse? Yes / No

Only if subject meets study criteria:

9. First and last name ____________________________
10. Best telephone number to reach you at during the day ____________________________
11. E-mail address ____________________________

Appendix E.

Pittsburgh Sleep Quality Index (PSQI)

Welstein, L.; Dement, W.C.; Redington, D.; and Guilleminault, C. Insomnia in the San Francisco Bay Area: A telephone survey. *Sleep/Wake Disorders: Natural History, Epidemiology, and Long-Term Evolution.* New York: Raven Press, 1983. pp. 73-85.

Appendix. Pittsburgh Sleep Quality Index (PSQI)

Instructions:
The following questions relate to your usual sleep habits during the past month *only*. Your answers should indicate the most accurate reply for the *majority* of days and nights in the past month. Please answer all questions.

1. During the past month, when have you usually gone to bed at night?
   USUAL BED TIME ____________
2. During the past month, how long (in minutes) has it usually take you to fall asleep each night?
   NUMBER OF MINUTES ____________
3. During the past month, when have you usually gotten up in the morning?
   USUAL GETTING UP TIME ____________
4. During the past month, how many hours of *actual sleep* did you get at night? (This may be different than the number of hours you spend in bed.)
   HOURS OF SLEEP PER NIGHT ____________

For each of the remaining questions, check the one best response. Please answer *all* questions.

5. During the past month, how often have you had trouble sleeping because you...

(a) Cannot get to sleep within 30 minutes

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(b) Wake up in the middle of the night or early morning

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(c) Have to get up to use the bathroom

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(d) Cannot breathe comfortably

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(e) Cough or snore loudly

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(f) Feel too cold

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(g) Feel too hot

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(h) Had bad dreams

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(i) Have pain

Not during the past month ____	Less than once a week ____	Once or twice a week ____	Three or more times a week ____

(j) Other reason(s), please describe ____

____

How often during the past month have you had trouble sleeping because of this?

Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

6. During the past month, how would you rate your sleep quality overall?

Very good _______
Fairly good _______
Fairly bad _______
Very bad _______

7. During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?

Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

No problem at all _______
Only a very slight problem _______
Somewhat of a problem _______
A very big problem _______

10. Do you have a bed partner or roommate?

No bed partner or roommate _______
Partner/roommate in other room _______
Partner in same room, but not same bed _______
Partner in same bed _______

If you have a roommate or bed partner, ask him/her how often in the past month you have had...

(a) Loud snoring

Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

(b) Long pauses between breaths while asleep

Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

(c) Legs twitching or jerking while you sleep

Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

(d) Episodes of disorientation or confusion during sleep

Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

(e) Other restlessness while you sleep; please describe ________________________________

____

Not during the past month _____ Less than once a week _____ Once or twice a week _____ Three or more times a week _____

Appendix F.

Consensus Sleep Diary (CSD-M)

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NSDR Study – Sleep Diary Instructions (CSD-M)

General Instructions

What is a Sleep Diary? A sleep diary is designed to gather information about your daily sleep pattern.

How often and when do I fill out the sleep diary? It is necessary for you to complete your sleep diary <u>every day</u>. If possible, the sleep diary should be completed within one hour of getting out of bed in the morning.

What should I do if I miss a day? If you forget to fill in the diary or are unable to finish it, leave the diary blank for that day.

What if something unusual affects my sleep or how I feel in the daytime? If your sleep or daytime functioning is affected by some unusual event (such as an illness, or an emergency) you may make brief notes on your diary.

What do the words "bed" and "day" mean on the diary? This diary can be used for people who are awake or asleep at unusual times. In the sleep diary, the word "day" is the time when you choose or are required to be awake. The term "bed" means the place where you usually sleep.

Will answering these questions about my sleep keep me awake? This is not usually a problem. You should not worry about giving exact times, and you should not watch the clock. Just give your best estimate.

Sleep Diary Item Instructions

Use the guide below to clarify what is being asked for each item of the Sleep Diary.

Date: Write the date of the morning you are filling out the diary.

1. What time did you get into bed? Write the time that you got into bed. This may not be the time you began "trying" to fall asleep.

2. What time did you try to go to sleep? Record the time that you began "trying" to fall asleep.

3. How long did it take you to fall asleep? Beginning at the time you wrote in question 2, how long did it take you to fall asleep.

4. How many times did you wake up, not counting your final awakening? How many times did you wake up between the time you first fell asleep and your final awakening?

5. In total, how long did these awakenings last? What was the total time you were awake between the time you first fell asleep and your final awakening. For example, if you woke 3 times for 20 minutes, 35 minutes, and 15 minutes, add them all up (20+35+15= 70 min or 1 hr and 10 min).

6a. What time was your final awakening? Record the last time you woke up in the morning.

6b. After your final awakening, how long did you spend in bed trying to sleep? After the last time you woke-up (Question 6a), how many minutes did you spend in bed trying to sleep? For example, if you woke up at 8 am but continued to try and sleep until 9 am, record 1 hour.

6c. Did you wake up earlier than you planned? If you woke up or were awakened earlier than you planned, check yes. If you woke up at your planned time, check no.

6d. If yes, how much earlier? If you answered "yes" to question 6c, write the number of minutes you the alarm went off, record 15 minutes here.

7. What time did you get out of bed for the day? What time did you get out of bed with no further attempt at sleeping? This may be different from your final awakening time (e.g. you may have woken up at 6:35 a.m. but did not get out of bed to start your day until 7:20 a.m.)

8. In total, how long did you sleep? This should just be your best estimate, based on when you went to bed and woke up, how long it took you to fall asleep, and how long you were awake. You do not need to calculate this by adding and subtracting; just give your best estimate.

9. How would you rate the quality of your sleep? "Sleep Quality" is your sense of whether your sleep was good or poor.

10. How restful or refreshed did you feel when you woke up for the day? This refers to how you felt after you were done sleeping for the night, during the first few minutes that you were awake.

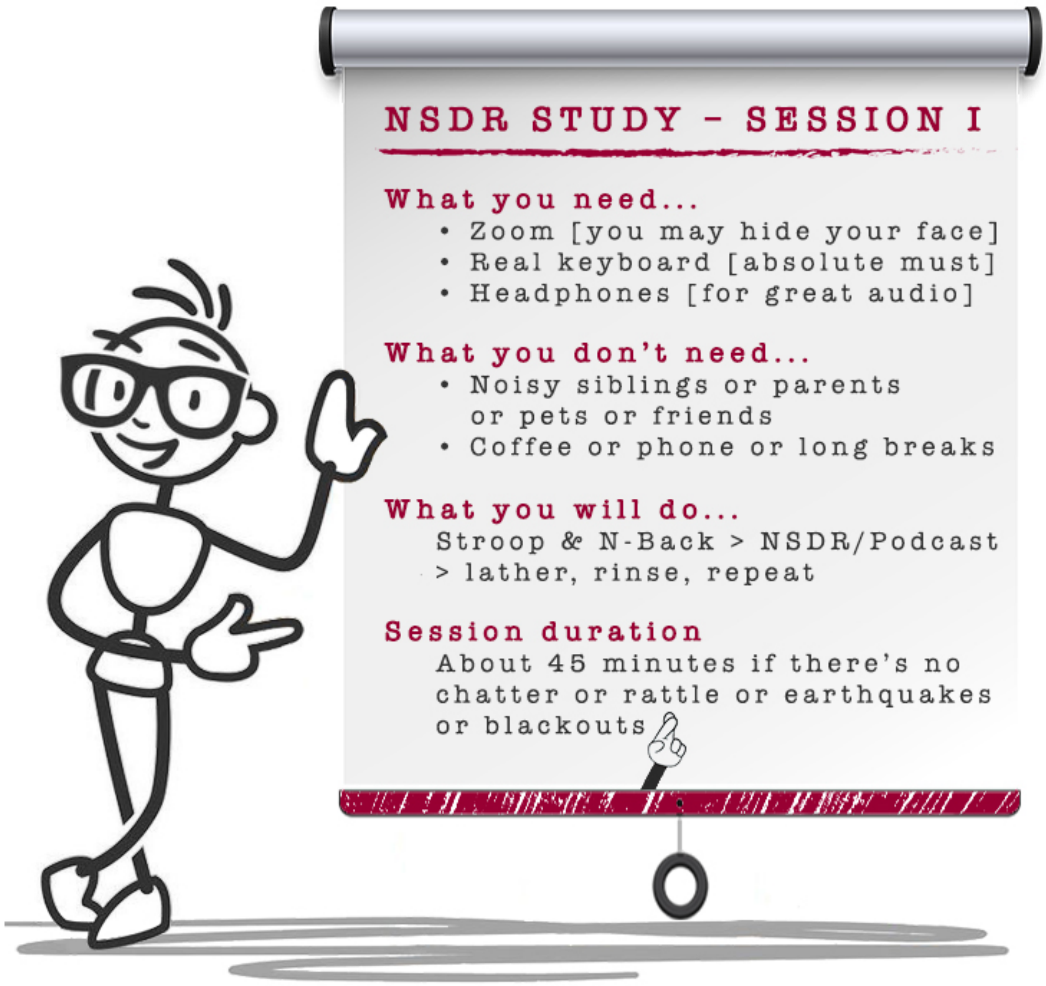
WEEK 1 **Consensus Sleep Diary (please complete upon awakening)** **UID:**

	Sample							
Today's Date	**11/04/23**							
1. What time did you get into bed?	10:15 p.m.							
2. What time did you try to go to sleep?	11:30 p.m.							
3. How long did it take you to fall asleep?	55 min.							
4. How many times did you wake up, not counting your final awakening?	6 times							
5. In total, how long did these awakenings last?	2 hours 5 min.							
6a. What time was your final awakening?	6:35 a.m.							
6b. After your final awakening, how long did you spend in bed trying to sleep?	45 min.							
6c. Did you wake up earlier than you planned?	☑ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
6d. If yes, how much earlier?	1 hour							
7. What time did you get out of bed for the day?	7:20 a.m.							
8. In total, how long did you sleep?	4 hours 10 min.							
9. How would you rate the quality of your sleep?	☐ Very Poor ☑ Poor ☐ Fair ☐ Good ☐ Very Good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good	☐ Very poor ☐ Poor ☐ Fair ☐ Good ☐ Very good
10. How rested or refreshed did you feel when you woke-up for the day?	☐ Not at all rested ☑ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested	☐ Not at all rested ☐ Slightly rested ☐ Somewhat rested ☐ Well-rested ☐ Very well-rested

NOTES

Appendix G.

Experiment Session Requirements



Appendix H.

Progress Update

Appendix I.

Acknowledgement Note

References

Ahrberg, K., Dresler, M., Niedermaier, S., Steiger, A., & Genzel, L. (2012). The interaction between sleep quality and academic performance. *Journal of Psychiatric Research*, *46*(12), 1618–1622. https://doi.org/10.1016/j.jpsychires.2012.09.008

Armitage, J., & Eerola, T. (2020). Reaction Time Data in Music Cognition: Comparison of Pilot Data From Lab, Crowdsourced, and Convenience Web Samples. *Frontiers in Psychology*, *10*, 2883. https://doi.org/10.3389/fpsyg.2019.02883

Ban, D. J., & Lee, T. J. (2001). Sleep Duration, Subjective Sleep Disturbances and Associated Factors Among University Students in Korea. *Journal of Korean Medical Science*, *16*(4), 475. https://doi.org/10.3346/jkms.2001.16.4.475

Bartels, C., Wegrzyn, M., Wiedl, A., Ackermann, V., & Ehrenreich, H. (2010). Practice effects in healthy adults: A longitudinal study on frequent repetitive cognitive testing. *BMC Neuroscience*, *11*(1), 118–118. https://doi.org/10.1186/1471-2202-11-118

Basso, J. C., McHale, A., Ende, V., Oberlin, D. J., & Suzuki, W. A. (2019). Brief, daily meditation enhances attention, memory, mood, and emotional regulation in non-experienced meditators. *Behavioural Brain Research*, *356*, 208–220. https://doi.org/10.1016/j.bbr.2018.08.023

Baum, K. T., Desai, A., Field, J., Miller, L. E., Rausch, J., & Beebe, D. W. (2014). Sleep restriction worsens mood and emotion regulation in adolescents. *Journal of Child Psychology and Psychiatry*, *55*(2), 180–190. https://doi.org/10.1111/jcpp.12125

Beebe, D. W., Fallone, G., Godiwala, N., Flanigan, M., Martin, D., Schaffner, L., & Amin, R. (2008). Feasibility and behavioral effects of an at-home multi-night sleep restriction protocol for adolescents. *Journal of Child Psychology and Psychiatry*, *49*(9), 915–923. https://doi.org/10.1111/j.1469-7610.2008.01885.x

Benedict, R. H. B., & Zgaljardic, D. J. (1998). Practice Effects During Repeated Administrations of Memory Tests With and Without Alternate Forms. *Journal of Clinical and Experimental Neuropsychology*, *20*(3), 339–352. https://doi.org/10.1076/jcen.20.3.339.822

Blampied, N. M. (2022). Reliable change and the reliable change index: Still useful after all these years? *The Cognitive Behaviour Therapist*, *15*, e50. https://doi.org/10.1017/S1754470X22000484

Braver, T. S., Cohen, J. D., Nystrom, L. E., Jonides, J., Smith, E. E., & Noll, D. C. (1997). A Parametric Study of Prefrontal Cortex Involvement in Human Working Memory. *NeuroImage (Orlando, Fla.)*, *5*(1), 49–62. https://doi.org/10.1006/nimg.1996.0247

Brefczynski-Lewis, J. A., Lutz, A., Schaefer, H. S., Levinson, D. B., & Davidson, R. J. (2007). Neural correlates of attentional expertise in long-term meditation practitioners. *Proceedings of the National Academy of Sciences*, *104*(27), 11483–11488. https://doi.org/10.1073/pnas.0606552104

Brickenkamp, R. (1962). *Test d2: Aufmerksamkeits-belastungs-test*.

Brown, C., Qin, P., & Esmail, S. (2017). "Sleep? Maybe Later…" A Cross-Campus Survey of University Students and Sleep Practices. *Education Sciences*, *7*(3), 66. https://doi.org/10.3390/educsci7030066

Buboltz Jr, W., Jenkins, S. M., Soper, B., Woller, K., Johnson, P., & Faes, T. (2009). Sleep Habits and Patterns of College Students: An Expanded Study. *Journal of College Counseling*, *12*(2), 113–124. https://doi.org/10.1002/j.2161-1882.2009.tb00109.x

Buysse, D. J., Reynolds, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. *Psychiatry Research*, *28*(2), 193–213. https://doi.org/10.1016/0165-1781(89)90047-4

Carney, C. E., Buysse, D. J., Ancoli-Israel, S., Edinger, J. D., Krystal, A. D., Lichstein, K. L., & Morin, C. M. (2012). The Consensus Sleep Diary: Standardizing Prospective Sleep Self-Monitoring. *Sleep*, *35*(2), 287–302. https://doi.org/10.5665/sleep.1642

Carpi, M., Cianfarani, C., & Vestri, A. (2022). Sleep Quality and Its Associations with Physical and Mental Health-Related Quality of Life among University Students: A Cross-Sectional Study. *International Journal of Environmental Research and Public Health*, *19*(5), 2874-. https://doi.org/10.3390/ijerph19052874

Ciapponi, A., Belizán, J. M., Piaggio, G., & Yaya, S. (2021). There is life beyond the statistical significance. *Reproductive Health*, *18*(1), 80, s12978-021-01131-w. https://doi.org/10.1186/s12978-021-01131-w

Claßen, M., Friedrich, A., & Schlarb, A. A. (2022). Sleep better—Think better! - The effect of CBT-I and HT-I on sleep and subjective and objective neurocognitive performance in university students with insomnia. *Cogent Psychology*, *9*(1). https://doi.org/10.1080/23311908.2022.2045051

Curcio, G., Ferrara, M., & De Gennaro, L. (2006). Sleep loss, learning capacity and academic performance. *Sleep Medicine Reviews*, *10*(5), 323–337. https://doi.org/10.1016/j.smrv.2005.11.001

Datta, K., Mallick, H. N., Tripathi, M., Ahuja, N., & Deepak, K. K. (2022). Electrophysiological Evidence of Local Sleep During Yoga Nidra Practice. *Frontiers in Neurology*, *13*, 910794. https://doi.org/10.3389/fneur.2022.910794

Datta, K., Tripathi, M., Verma, M., Masiwal, D., & Mallick, H. N. (2021). *Yoga nidra* practice shows improvement in sleep in patients with chronic insomnia: A randomized controlled trial. *The National Medical Journal of India*, *34*, 143–150. https://doi.org/10.25259/NMJI_63_19

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using GPower 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149–1160. https://doi.org/10.3758/BRM.41.4.1149

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). GPower 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/BF03193146

Fleckenstein, J., Gerten, S., & Banzer, W. (2022). Preventive Effects of a Single Bout of Exercise on Memory and Attention following One Night of Sleep Loss in Sports Students: Results of a Randomized Controlled Study. *Behavioral Sciences*, *12*(10), 350-. https://doi.org/10.3390/bs12100350

Friedrich, A., & Schlarb, A. A. (2017). Let’s talk about sleep: A systematic review of psychological interventions to improve sleep in college students. *Journal of Sleep Research*, *27*(1), 4–22. https://doi.org/10.1111/jsr.12568

Fu, L., Wei, S., Cheng, J., Wang, X., Zhou, Y., Li, Y., & Zheng, H. (2022). Effectiveness of a Mindfulness-Based Group Intervention for Chinese University Students with Sleep Problems. *International Journal of Environmental Research and Public Health*, *19*(2), 755. https://doi.org/10.3390/ijerph19020755

Gao, C., Terlizzese, T., & Scullin, M. K. (2019). Short sleep and late bedtimes are detrimental to educational learning and knowledge transfer: An investigation of individual differences in susceptibility. *Chronobiology International*, *36*(3), 307–318. https://doi.org/10.1080/07420528.2018.1539401

Gau, S. S. F., Kessler, R. C., Tseng, W.-L., Wu, Y.-Y., Chiu, Y.-N., Yeh, C.-B., & Hwu, H.-G. (2007). Association between sleep problems and symptoms of attention-deficit/hyperactivity disorder in young adults. *Sleep: Journal of Sleep and Sleep Disorders Research*, *30*(2), 195–201. https://doi.org/10.1093/sleep/30.2.195

Gaultney, J. F. (2010). The Prevalence of Sleep Disorders in College Students: Impact on Academic Performance. *Journal of American College Health*, *59*(2), 91–97. https://doi.org/10.1080/07448481.2010.483708

Germine, L., Nakayama, K., Duchaine, B. C., Chabris, C. F., Chatterjee, G., & Wilmer, J. B. (2012). Is the Web as good as the lab? Comparable performance from Web and lab in cognitive/perceptual experiments. *Psychonomic Bulletin & Review*, *19*(5), 847–857. https://doi.org/10.3758/s13423-012-0296-9

Giraudier, M., Ventura-Bort, C., Wendt, J., Lischke, A., & Weymar, M. (2022). Memory advantage for untrustworthy faces: Replication across lab- and web-based studies. *PLOS ONE*, *17*(2), e0264034. https://doi.org/10.1371/journal.pone.0264034

Green, E., & Green, A. (1977). *Beyond biofeedback*. Delacorte Press/S. Lawrence.

Guo, N., Tsun Luk, T., Wu, Y., Lai, A. Y.-K., Li, Y., Cheung, D. Y. T., Wong, J. Y.-H., Fong, D. Y. T., & Wang, M. P. (2022). Between- and within-person associations of mobile gaming time and total screen time with sleep problems in young adults: Daily assessment study. *Addictive Behaviors*, *134*, 107408. https://doi.org/10.1016/j.addbeh.2022.107408

Hale, L., & Guan, S. (2014). Screen time and sleep among school-aged children and adolescents: A systematic literature review. *Sleep Medicine Reviews*, *21*, 50–58. https://doi.org/10.1016/j.smrv.2014.07.007

Hancevich, A., Hernández Lloreda, M. J., & Sánchez Bernardos, M. L. (2022). Associations between Extraversion and Working Memory: A facet-level correlational research. *Personality and Individual Differences*, *194*, 111660-. https://doi.org/10.1016/j.paid.2022.111660

Horton, J. J., Rand, D. G., & Zeckhauser, R. J. (2011). The online laboratory: Conducting experiments in a real labor market. *Experimental Economics*, *14*(3), 399–425. https://doi.org/10.1007/s10683-011-9273-9

Huber, R., Felice Ghilardi, M., Massimini, M., & Tononi, G. (2004). Local sleep and learning. *Nature*, *430*(6995), 78–81. https://doi.org/10.1038/nature02663

Huberman, A. (n.d.). *Dr. Gina Poe: Use Sleep to Enhance Learning, Memory & Emotional State* (111).

Jacobson, N. S., Follette, W. C., & Revenstorf, D. (1984). Psychotherapy outcome research: Methods for reporting variability and evaluating clinical significance. *Behavior Therapy*, *15*(4), 336–352. https://doi.org/10.1016/S0005-7894(84)80002-7

Jaeggi, S. M., Buschkuehl, M., Perrig, W. J., & Meier, B. (2010). The concurrent validity of the N-back task as a working memory measure. *Memory (Hove)*, *18*(4), 394–412. https://doi.org/10.1080/09658211003702171

Jones, É., & Vlachou, S. (2021). Cannabidiol Does Not Cause Significant Changes to Working Memory Performance in the N-Back Task. *Pharmaceuticals*, *14*(11), 1165. https://doi.org/10.3390/ph14111165

Jun, E., Hsieh, G., & Reinecke, K. (2017). Types of Motivation Affect Study Selection, Attention, and Dropouts in Online Experiments. *Proceedings of the ACM on Human-Computer Interaction*, *1*(CSCW), 1–15. https://doi.org/10.1145/3134691

Kane, M. J., Conway, A. R. A., Miura, T. K., & Colflesh, G. J. H. (2007). Working Memory, Attention Control, and the N-Back Task: A Question of Construct Validity. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *33*(3), 615–622. https://doi.org/10.1037/0278-7393.33.3.615

Kim, J., Gabriel, U., & Gygax, P. (2019). Testing the effectiveness of the Internet-based instrument PsyToolkit: A comparison between web-based (PsyToolkit) and lab-based (E-Prime 3.0) measurements of response choice and response time in a complex psycholinguistic task. *PLOS ONE*, *14*(9), e0221802. https://doi.org/10.1371/journal.pone.0221802

Kirchner, W. K. (1958). Age differences in short-term retention of rapidly changing information. *Journal of Experimental Psychology*, *55*(4), 352–358. https://doi.org/10.1037/h0043688

Kohler, M., Rawlings, M., Kaeding, A., Banks, S., & Immink, M. A. (2017). Meditation is Effective in Reducing Sleepiness and Improving Sustained Attention Following Acute Sleep Restriction. *Journal of Cognitive Enhancement*, *1*(2), 210–218. https://doi.org/10.1007/s41465-017-0032-5

Kumar, K., & Joshi, B. (2009). Study on the effect of Pranakarshan pranayama and Yoga nidra on alpha EEG & GSR. *Indian Journal of Traditional Knowledge*, *8*(3), 453–454. http://nopr.niscpr.res.in/handle/123456789/5093

Lack, L. C. (1986). Delayed Sleep and Sleep Loss in University Students. *Journal of American College Health*, *35*(3), 105–110. https://doi.org/10.1080/07448481.1986.9938970

Léger, D., Roscoat, E. du, Bayon, V., Guignard, R., Pâquereau, J., & Beck, F. (2011). Short sleep in young adults: Insomnia or sleep debt? Prevalence and clinical description of short sleep in a representative sample of 1004 young adults from France. *Sleep Medicine*, *12*(5), 454–462. https://doi.org/10.1016/j.sleep.2010.12.012

Li, W., Yin, J., Cai, X., Cheng, X., & Wang, Y. (2020). Association between sleep duration and quality and depressive symptoms among university students: A cross-sectional study. *PloS One*, *15*(9), e0238811–e0238811. https://doi.org/10.1371/journal.pone.0238811

Linnman, C., Carlbring, P., Åhman, Å., Andersson, H., & Andersson, G. (2006). The Stroop effect on the internet. *Computers in Human Behavior*, *22*(3), 448–455. https://doi.org/10.1016/j.chb.2004.09.010

Littlewood, D. L., Kyle, S. D., Carter, L.-A., Peters, S., Pratt, D., & Gooding, P. (2019). Short sleep duration and poor sleep quality predict next-day suicidal ideation: An ecological momentary assessment study. *Psychological Medicine*, *49*(3), 403–411. https://doi.org/10.1017/S0033291718001009

Lou, H. C., Kjaer, T. W., Friberg, L., Wildschiodtz, G., Holm, S., & Nowak, M. (1999). A 15O-H2O PET study of meditation and the resting state of normal consciousness. *Human Brain Mapping*, *7*(2), 98–105. https://doi.org/10.1002/(SICI)1097-0193(1999)7:2<98::AID-HBM3>3.0.CO;2-M

Lu, L., Dong, M., Jian, S., Gao, J., Ye, L., Chen, H., Zhang, T., Liu, Y., Shen, H., Gai, X., & Liu, S. (2021). Sex differences in the factors associated with sleep duration in university students: A cross-sectional study. *Journal of Affective Disorders*, *290*, 345–352. https://doi.org/10.1016/j.jad.2021.04.025

Moore, A., Gruber, T., Derose, J., & Malinowski, P. (2012). Regular, brief mindfulness meditation practice improves electrophysiological markers of attentional control. *Frontiers in Human Neuroscience*, *6*, 18–18. https://doi.org/10.3389/fnhum.2012.00018

Morris, J., Firkins, A., Millings, A., Mohr, C., Redford, P., & Rowe, A. (2016). Internet-delivered cognitive behavior therapy for anxiety and insomnia in a higher education context. *Anxiety, Stress, and Coping*, *29*(4), 415–431. https://doi.org/10.1080/10615806.2015.1058924

Moszeik, E. N., von Oertzen, T., & Renner, K.-H. (2022). Effectiveness of a short Yoga Nidra meditation on stress, sleep, and well-being in a large and diverse sample. *Current Psychology*, *41*(8), 5272–5286. https://doi.org/10.1007/s12144-020-01042-2

Naccache, L., Gaillard, R., Adam, C., Hasboun, D., Clémenceau, S., Baulac, M., Dehaene, S., & Cohen, L. (2005). A direct intracranial record of emotions evoked by subliminal words. *Proceedings of the National Academy of Sciences*, *102*(21), 7713–7717. https://doi.org/10.1073/pnas.0500542102

NSDR Research Experiment. (n.d.). Retrieved January 23, 2024, from https://www.youtube.com/channel/UC-ngStawEjyhLvpqLLS5jtA

Pace-Schott, E. F. (2009). Sleep Architecture. In *Encyclopedia of Neuroscience* (pp. 983–989). Elsevier. https://doi.org/10.1016/B978-008045046-9.00054-1

Pace-Schott, E. F., & Jones, B. J. (2015). *Sleep and Dreaming* (pp. 9780199828340–0163) [dataset]. Oxford University Press. https://doi.org/10.1093/obo/9780199828340-0163

Parker, S. (2017). Yoga Nidrā: An Opportunity for Collaboration to Extend the Science of Sleep States. *Sleep and Vigilance*, *1*(2), 57–63. https://doi.org/10.1007/s41782-017-0026-5

Parker, S. (2019). Training attention for conscious non-REM sleep: The yogic practice of yoga-nidrā and its implications for neuroscience research. In *Progress in Brain Research* (Vol. 244, pp. 255–272). Elsevier. https://doi.org/10.1016/bs.pbr.2018.10.016

Parker, S., Bharati, S. V., & Fernandez, M. (2013). Defining yoga-nidra: Traditional accounts, physiological research, and future directions. *International Journal of Yoga Therapy*, *23*(1), 11–16. https://doi.org/10.17761/ijyt.23.1.t636651v22018148

Pilcher, J. J., Ginter, D. R., & Sadowsky, B. (1997). Sleep quality versus sleep quantity: Relationships between sleep and measures of health, well-being and sleepiness in college students. *Journal of Psychosomatic Research*, *42*(6), 583–596. https://doi.org/10.1016/S0022-3999(97)00004-4

Rattenborg, N. C., Lima, S. L., & Lesku, J. A. (2012). Sleep Locally, Act Globally. *The Neuroscientist*, *18*(5), 533–546. https://doi.org/10.1177/1073858412441086

Reips, U.-D. (2002). Standards for Internet-Based Experimenting. *Experimental Psychology*, *49*(4), 243–256. https://doi.org/10.1026//1618-3169.49.4.243

Riquelme, D., Perry, A., Ugarriza, D., Jacobs, K., Gattamorta, K., & Arwari, B. (2016). Effects Of Moderate-intensity Aerobic Exercise On Cognition And Arousal In Extrovert/introvert Personality Types: 1560 Board #213 June 2, 9. *Medicine & Science in Sports & Exercise*, *48*, 427. https://doi.org/10.1249/01.mss.0000486285.87215.a3

Scarpina, F., & Tagini, S. (2017). The Stroop Color and Word Test. *Frontiers in Psychology*, *8*. https://doi.org/10.3389/fpsyg.2017.00557

Schlarb, A., Friedrich, A., & Claßen, M. (2017). Sleep problems in university students – an intervention. *Neuropsychiatric Disease and Treatment*, *Volume 13*, 1989–2001. https://doi.org/10.2147/NDT.S142067

Semsarian, C. R., Rigney, G., Cistulli, P. A., & Bin, Y. S. (2021). Impact of an Online Sleep and Circadian Education Program on University Students’ Sleep Knowledge, Attitudes, and Behaviours. *International Journal of Environmental Research and Public Health*, *18*(19), 10180. https://doi.org/10.3390/ijerph181910180

Stickgold, R., & Walker, M. P. (2007). Sleep-dependent memory consolidation and reconsolidation. *Sleep Medicine*, *8*(4), 331–343. https://doi.org/10.1016/j.sleep.2007.03.011

Stoet, G. (2010). *PsyToolkit: A software package for programming psychological experiments using Linux*. 1096–1104. https://www.proquest.com/docview/852754672/abstract/B7D4CC4CF6D44933PQ/1

Stoet, G. (2017). PsyToolkit: A Novel Web-Based Method for Running Online Questionnaires and Reaction-Time Experiments. *Teaching of Psychology*, *44*(1), 24–31. https://doi.org/10.1177/0098628316677643

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*(6), 643–662. https://doi.org/10.1037/h0054651

Tang, Y.-Y., Ma, Y., Wang, J., Fan, Y., Feng, S., Lu, Q., Yu, Q., Sui, D., Rothbart, M. K., Fan, M., & Posner, M. I. (2007). Short-term meditation training improves attention and self-regulation. *Proceedings of the National Academy of Sciences*, *104*(43), 17152–17156. https://doi.org/10.1073/pnas.0707678104

Taylor, D. J., Bramoweth, A. D., Grieser, E. A., Tatum, J. I., & Roane, B. M. (2012). Epidemiology of Insomnia in College Students: Relationship With Mental Health, Quality of Life, and Substance Use Difficulties. *Behavior Therapy*, *44*(3), 339–348. https://doi.org/10.1016/j.beth.2012.12.001

Temkin, N. R., Heaton, R. K., Grant, I., & Dikmen, S. S. (1999). Detecting significant change in neuropsychological test performance: A comparison of four models. *Journal of the International Neuropsychological Society*, *5*(4), 357–369. https://doi.org/10.1017/S1355617799544068

Virtusan App (Director). (2022, September 11). *#NSDR (Non-Sleep Deep Rest) with Dr. Andrew Huberman*. https://www.youtube.com/watch?v=AKGrmY8OSHM

Visentin, D. C., Cleary, M., & Hunt, G. E. (2020). *The earnestness of being important*: Reporting non-significant statistical results. *Journal of Advanced Nursing*, *76*(4), 917–919. https://doi.org/10.1111/jan.14283

Werner-Seidler, A., Johnston, L., & Christensen, H. (2018). Digitally-delivered cognitive-behavioural therapy for youth insomnia: A systematic review. *Internet Interventions : The Application of Information Technology in Mental and Behavioural Health*, *11*(C), 71–78. https://doi.org/10.1016/j.invent.2018.01.007

Wolff, B., Franco, V. R., Magiati, I., Pestell, C. F., & Glasson, E. J. (2023a). Neurocognitive and self-reported psychosocial and behavioral functioning in siblings of individuals with neurodevelopmental conditions: A study using remote self-administered testing. *Journal of Clinical and Experimental Neuropsychology*, *45*(5), 513–536. https://doi.org/10.1080/13803395.2023.2259042

Wolff, B., Franco, V. R., Magiati, I., Pestell, C. F., & Glasson, E. J. (2023b). Psychosocial and neurocognitive correlates of suicidal thoughts and behaviours amongst siblings of persons with and without neurodevelopmental conditions. *Research in Developmental Disabilities*, *139*, 104566. https://doi.org/10.1016/j.ridd.2023.104566

Yang, C.-M., Wu, C.-H., Hsieh, M.-H., Liu, M.-H., & Lu, F.-H. (2003). Coping With Sleep Disturbances Among Young Adults: A Survey of First-Year College

Students in Taiwan. *Behavioral Medicine*, *29*(3), 133–138. https://doi.org/10.1080/08964280309596066