Exploring How Self-Monitoring Influences the Effects of Listening to Sleep Meditations to Improve Sleep Quality and Adherence

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Abstract

Many people have difficulties maintaining healthy sleep patterns, which is problematic as good sleep improves people's well-being. To find a potential solution, the one-week quantitative sleep study explored the following research question: To what extent does self-monitoring, as measured through an electronic sleep diary, enhance the impact of listening to meditation podcasts in improving sleep quality and adherence rates? Also, four hypotheses were tested. The hypotheses expected that the experimental and control group have better sleep quality outcomes after the study. Also, self-monitoring moderates meditation's effect on sleep quality. The experimental group has better sleep quality outcomes than the control group. Lastly, it assumed that the experimental group had higher adherence rates than the control group.

Similarly, 43 participants were recruited via WhatsApp private chat and 4 participants through the SONA System. Consequently, the convenience sampling method was used. Then, participants were assigned to the experimental or control group.

Moreover, the sleep study utilised an electronic sleep diary, a meditation podcast, and sleep questionnaires, all implemented inside the TIIM app. After the sleep intervention, the outcomes showed that listening to meditations and using a sleep diary did not increase sleep quality and adherence rates among the experimental group. Nevertheless, the control group had no sleep diary, and sleep quality improved. Besides, self-monitoring did not moderate the effects of listening to meditations and improving sleep quality. To conclude, the sleep study broadened the knowledge of the effectiveness of using a meditation podcast implemented inside an app.

Keywords: Meditation podcast, sleep diary, sleep quality

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Sleep is essential to human life to function throughout the day (Nelson et al., 2022). However, research shows that 66.67% of people have unhealthy sleep patterns and wish to improve their sleep quality. Thus, insufficient sleep has serious consequences, such as anxiety, depression and stroke (Nelson et al., 2022). In the following sections, the concepts to understand the sleep study will be clarified before elaborating on the research question and hypotheses.

Sleep Quality

Sleep quality is often subjectively self-rated by people, which refers to the emotional aspect of sleep to see how an individual feels before, while and after sleep (Nelson et al., 2022). In addition, sleep quality includes different sleep measures like sleep duration, latency, and maintenance (Fabbri et al., 2021). The American Academy of Sleep Medicine and sleep research shows that the optimal sleep duration is 6 to 8 hours among adults 18 years and above (Nelson et al., 2022). Moreover, sleep latency measures the time it takes to fall asleep; sleep latency between 16 and 30 minutes is healthy, and 60 to more minutes is related to poor sleep latency (Nelson et al., 2022). In sum, sleep quality is important because it allows people with sleep difficulties to understand whether they have sufficient sleep quality.

Self-Monitoring

Subjective sleep quality can be improved through the behaviour change technique of self-monitoring (Michie et al., 2015). Self-monitoring is when a person monitors and documents details of their behaviour to identify their patterns (Michie et al., 2015). This awareness is crucial as it allows individuals to make behaviour-change decisions to achieve the desired behaviour, like monitoring sleep to improve sleep quality (Sanders et al., 2016).

Digital Health Interventions

Exploring sleep quality and self-monitoring can be studied through a digital health intervention. The World Health Organization has defined digital health as the development of information and the application of digital technologies to increase the health of individuals (Verweel et al., 2023). Digital health interventions are beneficial as they are more flexible regarding location and time, can reach many participants, and are cost-effective compared to non-digital health interventions (Verweel et al., 2023). Conversely, even if digital health interventions have many benefits, they face challenges. The most common challenge it faces is participant engagement (Verweel et al., 2023). Sometimes, participants stop engaging with the digital health intervention, like a sleep app. Therefore, it is essential to know how to keep participants engaged. Examples are sending reminders and personalising the health intervention of a sleep app (Sucala et al., 2020).

App and Adherence

A valuable program to implement a digital health intervention is an app. Apps refer to software or computer programs created for a specific purpose (Basavaraju & Varde, 2017). Furthermore, research shows that in 2020, 6 billion people owned a smartphone, which indicates how much data researchers can gather from apps (Ananth, 2021). Collecting data through apps can be rewarding as it can increase the generalizability of the research findings due to a higher chance of obtaining a large sample size. Besides, it is easy and quick to install (Ananth, 2021). Furthermore, apps allow to send reminders to the participants, which can increase adherence rates (Burke et al., 2012). Adherence can be described as the extent the person's behaviour aligns with the agreed recommendations from the health advisor (Bertrand et al., 2022).

Electronic Sleep Diary

It is essential to mention that an electronic sleep diary can be implemented within an app to measure self-monitoring and help increase adherence rates (Burke et al., 2012). In an electronic sleep diary, users can manually track when they go to sleep and wake up. Additionally, whether they wake up multiple times during the night. Consequently, it helps users know their sleep patterns (Carney et al., 2012). Besides, individuals can increase their willingness to improve their sleep quality by becoming aware of their sleep patterns. Thus, it can increase adherence rates towards following the sleep app (Carney et al., 2012). In short, the electronic sleep diary is vital to implement as it allows people to understand their sleep patterns and quality of sleep.

Meditation Podcast

Moreover, some researchers support the effectiveness of implementing a meditation podcast within an app. Therefore, not only a sleep diary can improve sleep quality but also a meditation podcast (Rusch et al., 2019). Furthermore, a meditation podcast can be extended from a podcast or YouTube. Podcasts are audio recordings people listen to, usually via smartphones or other devices like laptops (Tobin & Guadagno, 2022). From 2017 to 2020, the number of people listening to a podcast in the UK has grown from 8.99 to 15.61 million (Tobin & Guadagno, 2022). YouTube is a free, public, online video archive, including a social networking feature platform (Soukup, 2014). Implementing a meditation podcast from the media formats YouTube and a podcast is beneficial because it has a low usage cost and threat risk. Besides, it provides impactful sleep interventions like mindfulness meditations to improve sleep quality (Liu, 2023).

Mindfulness Meditation

Notably, a meditation podcast implemented inside apps can be mindfulness meditations. Mindfulness means being aware of thoughts, feelings, and body sensations in the present moment (Nagendra et al., 2012). Studies have shown that practising mindfulness meditations between 10 and 20 minutes daily positively increases sleep quality (Nagendra et al., 2012). In addition, some studies prove that practising mindfulness meditation enhances sleep organisation, improves sleep quality, sleep regulation and stress reduction (Djonlagic et al., 2021). It can result in feeling physically good and emotionally stable, reinforcing participants to repeat the desired behaviour (Hubbling et al., 2014).

Aim of the Sleep Study

Generally, in the research field of sleep and sleep quality, there is a gap regarding the effectiveness of a sleep meditation podcast and an electronic sleep diary inserted in an app to improve sleep quality and adherence. Therefore, this sleep study explores the following research question: *To what extent does self-monitoring, as measured through an electronic sleep diary, enhance the impact of listening to meditation podcasts in improving sleep quality and adherence rates?*

By answering the research question, this paper aims to gather more data about the usefulness of an electronic sleep diary, moderating the effect of sleep meditations in improving sleep quality and adherence. Importantly, the outcomes can contribute to finding a potential solution for helping people maintain healthy sleep patterns. Furthermore, even if using a sleep diary and listening to meditations does not significantly improve sleep quality, it still widens the knowledge regarding improving sleep to investigate what methods do and do not work (Farrugia et al., 2010). Besides, the findings can help people be more open and trusting to seek help from a digital sleep intervention, like a sleep app and meditation podcast (Rusch et al., 2019). It also

helps to refine the hypotheses, identify confounding variables and create new research questions (Farrugia et al., 2010).

The main characteristic of this sleep study is that the intervention will last one week. The main reason for choosing this time frame is because studies that conducted a one-week sleep study, which are few, still succeeded in their intervention (Huberty et al., 2021). Additionally, studies show that listening to short sleep meditations has similar effects to long sleep meditations in improving sleep quality (Nagendra et al., 2012).

Subsequently, four hypotheses will be explored, which guide the discourse of the following research paper:

H1: *Listening to sleep meditations for one week significantly improves self-reported sleep quality among the experimental and control group assessed from the pre- and post-questionnaire.*

H2: *Self-monitoring measured through the sleep diary, moderates the effect between the sleep meditations and self-reported sleep quality.*

H3: *The experimental group will exhibit significant higher improvement in sleep quality compared to the control group assessed from the pre- and post-questionnaire.*

H4: *The experimental group who self-monitors their sleep is more likely to adhere to the sleep study compared to the control group assessed through the Evaluation Questionnaire.*

Methods

Design

A non-randomised controlled trial was conducted to ensure an even group size among the experimental and control group. This means groups were not randomly assigned to the

experimental or control group. In this approach, the researcher manually assigned participants to the groups and counted that both groups had almost the same sample size. The researcher conducted this through the TIIM Dashboard.

Participants

The inclusion criteria included people aged 18 years and above who understood English and had a smartphone to download the TIIM app. The exclusion criteria were people who took sleep medication and who had a diagnosed sleep disorder, which have been excluded after having filled out the screening questions.

Participants of the study had two ways to enter the sleep study. The first one was by being a psychology student from the University of Twente. Participants registered themselves through the SONA System to participate in the sleep study and received 0.75 Sona points when completing the study. Besides, the SONA System is a web-based application provided by the University of Twente (Faculty of Behavioural, Management and Social Sciences, n.d.). It allows researchers to publish their studies, and students receive Sona points that are sometimes essential to complete their university degree.

Moreover, convenience sampling was used as the participants were easy to gather for the sleep study through the SONA System (Berndt, 2020). The sleep study recruitment period occurred from November 13, 2023, to November 20, 2023. Four out of seven participants finished the sleep study and met the inclusion criteria.

The other way participants were gathered was through WhatsApp in private chat. Therefore, the convenience sampling method was used based on proximity and familiarity of the participants. The first recruitment period was from October 03, 2023, to October 24, 2023. The second recruitment period lasted from November 06, 2023, to November 14, 2023. Initially, 64

people were willing to participate in both recruitment periods, but only 43 started the sleep study and met the inclusion criteria.

Table 1

Demographic Characteristics of the Participants of the Experimental and Control Group

Demographics	Categories	Experimental Group	Control Group
Gender	Male	4 (16.67%)	4 (17.39%)
	Female	20 (83.33%)	18 (78.26%)
	Other		1 (4.35%)
Age	Adults	18 to 35	18 to 64
Mean (SD)		22.87 (3.67)	28.95 (14.03)
Nationality	German	20 (83.33%)	19 (82.61%)
	Dutch	1 (4.17%)	1 (4.35%)
	Other	3 (12.50%)	3 (13.04%)
Education level	Lower sec. education	0	1 (4.35%)
	Higher sec. education	12 (50.0%)	12 (52.17%)
	Bachelor's degree	9 (37.50%)	6 (37.04%)
	Master´s degree	3 (12.50%)	4 (17.39%)

Note. The percentages are based on the total number of participants in each category.

Materials

The Twente Intervention and Interaction Machine

According to the Faculty of Behavioural, Management and Social Sciences (n.d.), TIIM is an effective software for obtaining data. It allows students, teachers, and researchers from the University of Twente to create interventions or questionnaires through the TIIM Dashboard web application. Besides, the sleep study was conducted on TIIM because all the tasks could be inserted in the TIIM app, giving the users a clear overview and structure that was easy to follow (Faculty of Behavioural, Management and Social Sciences, n.d). In addition, reminders could be implemented into each module to ensure the users could follow and complete the sleep study and avoid obtaining missing data. Lastly, on the TIIM Dashboard, the sleep study was designed with pictures, titles, and descriptions, which made it visually more appealing for the participants.

Informed Consent, Demographic Questions and Screening Questions

The informed consent, demographic, and screening questions were implemented into one module to ensure that participants meeting the inclusion criteria continued with the sleep study (see Appendix B and C). The participants were screened for meeting the criteria through these questions: “How old are you?”, “Do you take medication to be able to sleep?” and “Have you previously been diagnosed with a clinical sleep disorder?”. These questions enhanced the internal validity as only people who did not have severe sleep problems and were 18 years and above were studied. It helped create a more homogenous group and reduced confounding variables (Chen et al., 2022).

Groningen Sleep Quality Questionnaire

The Groningen Sleep Quality Questionnaire (see Appendix D) is a scale that measures the sleep quality obtained the previous night. It is a straightforward and short questionnaire, as

participants only answer yes or no questions (Jafarian et al., 2008). The first question is not counted, and for the answer option yes from items 2, 3, 4, 5, 6, 7, 9, 11, 13, 14, and 15, the participant gets 1 point. When answering no to items 8, 10, and 12, the scoring is reversed, meaning getting 1 point (Jafarian et al., 2008). The scale can range between 0 to 14 points. A score above 6 indicates poor sleep quality from last night (Jafarian et al., 2008). In the questionnaire, there are 15 items in total, such as “I had a deep sleep last night” and “It took me more than half an hour to fall asleep last night”.

Many researchers, like Jafarian et al. (2008) and Serrano-Fernández et al. (2020), claimed that the Groningen Sleep Quality Questionnaire is valid and reliable for measuring subjective sleep quality.

The Consensus Sleep Diary

The Consensus Sleep Diary (see Appendix E) is used for research and clinical applications and can assess sleep patterns (Taylor et al., 2022). In this sleep diary, users insert information on the date of the sleep entry, wake time, number of awakenings, and many more questions that help to identify individuals' sleep quality (Carney et al., 2012). Moreover, The Consensus Sleep Diary consists of seven items: "What time did you get into bed?" or "How many times did you wake up, not counting your final awakening?". Each item scores from zero to four, and higher scores indicate poor sleep quality (Carney et al., 2012). Then, all the scores for each item are added to obtain a total score. A total score of 50 or higher indicates poor sleep quality (Carney et al., 2012).

Besides, Maich et al. (2018) evaluated the psychometric properties of the Consensus Sleep Diary. They figured out that the diary provides internal consistency, meaning measuring

the same construct, test-retest reliability, which is the consistency of measurement over time and convergent validity, which correlates with the scores obtained from other sleep diaries (Maich et al., 2018).

The Evaluation Questionnaire

Moreover, another questionnaire was implemented to measure adherence rates towards the intervention and was called the Evaluation Questionnaire (see Appendix F). The questionnaire was scored by giving answer option yes, a score of 1, and answer option no, a score of 0. Some example items included in the Evaluation Questionnaire were: “The sleep meditations were easy to integrate into my night routine” and “The reminders for the sleep meditations were timed well”. The items stem from a research article by Horsch et al. (2017). However, only a few questions from the original study of Horsch et al. (2017) were used, and some words from the questions constructed by Horsch et al. (2017) were changed; instead of initially stating, “The relaxation exercises were easy to integrate into my daily routines”, it was adapted for the sleep study by stating, “The sleep meditations were easy to integrate into my night routine”.

The questions used by Horsch et al.(2017) did not mentioned whether the questions met the reliability and validity criteria or any other psychometric properties. Nevertheless, it is a peer-reviewed article and is published in a reputable journal called Health and Technology 2017 (Horsch et al., 2017).

Meditation Podcast

The sleep podcast was extended from the YouTube channel called @GreatMeditation (GreatMeditation, n.d.). The sleep meditations from this channel were selected as they belong to mindfulness meditations focused on sleep, in which the participant was guided during the meditation to fall asleep and focused on the body sensations in the current moment. The sleep meditations were mindful, as participants were asked to observe the present non-judgmentally and feel their body sensations during the meditations. Also, they had to focus on their breathing. The female gentle voice, for example, used sentences like "observe the flow of your breath", "feeling the clothes on your skin", and "notice what it feels like to be present right now" (GreatMeditation, n.d.).

Procedure

The sleep study was approved by the Ethics Committee of the Faculty for Behavioural Management and Social Science (BMS) from the University of Twente on 17 October 2023, with reference number 231225. The sleep study started by sending participants messages on WhatsApp and inviting them to participate in the sleep study. Then, the participants who agreed to participate were sent information on WhatsApp about how TIIM works with a YouTube link (The BMS Lab University of Twente, 2023). Additionally, the psychology students recruited on the SONA system saw the study description on the system and were informed that they would earn 0.75 Sona points after completing the sleep study. Then, the participants gathered through WhatsApp and the Sona system were sent an acceptance letter via email thanking them for participating and a short description of the sleep study (see Appendix A). In addition, the code to access the sleep study on the TIIM app was inserted in the acceptance letter. The sleep study was called "Falling asleep with sleep meditations". Then, each participant was assigned to either the experimental or control group, ensuring that both groups had almost the same number of people.

The first task the participants had to follow was filling out the informed consent, the demographic questions and screening questions to exclude participants not meeting the inclusion criteria (see Appendix B and C). Then, they had to answer the pre-questionnaire from the Groningen Sleep Quality Questionnaire (see Appendix D). Afterwards, the participants had to listen to the sleep meditations every night for six days before sleeping for 10 minutes. The experimental group also filled in The Consensus Sleep Diary (see Appendix E) after hearing the sleep meditations the morning after sleep for six days. The control group followed almost the same steps except for filling out the Consensus Sleep Diary, which was not given to them. Finally, both groups had to complete the post-questionnaire and the Evaluation Questionnaire (see Appendix F).

Data Analysis

The data to analyse the outcomes of the sleep study was obtained through the CSV file that was downloaded on TIIM for each module representing another questionnaire or meditation. However, the CSV file was transformed into an XLS file to run the data on R Studio. Then, the participants who did not meet the inclusion criteria were eliminated. Afterwards, the data was analysed using R Studios version 2023.06.0+421. The packages tidyverse, dplyr, readxl, hms, rcompanion, ggplot2 and tidyr were installed and were run to get an insight into the outcomes of the sleep study. Then, missing data, which were “na” values in R studio, were eliminated before testing the hypotheses to ensure accuracy and reliability of the findings.

H1: Sleep Meditations Improve Sleep Quality in the Experimental and Control Group

The first hypothesis was analysed by first checking whether the data was normally distributed and if it was then a paired t-test was run to compare the mean among both groups

separately. If it was not normally distributed, then a non-parametric test, the Wilcoxon signed-rank test, was run to compare both groups.

H2: Self-Monitoring has a Moderating Effect Between the Sleep Meditations and Sleep Quality

The second hypothesis was tested by running a moderation analysis and then visualising it through an interaction plot.

H3:The Experimental Group will Exhibit Significant Higher Improvement in Sleep Quality Compared to the Control Group Assessed from the Groningen Sleep Quality Questionnaire

If the data was normally distributed, the independent samples t-test was run to compare the mean among both groups separately. Then, the two groups were combined into one dataset, and the same test was run to see whether there was a significant difference in the average values between the groups. If the data was not normally distributed, the Wilcoxon signed-rank test was run first separately and then it was run again by combining both groups into one dataset.

H4: The Experimental Group is more Likely to Adhere to the Sleep Study Compared to the Control Group

The hypothesis was tested by comparing the adherence items from the Evaluation Questionnaire from both groups by first checking for normality. If the data was normally distributed, the data of the Evaluation Questionnaire from the two groups were together inserted in the independent samples t-test. If the data was not normally distributed, then the Wilcoxon signed-rank test was conducted, inserting both data groups inside the test.

Results

H1

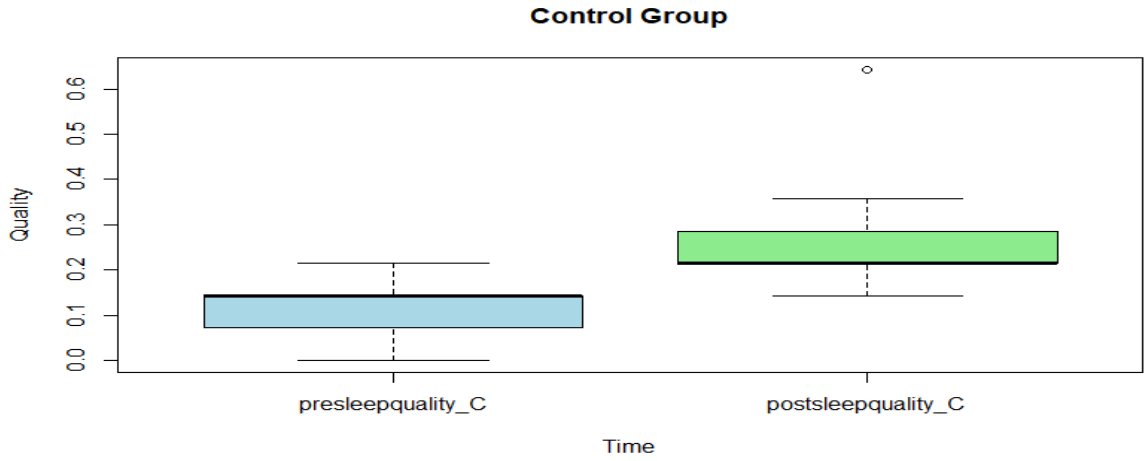
The first hypothesis was checked by calculating the final mean of the pre- and post-questionnaire according to the Groningen Sleep Quality scoring rules. Then, four histograms were run over the pre-and post-questionnaire from both groups. All the histograms showed that the data was not normally distributed (see Appendix G). As the results from the pre-and post-questionnaire were not normally distributed, a non-parametric test was conducted among both groups called the Wilcoxon signed-rank test.

The Wilcoxon signed-rank test for the control group indicated that the scores from the post-questionnaire were statistically different from the scores of the pre-questionnaire (z = -2.76, p = .01). This meant that sleep quality improved for the control group after the intervention.

The boxplot underneath demonstrates the difference in the mean score between the pre-and post-questionnaire from the control group.

Figure 1

Boxplot for the Control Group of the Pre- and Post-Questionnaire



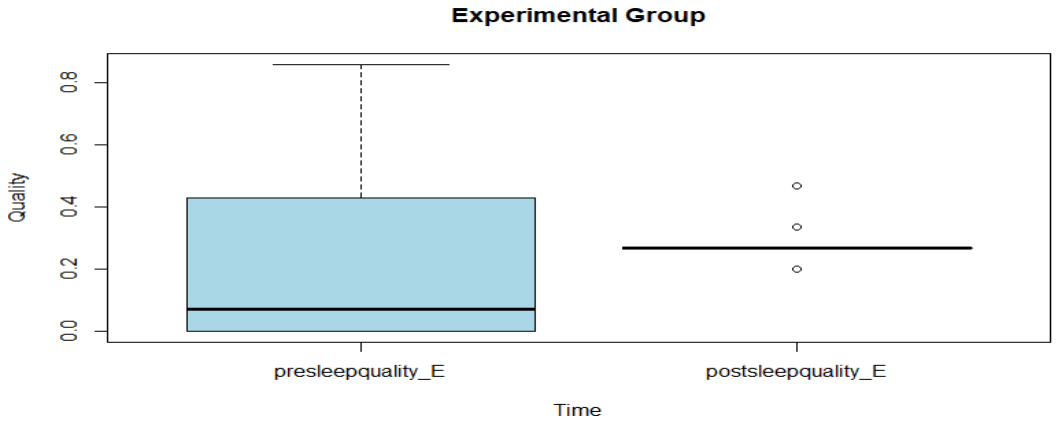
Note. It can be observed from the boxplots that the distribution in sleep quality scores in pre-questionnaire differs from the post-questionnaire scores. In addition, the post-questionnaire data recorded an outlier.

The Wilcoxon signed-rank test for the experimental group showed that the scores from the post-questionnaire were not significantly different from the scores of the pre-questionnaire (z = -0.59, p = .59). The test showed that the sleep quality among the experimental group did not improve after the sleep intervention.

The boxplot beneath demonstrates the difference in the mean score among the pre-and post-questionnaire from the experimental group.

Figure 2

Boxplot for the Experimental Group of the Pre- and Post-Questionnaire



Note. The boxplot for the experimental group showed that the median of sleep quality among the pre-questionnaire and post-questionnaire was different. The median of the post-questionnaire scores was higher.

To conclude, the hypothesis was rejected as sleep quality did not improve among both groups.

H2

The second hypothesis was tested by inserting the independent variable meditations. Then, the dependent variable, called post-sleep quality scores from the post-questionnaire and the sleep quality scores from the sleep diaries, were implemented together in a dataset. Then, the dataset was tested to determine whether the sleep quality scores moderate the effect between the meditations and improving post-sleep quality. The results showed no moderation effect (interaction coefficient of -0.17, SE [0.11], $p = .18$). This finding was supported by the interaction plot (see Appendix H), as the red line did not cross the blue line. Also, the negative interaction coefficient indicated that, on average, there was a slight decrease in sleep quality when the participants listened to the sleep meditations and self-monitored their sleep through the sleep diary, but it was not enough to be significant. To conclude, the hypothesis was rejected.

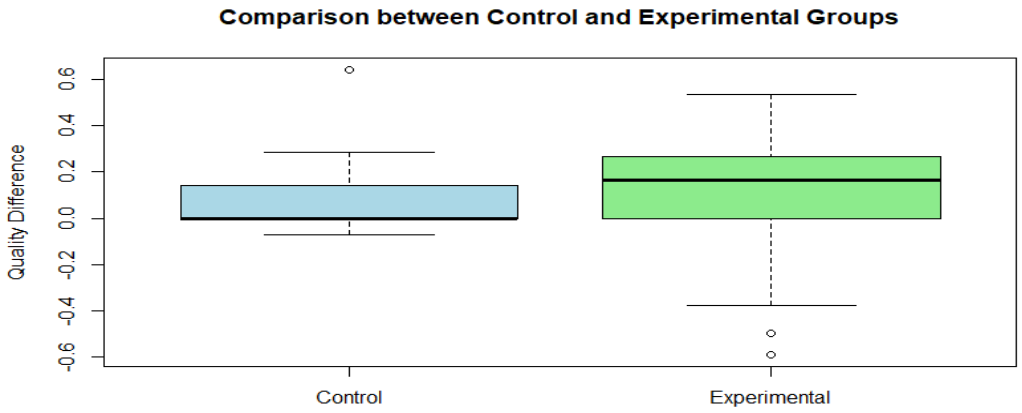
H3

The experimental and control group were implemented together into one dataset and then the Wilcoxon signed-rank test was run showing that the experimental group did not have higher sleep quality outcomes compared to the control group ($z = -0.85$, $p = .40$). Therefore, the hypothesis was rejected.

The boxplot below demonstrates the difference in the mean score among the experimental and control group from the pre-and post-questionnaire.

Figure 3

Boxplot for Experimental and Control Group Together



Note. The boxplot showed that the median of the control group was lower compared to the median of the experimental group. The control group had an extreme high outlier and the experimental group had two extreme low outliers.

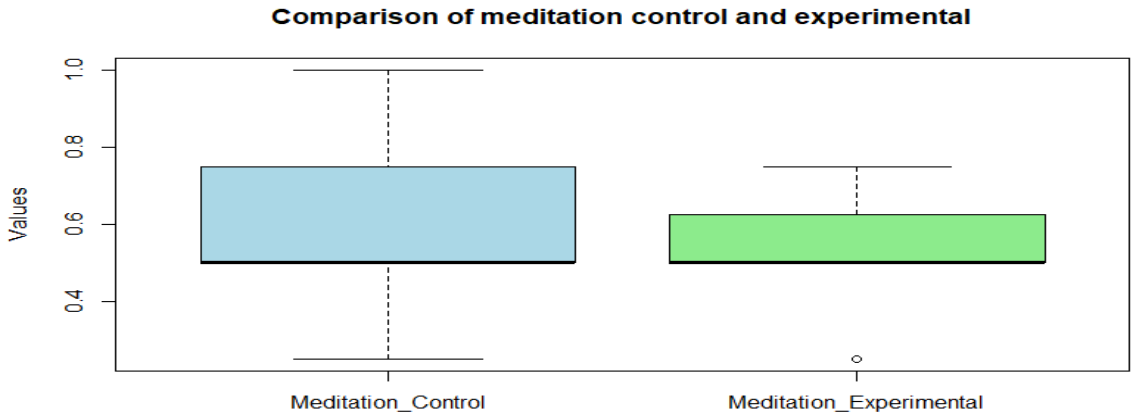
H4

The data from both groups was not normally distributed, which can be seen from the two histograms inserted in the Appendix I. Therefore, a non-parametric test was used among both groups together called the Wilcoxon signed-rank test. The outcomes showed that the experimental group did not have higher adherence rates compared to the control group, as the p-value was higher than 0.05 (z = -0.17, p = .88). The hypothesis was rejected.

The boxplot below demonstrates the mean score between the experimental and control group from the Evaluation Questionnaire.

Figure 4

Boxplot of the Evaluation Questionnaire Presenting the Experimental Group and Control Group Together



Note. The boxplot demonstrated that the median between the Evaluation Questionnaire of the control and experimental group was almost the same. The experimental group had an extremely low outlier.

Discussion

Research Question

The research question of this sleep study was: To what extent does self-monitoring, as measured through an electronic sleep diary, enhance the impact of listening to meditation podcasts in improving sleep quality and adherence rates?

The sleep study results showed that listening to sleep meditations and using a sleep diary did not increase sleep quality. Neither did adherence rates among the experimental group. However, sleep quality increased for the control group, which had no sleep diary, during the sleep study.

The findings of the experimental group and its potential causes could be explained by the sleep study conducted by Johnson et al. (2023), in which sleep meditations were also implemented inside an app. Participants reported difficulties listening to the meditations due to a lack of time or issues using the sleep app. Consequently, it prevented participants from

improving their sleep quality (Johnson et al., 2023). This might explain the sleep quality outcomes of the experimental group, as some participants had difficulty managing the modules of the sleep diary and sleep meditations.

Besides, a study by Lawrence and Muza (2018) showed that participants had difficulty accurately reporting their sleep patterns, especially in documenting sleep time. This might have also occurred during this sleep study. Participants might have inserted random answers, which biased the outcomes and led to receiving no improvement in sleep quality (Lawrence & Muza, 2018).

Other sleep studies reported a more positive answer towards the research question. Even if Johnson et al. (2023) found outcomes that aligned with this sleep study's findings, contradicting findings were also found. For example, Johnson et al. (2023) reported that for some participants who used the sleep app in which mindfulness meditations were implemented, their sleep quality was enhanced. Mainly when they listened to the sleep meditation during the evenings, as they could fall asleep faster and stay asleep (Johnson et al., 2023). In this sleep study, the participants also listened to the sleep meditations before falling asleep.

Moreover, a study conducted by Short et al. (2017) reported that up to five sleep diary entries can give reliable overall sleep quality estimates (Short et al., 2017). These findings were necessary to mention as it could indicate that six sleep diaries, as in this sleep study, were already adequate for gathering reliable sleep quality data. In addition, Britton et al. (2010) stated that only using sleep diaries without listening to meditations can improve sleep quality.

Hypothesis One

The first hypothesis tested whether listening to sleep meditations improved sleep quality among the experimental and control group, which was rejected.

Some researchers would agree with rejecting the hypothesis, stating that an increase in sleep quality is more likely to occur when the meditations are listened to during the day instead of at night (Zhang et al., 2021).

Furthermore, other studies mentioned that there might be only an increase in sleep quality when clinicians test and approve the meditation podcast. In this sleep study, clinicians did not test the meditation podcast extended from the YouTube channel @GreatMeditation. The finding could explain the outcome of the experimental group (Ananth, 2021).

Conversely, other studies would confirm the hypothesis. Researchers state that mindfulness meditations listened through an app increase a sense of calmness and can lower heart rate (Rusch et al., 2018).

Additionally, other researchers would also accept the hypothesis that sleep meditations improve sleep quality as practising mindfulness meditations enhances sleep quality similarly to doing exercise (Black et al., 2015).

Hypothesis Two

The second hypothesis tested whether self-monitoring moderated the effect between sleep meditations and sleep quality, which was rejected. This meant that self-monitoring did not strengthen participants' sleep quality.

The findings were partly supported by a study conducted by Hoge et al. (2013), who showed that self-monitoring measured with a sleep diary did not significantly improve sleep latency. By contrast, the sleep diary did moderate the effects in improving sleep efficiency, which means it improved some aspects of sleep quality (Hoge et al., 2013).

Furthermore, Herscu et al. (2023) agrees with rejecting the hypothesis, stating that using a sleep diary during the whole intervention can even be counterproductive for the participants as

it might lead to experiencing overconcern towards sleep. Additionally, it could lead to experiencing uncomfortable feelings that can even worsen participants' sleep quality.

Hypothesis Three

The third hypothesis tested whether the experimental group would exhibit significantly higher sleep quality improvement outcomes than the control group assessed from the pre- and post-questionnaire. The hypothesis was rejected.

Carney et al. (2012) confirmed the rejection of the hypothesis as they developed a study using the Consensus Sleep Diary. They figured out that the participants sometimes felt they could not fully express their sleep experience due to the perceived incomplete items from the Consensus Sleep Diary. In addition, they would need additional sleep items or methods to report their sleep experience. This could be achieved using another sleep diary or other sleep methods like a clock face. A clock face is a circular diagram representing hours and minutes (Medical News Today, 2023).

At the same time, there is still evidence for supporting the hypothesis, as some studies showed that self-monitoring increases sleep quality. When people become aware of their sleep patterns, they become more motivated to adjust their sleep habits to increase their sleep quality (Torossian et al., 2021).

Moreover, another study would accept the hypothesis because the Consensus Sleep Diary is research-based and contains participants' input, making the sleep diary reliable and valid (Maich et al., 2018).

Hypothesis Four

The last hypothesis tested whether the experimental group was more likely to adhere to the sleep study than the control group; the hypothesis was rejected.

A study conducted by Mellor et al. (2021) showed that adhering to a sleep diary did not predict better treatment outcomes, in this case, higher sleep quality. Mellor et al. (2021) explained the non-significant results as the participants had to fill in the Consensus Sleep Diary for six days, which might have increased adherence initially. Then, it decreased as participants were already aware of their sleep patterns. Therefore, they were no longer interested in filling out the sleep diaries and adhering to them (Mellor, et al., 2021).

At the same time there is still evidence to support the hypothesis that using a sleep diary increases adherence rates. Becoming aware of one's sleep patterns through a sleep diary can increase motivation to see improvements in sleep quality. Leading the participants to stay engaged with the sleep app (Kearns et al., 2023).

Limitations of the Sleep Study

As already mentioned in the discussion section, some limitations in the sleep study were found. Now, further limitations will be elaborated.

The first limitation was that the participants sometimes needed help understanding the TIIM app. The participants reported having difficulties completing the modules inserted in the app. For example, when filling out the sleep diary, sometimes the app did not recognize that the participant finished the module. Thus, Goyal (2014) reports that these technical problems hindered the participant from increasing sleep quality and made the user feel less trusting in following the sleep study (Goyal, 2014). Furthermore, technical issues might explain the high drop-out rates that took place in this sleep study at the beginning.

Even if some studies report that using sleep diaries for five days is beneficial, other studies would disagree. Some researchers claim that the sleep diary was used too often in the sleep study, as the experimental group, which used the sleep diary had no increase in sleep

quality. Consequently, making use of a sleep diary can result in making participants feel uncomfortable when becoming aware of their sleep patterns (Herscu et al., 2023).

The last limitation was that the dropout rate when recruiting the participants was high. Initially, 65 participants were willing to participate in the sleep study, but only 47 participants started and finished the study. The participants dropped out before starting the sleep study because the duration was too long for them, even if it was already mentioned when recruiting the participants.

In addition, other people claimed that they felt uncomfortable inserting their emails inside the TIIM app. The privacy concern might indicate that the researcher did not clearly communicate the privacy and confidentiality of the given data.

Another reason might be that the participants did not read the informed consent thoroughly (Meyerowitz-Katz et al., 2020). Thus, decreased the generalizability of the findings (Atilgan, 2013).

Strengths of the Sleep Study

Even though the sleep study had limitations, it also had notable strengths. The first was the differences in ages participating in the sleep study, ranging from 18 to 65. This age difference made the study findings more representative (Geifman et al., 2013).

Another benefit of the sleep study was the use of the convenience sampling method for gathering participants. Convenience sampling can increase participants' trustworthiness in the sleep study by knowing the researcher personally (Stratton, 2021).

In addition, some participants received Sona points when they followed the whole sleep study, which could have increased participants' engagement and motivation to continue the sleep study (Stratton, 2021).

Furthermore, researchers have shown that the number of sleep diary entries that took place during this sleep, which was 6, was already sufficient to obtain credible outcomes.

Even though the TIIM app resulted in technical issues and confusion for some participants, it still had benefits. The TIIM app was a valuable digital tool for implementing the sleep study as the whole sleep intervention could be inserted. Many participants could still follow the study and did not encounter technical issues while using the TIIM app. Additionally, reminders could be sent out to the participants to remind them to fill out the different modules.

Furthermore, the TIIM app was helpful as all the data was protected and stored securely by the BMS Data Lab of The University of Twente (University of Twente, n.d.).

Lastly, another strength the sleep study holds is using research-based sleep questionnaires like the Groningen Sleep Quality Questionnaire and the Consensus Sleep Diary. The questionnaires are all proven by researchers to be valid and reliable questionnaires (Smyth, 2000). Thus, increased the validity and reliability of the study findings. Additionally, it elevated participants' trustworthiness in the materials used in the sleep study (Acharya, 2010).

Future Research

In this section future research recommendations will be explained to overcome the limitations and improve the sleep study.

Firstly, future research should test whether implementing various sleep study methods, like combining different sleep diaries, has better sleep quality outcomes. For example, using the Consensus Sleep Diary and including the sleep diary from the National Sleep Foundation. The National Sleep Foundation also asks the participants to insert information regarding their caffeine and alcohol intake. It could be more effective as it might increase participants' interest in filling out the sleep diaries and stay engaged (Knutson et al., 2017).

Besides, to allow the participants to fully express their sleep patterns it would have been helpful to include clock faces. For instance, choosing the colour and design of the clock face and letting users insert their sleep information. This might enhance users' engagement with the sleep intervention and allow them to express their sleep experience fully.

In addition, future research should integrate different nationalities in the study, as only German and Dutch participants were primarily involved. By including different nationalities the findings of the study are more likely to be representative for the whole population (Irwin et al., 2006).

Furthermore, it would be beneficial to personalize the study inserted in the app, in which the participants have the option to adjust the study according to their time schedule. For example, when the meditations and reminders should appear to them in the app. This possibility might avoid dropout rates.

Moreover, research-based meditations tested by clinicians would be a better option to implement next time, as it would be interesting to investigate in the future whether tested meditations are more likely to enhance sleep quality. Additionally, inserting meditations with a more soothing voice would be more effective to implement in the future, as two participants criticized the voice of the given meditations.

Likewise, to overcome technical issues from the TIIM app in which the sleep study was implemented, the participant could receive an individual module at the beginning of the sleep study. Stating what the participant can do in case of encountering problems coming from the TIIM app, for example, closing the app and reopening it. Similarly, receiving information on what to do when modules like the sleep diary do not appear (Hinze et al., 2022). This might help

the participant become aware of how to handle these technical issues next time instead of getting confused (Hinze et al., 2022).

Besides, it would be beneficial to send the participants reminders during the study about the confidentiality of the given data. Furthermore, the importance of trying to accurately represent their sleep patterns in the module.

Conclusion

To conclude, the sleep study demonstrated that a meditation podcast can improve sleep quality. However, adding an electronic sleep diary should be used sparingly. Its effectiveness needs to be researched more as there are still contradicting findings on whether it can improve sleep quality and adherence.

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Appendix A

Acceptance Letter for Participating in the Sleep Study

Dear participant,

I am delighted that you decided to participate in the sleep study!

The sleep study mainly consists of answering demographic questions, sleep-related questionnaires, and listening to sleep meditations. The meditations last 10 minutes and will be listened to for six nights. The sleep questionnaires are research-based and only take 7 minutes to complete during the study. Please follow all the study steps and complete all questions to gather reliable and valid outcomes.

The sleep study is a chance to explore how sleep meditations might benefit you.

Please insert the following code to enter the sleep study in the TIIM app: 7vus5

If you need any help during the study, please contact me.

Researcher: Valentina Uhlke (v.c.uhlke@student.utwente.nl)

I wish you the best of luck with the sleep study.

Appendix B

Informed Consent Form for the Sleep Study

Summary of the Sleep Study:

In this informed consent, you will receive information about the purpose, benefits, and risks of participating in the sleep study. Moreover, participating in the study is entirely voluntary. The sleep study aims to explore how effective a digital health intervention is by focusing on the relationship between listening to sleep meditation podcasts and improving sleep quality.

The study will last one week, and the participants will listen to sleep meditations each day for six days that last 10 minutes before going to sleep. Also, the participants will answer sleep-related questionnaires. The sleep questionnaires will take 4 to 6 minutes during the intervention. It is essential to complete the sleep study to get reliable study results and widen knowledge in the digital health intervention field. The sleep questionnaires are research-based. Therefore, they have a higher probability of providing reliable and valid outcomes.

- **Purpose of the Study:**

The sleep study investigates how digital health interventions, mainly a youTube podcast focused on sleep meditations, can improve sleep quality. Poor sleep quality can lead to various health issues, while good sleep quality contributes to emotional stability and stress reduction.

- **Benefits and Risks:**

By participating in the sleep study, you can contribute to gathering valuable insights into the field of digital health interventions. There are no risks associated with participating in the sleep study. However, becoming aware of your sleep patterns could be a potential consequence leading to feelings of discomfort.

- **BMS Ethics Committee Approval:**

The BMS Ethics Committee/domain Humanities and Social Sciences has approved the sleep study.

- **Withdrawal from the Study:**

Participants can withdraw at any time without negative consequences. You can also decide to have your data withdrawn even after having completed the sleep study until December 12, 2023.

- **Data Collection and Privacy:**

Personal information will be collected, but all identifiable data will be deleted by December 12, 2023, for complete anonymity.

- **Data Usage and Safety:**

Collected data will be used for research, anonymized, and stored safely for up to 10 years based on the faculty standard procedure.

- **Contact Information:**

You can contact the researcher or involved parties anytime with questions or concerns about the study.

Researcher: Valentina Uhlke v.c.uhlke@student.utwente.nl

Supervisor: Lina Bareisyte l.b.bareisyte@utwente.nl

BMS Ethics Committee/domain Humanities and Social Sciences

ethicscommittee-hss@utwente.nl

Informed Consent Form:

Please tick the boxes to indicate that you understand and agree to the following conditions to make sure you understand the nature of the research, as outlined in the summary section:

- I have read and understood the study information, or it has been read to me. I have been able to ask questions about the study, which have been answered to my satisfaction.

○ Yes ○ No

- I consent voluntarily to participate in this study and understand that I can refuse to answer questions. I can withdraw from the study at any time without giving a reason.

○ Yes ○ No

- I understand that participating in the sleep study involves using my smartphone and the TIIM app. The study will collect data about my sleep patterns and sleep quality and investigate the behaviour change of self-monitoring and adherence. The study will last one week and consists of answering questionnaires and listening to sleep meditations.

○ Yes ○ No

- Use of the information in the study:

I understand that the information I provide will be used for research reports.

○ Yes ○ No

- I understand that personal information collected about me that can identify me, such as my name, will be stored securely to protect participants' privacy.

○ Yes ○ No

- Risks and Benefits of Participating:

Participating in the sleep study might increase my sleep awareness, which can lead to discomfort. If that is the case, I can contact the researcher anytime.

○ Yes ○ No

- I might benefit from the sleep study as I will become more aware of my sleep patterns. The meditations may be helpful for my sleep. Also, I can contribute to widening the knowledge in research about sleep through YouTube podcasts belonging to the field of digital health interventions.

○ Yes ○ No

- Use of the information in the sleep study:
- I understand that my information will be used for data processing to determine the effectiveness of digital health interventions like the Sleep YouTube podcast. The data will be safely stored and handled responsibly. The results can be sent to the participants interested in the study outcomes.

  ○ Yes ○ No
- I understand that my email, inserted in TIIM, will stay only within the study team. Also, it will be deleted by December 12th at the latest.

  ○ Yes ○ No
- Future use and reuse of the information by others:

I permit the sleep diary records and questionnaire responses from the TIIM app to be used for future research and learning.

○ Yes ○ No

Please press the appropriate circle whether you agree with the informed consent. Remember that your name will show up through TIIM due to the registration. However, it will be deleted on December 12th and not be mentioned when reporting the study outcomes in the research paper.

○ Yes ○ No

Appendix C

Demographic Questions and Screening Questions

Now I will ask you for some personal information like your age:

1. How old are you?
2. What is your sex?
3. What is your educational level?
4. What is your nationality?

Please answer the screening questions with yes or no:

5. Have you previously been diagnosed with a clinical sleep disorder?
6. Do you take medication to be able to sleep?

Sleep study procedure:

1. Informed consent.

2. Turn on the notifications on TIIM (to receive reminders when having to answer questionnaires).

3. Answer the pre questionnaire.

4. Listen to the meditations, and some participants might also need to answer a sleep diary.

5. Answer the post questionnaire.

6. Finally, answer the evaluation questionnaire.

Appendix D

Groningen Sleep Quality Questionnaire

Please answer the following sleep questionnaire by pressing yes or no:

.

1. I had a deep sleep last night.
2. I feel that I slept poorly last night.
3. It took me more than half an hour to fall asleep last night.
4. I woke up several times last night.
5. I felt tired after waking up this morning.
6. I feel that I didn't get enough sleep last night.
7. I got up in the middle of the night.
8. I felt rested after waking up this morning.
9. I feel that I only had a couple of hours' sleep last night.
10. I feel that I slept well last night.
11. I didn't sleep a wink last night.
12. I didn't have trouble falling asleep last night.
13. After I woke up last night, I had trouble falling asleep again.
14. I tossed and turned all night last night.
15. I didn't get more than 5 hours' sleep last night.

All items are scored true / false

The first question does not count for the total score.

One point if answer is 'true': questions 2, 3, 4, 5, 6, 7, 9, 11, 13, 14, 15.

One point if answer is 'false': questions 8, 10, 12.

Maximum score 14 points, indicating poor sleep the night before.

Appendix E

Consensus Sleep Diary

Sample **Consensus Sleep Diary-Core** ID/Name:________________________________

Today's date	4/5/11							
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?	3 times							
5. In total, how long did these awakenings last?	1 hour 10 min.							
6. What time was your final awakening?	6:35 a.m.							
7. What time did you get out of bed for the day?	7:20 a.m							
8. 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
9. Comments (if applicable)	I have a cold							

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Appendix F

Evaluation Questionnaire

The answer possibilities are yes and no:

1. The sleep meditations were easy to integrate into my night routine.
2. I had to put in a lot of effort to not forget to listen to the sleep meditations.
3. The reminders for the sleep meditations arrived at inopportune times.
4. The reminders for the sleep meditations were timed well.

Appendix G

Histograms for Hypothesis One

Figure 1

Visualization of the Pre Sleep Quality Questionnaire from the Experimental Group. Showing the Data is not Normally Distributed

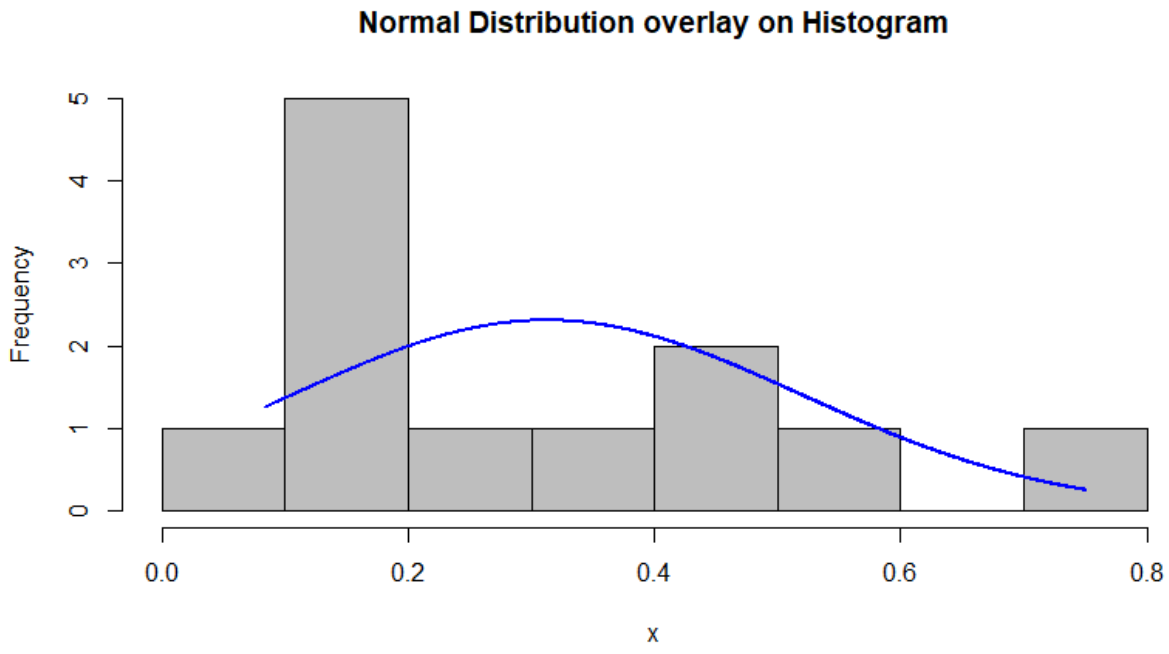


Figure 2

Visualization of the Post Sleep Quality Questionnaire from the Experimental Group. Showing the Data is not Normally Distributed

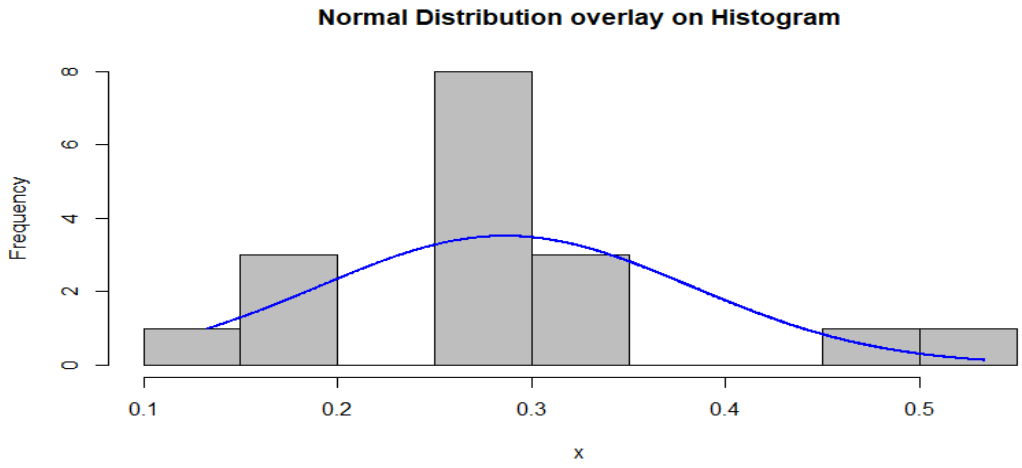


Figure 3

Visualization of the Pre Sleep Quality Questionnaire from the Control Group. Showing the Data is not Normally Distributed

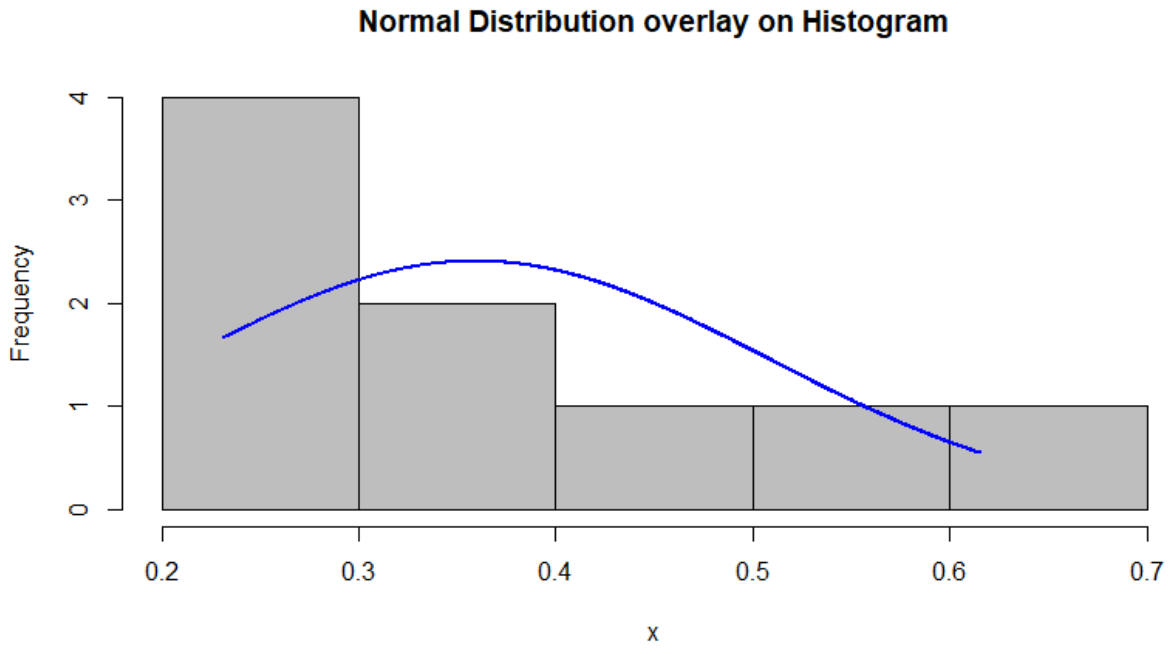
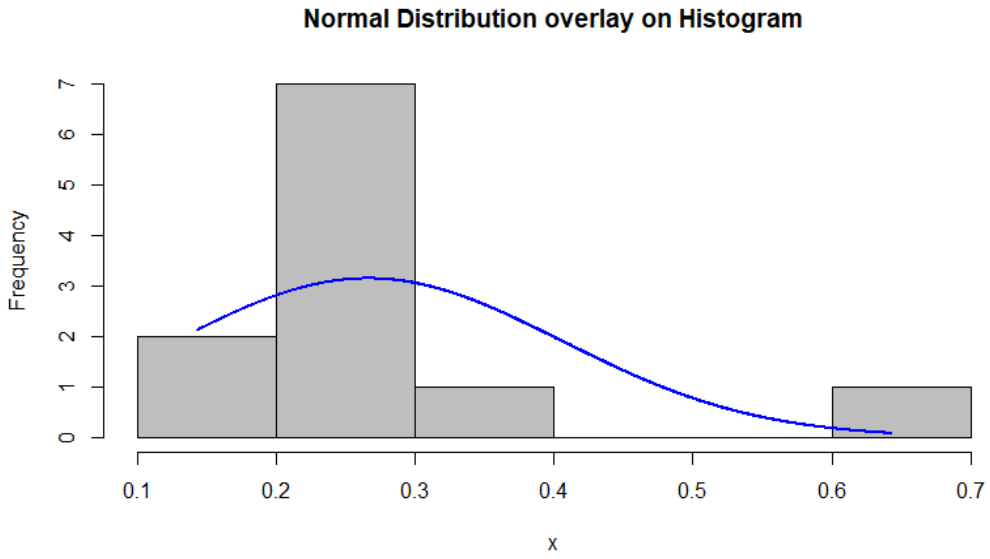


Figure 4

Visualization of the Post Sleep Quality Questionnaire from the Control Group. Showing the Data is not Normally Distributed

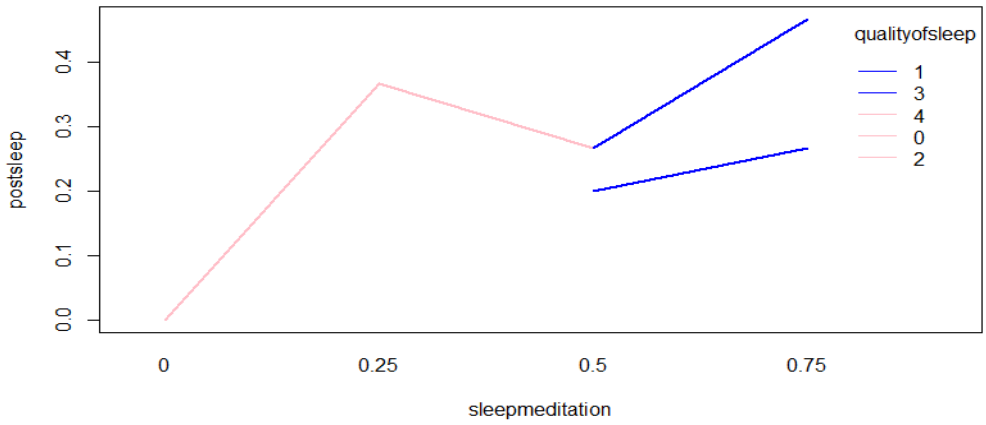


Appendix H

Moderation Test for Hypothesis Two

Figure 5

Visualization of the Moderation Test. Showing Self-Monitoring does not Moderate the Effect on Sleep Meditations Increasing Sleep Quality



Appendix I

Histograms for Hypothesis Four

Figure 6

Visualization of the Evaluation Questionnaire from the Control Group. Showing the Data is not Normally Distributed

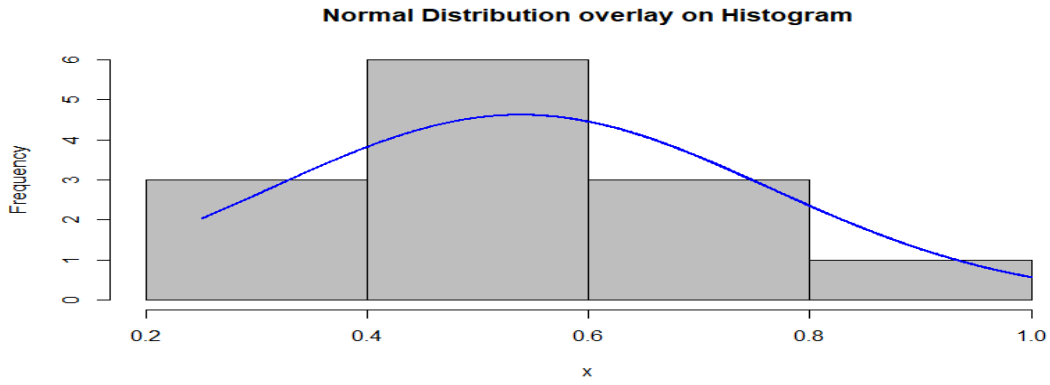


Figure 7

Visualization of the Evaluation Questionnaire from the Experimental Group. Showing the Data is not Normally Distributed