Examining the Influence of Informative Podcasts About Sleep Health on the Development of Sleep Hygiene Behaviour in Young Adults: A Randomised Controlled Trial

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Abstract

Even though sleep is considered crucial for maintaining mental and physical health, sleep quality remains notably low in many developed countries. This study utilises a randomised controlled trial with repeated measurements to examine the influence of an informative podcast on sleep hygiene behaviour adoption, as well as an associated change in sleep quality. The aim is to explore the potential efficiency of podcasts in achieving health behaviour change to deliver efficient and cost-effective health interventions. The experiment was conducted on a total of 37 participants aged 18 to 28 with an average of 22.2 (*SD*=2.41) years. Participants' sleep quality was assessed before and after the intervention period of one week, in which participants either listened to a podcast about sleep hygiene in the intervention group or read the same information in the control group for four successive days. Three sleep hygiene behaviours, namely caffeine ingestion, sunlight viewing and evening display interaction, were measured daily to track changes over time. While a change in sleep quality was observed for neither group, a significant difference in evening display interaction was recorded in the intervention group but not the control group. These findings must be regarded in the light of a small and homogenous sample but imply that podcasts hold the potential to change the behaviours of listeners. It is thought that established behavioural change techniques and the audio-based nature of the medium explain its effectiveness in influencing listeners' behaviours.

Keywords: podcast, sleep hygiene, health intervention, sleep, behavioural change

Table of Content

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Introduction

Chronic diseases like Alzheimer's, obesity, and cancer are on the rise and exert enormous strain on affected individuals and society (Busse et al., 2010). Even though medicine provides various treatment options, little focus lies on preventing such diseases in the first place (Gmeinder et al., 2017). Sleep is an attractive candidate for preventive interventions as it has been identified as crucial for physical and mental health (Grandner, 2020; Grandner et al., 2010; Luyster et al., 2012) as it fosters the body's sophisticated and capable ability to maintain health (Walker, 2018). Besides direct health consequences, estimates show costs of 700 million euros for the clinical treatment of sleep disorders in Germany alone. Almost every fourth fatal car accident in Bavaria is caused by falling asleep while driving as a consequence of compromised sleep (Penzel et al., 2005). The consequences of sleep deprivation undoubtedly have severe effects on individuals' physical and mental health and consequently pose a financial burden on society as a whole.

Despite the serious consequences of impaired sleep, sleep satisfaction is notably low in many developed countries. For instance, 41% of Germans and up to 49% of the Swedish population suffer from sleep problems (Bocksch, 2023). According to Shochat (2012), modern lifestyles disrupt sleep through environmental factors like shift work, artificial light exposure, and electronic media interaction, as well as behavioural factors such as inactivity and the consumption of sleep-affecting substances like caffeine, nicotine, and alcohol. Consequently, a significant number of individuals suffer the consequences of compromised sleep, likely attributed to these modern factors and influences.

Sleep hygiene is a concept that relates to behaviours aimed at improving sleep quality or reducing sleep-compromising behaviours (Riedel, 2000). In the past, sleep hygiene education has been used to treat insomnia in patients but has been considered insufficient for clinical practice in severe cases (Morgenthaler et al., 2006). However, a study by Mastin et al. (2006) demonstrates a

strong link between sleep hygiene implementation and increased sleep quality in a non-clinical population which follows a general trend (Kakinuma et al., 2010; Morita et al., 2012; Hudson et al., 2008). There is presently a lack of general recommendations for sleep hygiene applicable to the broader population due to inconsistent concepts in research regarding the content of sleep-related behaviours for such a matter (Irish et al., 2015). However, many sleep-compromising behaviours have been identified.

To name a few such behaviours, artificial light exposure at night, often due to higher frequency blue light is known to disrupt the natural circadian rhythm by inhibiting melatonin (West et al., 2011) and, thus, reduces sleep quality (Silvani et al., 2022; Cho et al., 2015). Contrasting, daylight exposure is a crucial stimulus for the circadian rhythm (Lack & Wright, 2007) and a lack of light during the day is generally associated with compromised sleep quality (Bano et al., 2014; Figueiro et al., 2017; Nagare et al., 2021). Another sleep-impairing behaviour is associated with a stimulant consumed by many people daily. Caffeine is a drug that binds the adenosine receptors and reduces the feeling of sleepiness and increases arousal (Institute of Medicine (US) Committee on Military Nutrition Research, 2001). With a half-life time of around 5 hours (Evans et al., 2019) and an unproblematic daily dose of up to 400mg (FDA, 2018), high caffeine consumption too close before sleep can reduce sleep quality (Lunsford-Avery et al., 2021). These three behaviours are known to impair sleep quality and will be the focus of this study.

When discussing sleep hygiene recommendations, it is crucial to quantify restorative sleep. While sleep can be best quantified in a laboratory using a polysomnography that requires special equipment, self-reports are considered a good marker for overall sleep quality (Cudney et al., 2021). First, objective indicators like sleep duration, consistency, and factors interfering with sleep continuity are generally important. A minimum of seven hours of sleep is considered optimal (Watson et al., 2015), while consistent bedtime and waking time are similarly important (Lunsford-Avery et al., 2018). External influences like noise that disrupt sleep are problematic, while continuous and uninterrupted sleep seems to be at least equally important as sleep duration (Van Someren et al., 2015). Second, subjective markers are generally helpful in determining sleep quality as well. Feeling

refreshed upon waking up and being energetic and clear-headed during the day are feelings associated with restful and restorative sleep (Libman et al., 2016). Experiences like having difficulties getting up in the morning, irritability, as well as difficulty concentrating during the day can be symptoms of impaired sleep (MedlinePlus, 2019). To avoid the consequences of poor sleep, sleep hygiene behaviours can be a valuable first line of intervention.

Before encouraging individuals to practise sleep hygiene behaviours, it is important to discuss the concept of behavioural change interventions. Such interventions aim to change individuals' behaviours or habits by integrating various psychological strategies and addressing cognitive or motivational factors. Numerous theories, such as the Elaboration Likelihood Model (ELM) (Petty & Cacioppo, 1986), formulate the idea of behavioural change by providing a model that encompasses several dimensions, such as the importance of information processing in persuasion. The ELM states that the effectiveness of persuasion of individuals is dependent on information processing in two routes, the central route and the peripheral route.

The central route of information delivery requires a high degree of elaboration on the information but will generally lead to more robust and enduring behavioural changes in the individual. It is generally assumed that individuals with a preexisting interest and background in a topic are more likely to engage in elaboration through the central route. Alternatively, the peripheral route involves little elaboration on a given topic due to little preexisting engagement with given information. Information aimed for peripheral processing generally involves less complex information and appeals to superficial ideas and biases about the information at hand. Special attention is given to its form of delivery or emotional appeal. The peripheral route generally leads to less enduring changes in attitude compared to the central route (Petty & Cacioppo, 1986).

Theories like the ELM frame the theoretical process of persuasion and behavioural change and provide the theoretical foundation for tangible interventions that use practical techniques to achieve behavioural change. Such techniques are generally referred to as behaviour change techniques (BCTs), which are observable, irreducible, and replicable parts of the intervention design (Michie & Johnston, 2013). A wide range of BCTs used in studies have been identified and grouped by

Michie et al. (2015), which will serve as the basis for further discussion about BCTs. The categorisation of BCTs provides a common ground for future discussions and research, enabling the exploration of new approaches to behavioural change.

Considering the increasing popularity of podcasts with an increase in listeners of almost 200 million in the past three years (Götting, 2021), it can be valuable to scrutinise this medium for behavioural change interventions. A podcast is a medium- to long-form digital audio or video program with the general intention of entertaining or educating listeners. Podcasts, due to their lengthy format, are often minimally edited to convey a complex topic and/or discussion authentically and comprehensively. Health podcasts are one of the leading genres in many countries in Europe as well as in the United States (Götting, 2020; Götting, 2022). Moreover, the ELM provides an interesting framework for podcasts as a platform for digital health interventions. When considering that persuasion occurs either via the central or the peripheral route, it is helpful to contemplate how podcasts can be structured to appeal to either route. Podcasts have the potential to be tailored for peripheral processing by using, for example, a trustworthy and expert host, emotional appeals, and engaging content that simplifies information for individuals with less previous involvement. On the contrary, podcasts can also make use of their long-form format to provide detailed information and backgrounds about singular topics designed for the central processing route of already invested listeners. Tailoring podcasts based on either the peripheral or the central processing route might be a valuable consideration when aiming to maximise the persuasiveness of this medium.

When considering podcasts for behavioural change interventions, feasible BCTs must be integrated. For sleep hygiene adoption, a podcast could provide instructions on how to perform specific behaviours and inform about the health consequences of impaired sleep. Additionally, the BCT of incentive outcome could be effective by describing positive benefits associated with sleep hygiene behaviour, such as daytime alertness and physical and mental recovery. Furthermore, the BCT of a credible source could be beneficial, especially when appealing to less invested listeners. Even though podcasts can be used to implement numerous BCTs, it is crucial to tailor the BCTs and the general format of the podcast to the targeted listeners.

One of the most popular scientific health podcasts is the Huberman Lab podcast (Huberman Lab, n.d.), which is hosted by Dr. Andrew Huberman, a neuroscientist and tenured professor in the Department of Neurobiology, and by courtesy, Psychiatry, and Behavioural Sciences at Stanford School of Medicine. He uploads weekly online content that is freely accessible but separate from his teachings at Stanford School of Medicine. In his podcast, he focuses on various health and performance-related topics, including sleep and sleep hygiene. Besides his academic status, numerous quality indicators that have been previously identified to indicate credible medical education are present in his content (Lin et al., 2015).

Even though the Huberman Lab podcast is not a theory-based podcast that is specifically tailored to one particular population, is generally considered a good representation of what a podcast-based health behaviour intervention could look like. It combines features that appeal to the peripheral route of processing, such as a credible host and an engaging and easily understandable delivery of information, as well as features that can be considered important for the central processing route. Invested listeners are provided with facultative information that is irrelevant to the understanding of the content but provides further elaboration on a given topic. Additionally, the passages about sleep hygiene hold several BCTs such as the presence of a credible host, information about the health consequences of impaired sleep, and instructions on how to perform sleep hygiene behaviours, such as adequate daylight viewing.

Until now, few studies like the "Pounds Off Digitally Study" by Turner-McGrievy et al. (2009) have investigated the potential of podcasts in health behavioural change. The Pounds Off Digitally Study utilised a podcast series based on social cognitive theory for weight loss in obese participants, which was more effective in achieving weight loss compared to a control podcast that was not theory-based. Another experiment conducted by Elbert et al. (2016) utilised audio-based information and compared its effectiveness in persuading participants to eat more fruits and vegetables in comparison to text and control. These studies give a glimpse of the potential of podcast-based interventions for health behaviour change. Turner-McGrievy et al. (2009) argue that the effectiveness of podcasts in interventions resides in listeners' great control over podcasts leading to a large degree of control over

their engagement with information. While web-based information can entice individuals to selectively scan information (Eveland & Dunwoody, 2002), Turner-McGrievy et al. (2009) hypothesise that the audio-based nature of podcasts prevents this from happening and facilitates greater information processing. Furthermore, Ko et al. (2013) suggest that information control and cognitive load, based on Sweller's (2011) cognitive load theory, influence the degree to which information is processed and elaborated. In the light of the ELM, elaboration through the central route generally leads to more robust and long-lasting behavioural change. Podcasts could, therefore, incentivise behavioural change as provided information cannot be easily selectively scanned and low cognitive load and high informational control over the interaction with the podcast is maintained.

Few studies have already demonstrated podcast effectiveness in health behaviour change. This study aims to further explore the potential of informational podcasts in terms of achieving health behaviour change in young adult listeners. To extend the findings of the Pounds Off Digitally Study and to touch upon the recommendations of Ko et al. (2013), a web-based intervention relying on written information will serve as a control to the audio-based podcast intervention to further understand the persuasive effect of podcasts. This study deploys a similar study design to Elbert et al. (2016) but examines young adults specifically as they are thought to be most familiar with podcasts, leading to greater adherence and motivation for participation. Additionally, the study shifts the focus from weight loss and diet to the impact of podcasts on the adoption of sleep hygiene behaviours, intending to extend findings to other types of health behaviours.

Research Question: To what extent can listening to an informative podcast about improving sleep hygiene motivate listeners to improve sleep hygiene and therefore improve sleep quality?

Hypothesis 1: Listening to short excerpts of a scientifically based podcast for 4 subsequent days helps listeners to adopt relevant sleep hygiene behaviours.

Hypothesis 1.1: The intervention group significantly reduced caffeine consumption behaviour compared to the control group.

Hypothesis 1.2: The intervention group significantly reduced evening screen interaction compared to the control group.

Hypothesis 1.3: The intervention group significantly increased sunlight viewing behaviour compared to the control group.

Hypothesis 2: Listening to short excerpts of a scientifically based podcast for 4 subsequent days helps listeners significantly increase their sleep quality compared to the control group.

Methods

Study Design

The present study employs a randomised controlled pre-post design to assess changes in sleep quality and a within-subjects approach with repeated measures to assess behavioural changes over one week.

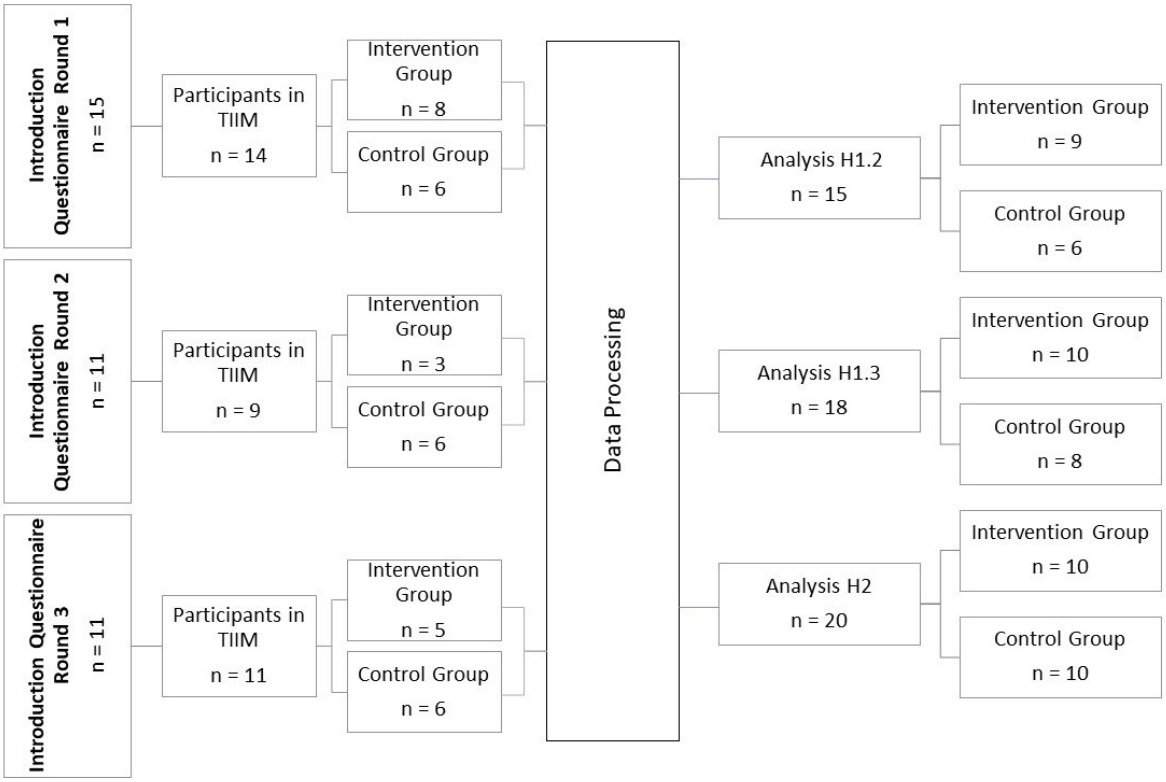
Participants

In this study, 14 Participants were recruited through voluntary response sampling methods via the Sona System, a participant distribution system of the University of Twente that allows students of the Department of Behavioural, Management, and Social Science department to apply for studies conducted by other students. Via this procedure, students can simply log in to an online platform, view and sign up for listed studies. Participants acquired through this system had an incentive to participate as they received 1.2 out of 15 required credits for the successful completion of the bachelor's degree. The remaining 23 participants were recruited by convenience sampling. Acquaintances of the researcher were directly asked for interest in participating in this study. No participants were excluded due to a diagnosed sleep disorder or regular medication usage to improve sleep quality, which has been defined as exclusion criteria. In total, three rounds of the experiment have been conducted, each lasting one week. The participant flow is visualised in Figure 1. To ensure random participant allocation, participants who signed up in TIIM were alternately allocated by the

researcher to either the control group or the intervention group, i.e., the first participant who signed up in TIIM was allocated to the intervention group, the second participant to the control group, the third participant to the intervention group, etc.

Figure 1

Participant Flow and sample sizes for analysis



Note: This figure illustrates the number of participants for each round, as well as the number of participants included in the analyses for each hypothesis. The data processing procedure involved clearing the data, as well as merging the data from each round into one final dataset used for analysis.

The initial introduction questionnaire was completed by 37 participants in total. Of these initial responses, 34 participants were included for analysis. Of these 34 Participants, 27 (79.41%) were *German*, five (14.71%) of them *Dutch* and three (8.82%) participants reported *another Nationality*. Participant's ages ranged from 18 to 28 with an average of 21.2(*SD*=2.01) years, while 18

(52.94%) participants reported being *male*, 15 (44.12%) reported their sex to be *female* and one (2.94%) participant described their sex as *other*. Overall, 26 (76.47%) participants indicated their educational level as *higher secondary school education* (including Abitur and A-levels) while eight (23.53%) participants hold a *bachelor's degree*.

Materials

Smartphone

To participate in this study, participants were required to own and use their smartphones. A smartphone was fundamental for the interaction with all other materials used for this study.

Qualtrics

A beginning questionnaire and a closing questionnaire were conducted via Qualtrics (Qualtrics, 2023), an online platform for creating and distributing questionnaires.

Twente Intervention and Interaction Machine (TIIM)

TIIM is a mobile application available on the App Store and Play Store and was developed by the Faculty of Behavioural, Management, and Social Sciences at the University of Twente (University of Twente, n.d.) TIIM sent notifications to participants' smartphones to inform them when a new study element was available. Furthermore, participants were able to answer questions and listen to media content via TIIM, which made it suitable for a study design that required repeated involvement of participants over several days.

Introduction questionnaire

The Introduction questionnaire began with the informed consent sheet (Appendix A) and the opportunity for participants to disclose their consent to voluntarily participate in the study. Afterwards, two items were asked, that served as a filter to exclude participants who did not fulfil the inclusion criteria, namely "Have you previously been diagnosed with a clinical sleep disorder?" and "Do you regularly take medication to improve your sleep?". If any of the two questions had been

answered with yes, participants were forwarded to an ending screen, informing them about their exclusion and thanking them for their interest in the study.

Furthermore, the introduction questionnaire collected demographical data such as age, sex, educational level and nationality. Additionally, one item probed for participant's familiarity with podcasts by asking for the time they spend listening to podcasts every week on a 5-point Likert scale ranging from "none at all" to "60min or more". This questionnaire ended with an image-supported step-by-step guide on how to download the TIIM application and subscribe to the study in TIIM itself using a code that was presented in the guide.

Pittsburgh Sleep Quality Index (PSQI)

In both, the introduction and closing questionnaire, the sleep quality of participants was assessed with the help of a modified version of the PSQI (Buysse et al., 1989). The PSQI is a commonly used scale with 24 items to assess sleep quality over seven categories that are combined into one global sleep quality score to evaluate sleep quality. It is considered a reliable and sensitive instrument with a diagnostic sensitivity of 89.6% and specificity of 86.5% as measured with Cohen's d of $d = 0.75$ ($p = < 0.001$) when tested on healthy individuals as well as patients with varying clinical diagnosis with an age range of roughly 20 to 80 years (Buysse et al., 1989). The PSQI provides a global score ranging from 0 to 23. The higher the score, the more severe the sleep impairments of participants (Buysse et al., 1989).

The modifications of the PSQI for this study mostly concerned the period it was assessing sleep quality (Appendix B). Instead of the original period of the past month, questions were reformulated to investigate sleep quality during the past week ("During the past week, what time have you usually gone to bed at night […]" instead of "During the past month, what time have you usually gone to bed at night […]"). Consequently, answer possibilities in the form of a 4-point Likert scale were reformulated to fit with the modified time frame. Choices like "less than once a week" or "Three or more times a week" were reformulated to "Once" or "Three or more times" per week

respectively. Lastly, an additional open question has been added which is a duplicate of the PSQI's question 4. This duplicate is the same item as the original but instead of a 4-point Likert scale, the participant is required to insert a duration in a text field. This duplicate is required to enable practical calculation of the global score of the PSQI in the statistical software as the result of the item is required as Likert scale format (1-4) for one category of the PSQI and as a duration (e.g. 8 hours) for the calculation of another category.

Closing questionnaire

The closing questionnaire started with a thank you message to the participants for their participation in this study followed by an open text entry in which participants were asked to report any conscious behavioural changes as a consequence of the intervention. Further, the question "Do you think the sleep quality and quantity you experienced in the last week is a good representation of your typical sleep patterns?" was thought to serve as an indicator of the reliability of individual data collected per participant. "How understandable was the information, either in the podcast or in the text you were confronted with? (1 = extremely easy to understand, 5 = extremely hard to understand)" was another item presented to the participants, aimed to further understand potential impacts the intervention might or might not have had. Lastly, the closing questionnaire entailed a text entry field for any remarks or feedback participants had at the end of the study.

Podcast

The intervention group was presented with a roughly 10-minute podcast clip from Tuesday to Friday in the TIIM application. The podcast was uploaded to YouTube, but participants were able to listen to the podcast in the TIIM application thanks to an integrated web player. As content for the podcast clips, the study used excerpts from three Huberman Lab episodes in which information about sleep hygiene was discussed (Appendix C). The three behaviours focused on in this study were chosen as they are the most discussed behaviours regarding sleep in the Huberman Lab podcast. These three behaviours examined in this study consist of caffeine intake, morning sunlight exposure, and evening

display interaction. Before the discussion of these behaviours, the first episode served as an introduction clip which explained some relevant concepts to help understand the upcoming clips.

Informational Text

The control group, on the other hand, was provided with a short informational text of approximately 180 to 250 words daily from Tuesday until Friday. The text was made available to the participants in TIIM as well and contained the same key information as the podcast did (Appendix D). The texts were retrieved from the Huberman Lab website (Huberman Lab, n.d.), which often provides text-based information sheets about topics that are discussed in its podcast episodes. If the website did not provide text-based information that covered a specific podcast clip used in the study, a text was created in a similar style to the original information sheets, covering the relevant information.

Daily questionnaire

Each set of daily questions included one item about waking time and bedtime of the previous day. To assess behavioural patterns and behavioural change, eight questions were asked about the relevant behaviours on the previous day via the TIIM app daily. There were two questions for each of the three behaviours discussed in the podcast and text that were either formatted as an open text entry or a 4-point Likert scale (e.g. “How long after waking up did you get out into the sunlight yesterday?” or “When was the last time you had caffeine yesterday? […]”) (Appendix E). Each two items assessing one behaviour were combined into one behavioural score, which served as a representation of one specific behaviour on the preceding day. The composition of this final score differs for each behaviour and will be explained in the following. For the final evaluation of the behaviours, there will be one score per behaviour evaluating the behaviour of the previous day as desired (1) to undesired (4) based on a 4-point Likert scale system.

The behaviour of caffeine consumption is defined by the number of caffeinated beverages consumed that day, measured by a 4-point Likert scale, ranging from "none" up to "three or more," and the time between the last caffeinated beverage and sleep time. This is measured by the

discrepancy between the time participants reported their last beverage and the time they indicated as sleep time. For analysis, this number was categorized into four categories to match the Likert scale nature of the related item concerning the number of caffeinated beverages. If the time between the last caffeine consumption and sleep time was longer than 12 hours, it was scored with a 1, for 12-10 hours, it was scored as 2, for 9-8 hours, it was scored as 3, and for less than 8 hours, it was scored as 4. This scoring allowed to calculate a score for the behaviour of caffeine consumption ranging from 1 (desired) up to 4 (undesired) based on the mean of the two items.

The behaviour of sunlight viewing will be evaluated by two items as well. The first item measures the time participants need to get outside in the sunlight after waking up the first time, evaluated by a 4-point Likert scale, ranging from "0-10 min" up to "90 min or more." The second item measures the time participants spent outside during their first venture outside each day, also measured by a 4-point Likert scale ranging from "5 min or less" to "30 min or more." For the analysis, the mean of both Likert scales will serve as a final score for the evaluation of the behaviour of sunlight viewing ranging from 1 (desired) up to 4 (undesired).

Evening display interaction, as the third behaviour of interest, will also be evaluated by two items. One item investigates the preventive measures to avoid screen light-related sleep disruption before sleep time taken by the participants. It does so through a 4-point Likert scale ranging from "I dim my screen and use blue light blockers" coded as 1, "I use blue light blockers," coded as 2, to "I dim my screen," which is coded as 3, up to the last option "none," which is coded as 4. The second item quantifies the minutes participants engage with digital screens before going to sleep with the help of an open-entry field. To match the nature of data to the previous item, the minutes are categorized into four categories. If the time between the last display use and sleep time is more than 60 minutes, it will be coded as 1, if it is 60-30 minutes it is coded as 2, if it is 30-10 minutes, it will be coded as 3, and if the time is 10 minutes or less, it will be coded as 4. Like the other behaviours, the mean of both Likert scales will be used as an evaluation for the behaviour of display viewing before sleep, ranging from 1 (desired) up to 4 (undesired).

Procedure

All participants signed up either via the Sona System or were contacted by the researcher directly. Both recruitment methods provided participants with a link forwarding them to the introduction questionnaire on Qualtrics. Initially, general information about the study and the procedure was provided, followed by the informed consent form (Appendix A). The initial pre-screening questions were followed by the modified version of the PSQI the question concerning participants' podcast engagement before the intervention, along with the step-by-step instructions on how to install the TIIM Application and join the study in the app.

The data collection period involved three rounds of the study, each starting on Monday and ending on Sunday. The registration period was not time-restricted, allowing participants to complete the introduction questionnaire on any day of the week to sign up for the upcoming period. Each period began on Monday, the last day for registration for that specific period. All registrations from Tuesday onwards were considered for the upcoming round of the following week. Once participants completed the introduction questionnaire and logged into the TIIM study, they were instructed to wait for the beginning of the study in TIIM on Monday. On Monday, participants were notified that the first set of questions was made available on TIIM. If participants registered on Mondays, they could start with the first set of questions immediately. Each day during the study week, participants received a notification at 8 a.m. indicating that new questions were available for that day. These daily questions measured the relevant behaviours of the previous day (see Appendix E). Additionally, on Tuesday, Wednesday, Thursday, and Friday, participants received a notification that a new podcast clip or informational text was made available for them, depending on the group they were assigned to. For all study elements, questions, podcasts and texts, a reminder notification was sent to participants’ smartphones if they had not completed the study element in TIIM 10 hours after it had been made available. Finally, on Sunday, after the last set of questions had been answered in TIIM, participants received a link via the app directing them to the closing questionnaire on Qualtrics which would finalize their study.

Data Analysis

Data analysis was conducted using R Studio (version 2023.09.01+494) (RStudio Team, 2020). The required packages for analysis included tidyverse, dplyr, ggplot2, PMCMRplus, FSA, stats, and rcompanion. Microsoft Excel (version 2310 Build 16.0.16924.20054) (Microsoft Corporation, 2018) was used for data formatting. Datasets exported separately from TIIM or Qualtrics but belonging together were merged (e.g. datasets for each experimental round were combined into one dataset). Responses lacking names were excluded from the dataset. Additionally, some participants completed the introduction questionnaire twice, participating in a subsequent experimental round due to technical issues in TIIM. For these cases, the initial response to the introduction questionnaire was removed. Missing items were predominantly recorded for the daily set of questions about the behaviours and were generally coded as NA-values in RStudio. All datasets were cleaned of irrelevant columns created by TIIM or Qualtrics, and column names were renamed for simplicity.

Hypothesis 1 – Behavioural Change

Hypothesis 1 investigated the change in caffeine consumption, sunlight viewing behaviour and evening display interaction over a week. Each behaviour was assessed based on the daily questions in TIIM, resulting in one behavioural score each. The measurements from each round were merged into one dataset and collectively analysed. However, only data was included from participants who answered the questions about the relevant behaviours on all successive seven days, i.e., if a participant forgot to answer the question about evening display interaction on Wednesday, his data was excluded for the analysis of hypothesis 1.2.

These three behavioural scores representing caffeine consumption, sunlight viewing and evening screen interaction, served as variables for the analysis related to the first hypothesis. Before relevant analyses were conducted, the data were checked for parametric assumptions. If the parametric assumptions for each behaviour were met, a repeated-measures ANOVA analysis was conducted. The analysis utilised three separate analyses, one for each behavioural score. The group

variable served as the between-group factor to locate potential differences in behavioural change between both groups. If this analysis displayed a significant effect, a post-hoc Bonferroni analysis served to gain insight into the nature of the change due to the intervention.

If the parametric assumptions were not met, a non-parametric analysis was considered, such as a Friedman's Test, to see whether there were statistically significant behavioural changes in the two groups. For further investigation of the outcome, a post-hoc analysis like Dunn's test could have been considered to gain greater insight into the nature of changes across time and groups.

Hypothesis 2 – Sleep Quality Change

The second hypothesis was tested based on the change in the outcome of the PSQI. The global score from the introduction questionnaire of the study was compared to the global score at the conclusion questionnaire of the study after the interventions had taken place. The measurements from each round were merged into one dataset and collectively analysed. For this analysis, only data from participants who filled in both the introduction and closing questionnaires was included.

First, parametric assumptions were tested, and a paired t-test would be conducted if the assumptions were met. If parametric assumptions were not met, a Wilcoxon test would be conducted as a non-parametric alternative. If a significant result was found, a visualization of the data could be useful to further understand the nature of the change.

Results

Hypothesis 1 – Behavioural Change

Due to some difficulties during the data collection process, which will be explained in the discussion, the behavioural value for caffeine consumption, relevant to hypothesis 1.1, could not be assessed to a reliable degree. Therefore, the behaviour of caffeine consumption was not included in the analysis as previously anticipated.

Table 1 illustrates the detailed descriptive statistics of the relevant data to analyse hypotheses 1.2 and 1.3. The table provides an overview of the means and standard deviations of the two behavioural scores at each respective day of the intervention for each condition. The analysis of hypothesis 1.2 and hypothesis 1.3 was conducted on 15 (podcast n=9, text n=6) and 18 (podcast n=10, text n=8) responses, respectively, as presented in Figure 1. This resulted in a dropout rate of 37.5% for Hypothesis 1.2 and 25% for Hypothesis 1.3 based on the initial 24 responses.

Table 1

Means and standard deviations for podcast and text groups and their sunlight viewing and evening display interaction behavioural scores at each measurement point

	Sunlight viewing		Screen interaction	
	Podcast	Text	Podcast	Text
	M(SD)	*M(SD)*	*M(SD)*	*M(SD)*
Monday	1.9(0.8)	2.5(0.5)	3.7(0.56)	3.0(1.0)
Tuesday	2.1(0.6)	2.25(0.4)	3.4(0.5)	3.0(0.8)
Wednesday	2.3(0.6)	2.38(0.4)	3.0(0.3)	2.5(0.7)
Thursday	2.1(0.7)	2.56(0.9)	3.4(0.6)	2.5(0.8)
Friday	2.4(0.4)	2.06(0.7)	3.2(0.9)	2.6(0.7)
Saturday	2.4(0.5)	1.94(0.6)	3.6(0.8)	2.5(0.5)
Sunday	2.2(0.7)	2.19(1.0)	3.7(0.6)	2.6(0.7)
Total	3.3(3.0)	2.1(0.7)	3.8(1.5)	2.8(2.7)

Note: This table visualises the means and standard deviation of the behavioural score of evening screen interaction and sunlight viewing for the previous day of measurement because the daily questions always inquired about the previous day's behaviour. The behavioural scores are a presentation of how well the given sleep hygiene behaviour was implemented (1 – undesired, 4 – desired).

Hypothesis 1.2 – Change in Evening Display Interaction

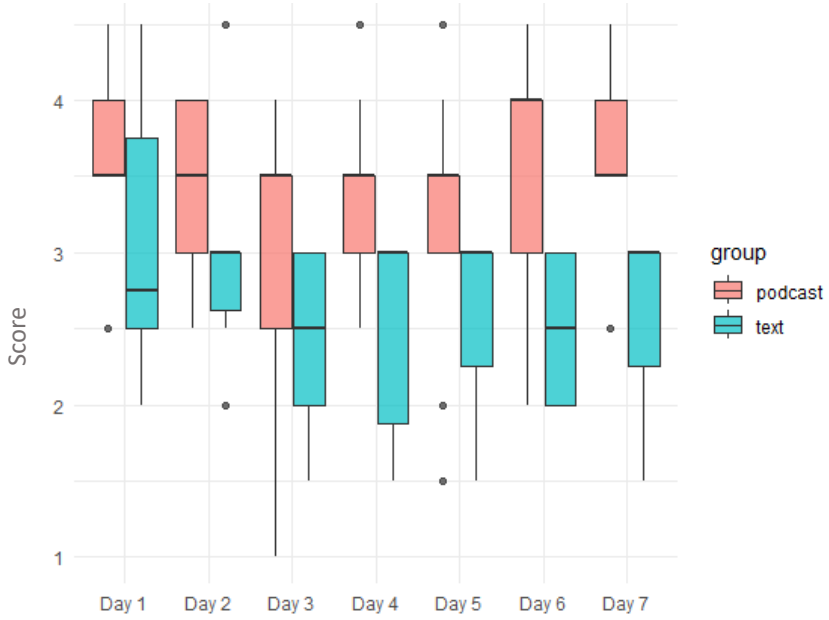
To test Hypothesis 1.2, Friedman's Test was used as the data did not meet the required parametric assumption of equal variance. The assumption of equal variance was tested by exploration of the variance of behavioural scores in the form of box plots (Appendix F). For the Friedman's Test, the condition served as the in-between factor while the behavioural data at each measurement were used as the within factor. In the case of sunlight viewing behaviour, the Friedman Test, $X2(6) = 14.421$, $p = .025$, was significant. Therefore, Hypothesis 1.2 was accepted. To gain a more nuanced understanding of the results, a box plot (Figure 2) visualises novel relationships and trends.

Hypothesis 1.3 – Change in Sunlight Viewing Behaviour

The Friedman's test was chosen as the corresponding data do not meet the parametric assumptions of normality (Appendix G). Results of Friedman's Test on the evening screen interaction, $X2(6) = 1.178$, $p = .978$, did not yield a significant result, leading to the rejection of hypothesis 1.3.

Figure 2

Box plot of evening display interaction scores across seven days



Note: The scores measured daily represent the sleep hygiene behaviour of evening display interaction at the previous day, as participants were asked about the previous day's behaviour. Therefore, Day 2 indicates behaviour on Monday, Day 3 on Tuesday and so forth. The behavioural scores are a presentation of how well the given sleep hygiene behaviour was implemented (1 – undesired, 4 – desired).

Hypothesis 2 – Change in Sleep Quality

In respect of hypothesis 2, the podcast group indicated a greater global PSQI score (M = 8.8, SD = 4.08) than the text group (M = 7.1, SD = 2.51) at the introduction questionnaire with a total of 20 responses included in the analysis resulting in a dropout rate of 16.67% of the initial 24 participants. A similar trend was visible in the closing questionnaire when the PSQI was filled out again. Here, the podcast group (M = 8, SD = 2.79) continued to score higher than the text group (M = 6.6, SD = 2.71).

Hypothesis 2 investigated whether sleep quality improved significantly in the podcast group compared to the text group over the time of the intervention. The assumption of normality was tested by exploration of the global PSQI scores in histograms (Appendix H). As the parametric

assumption of normality is not met, the Wilcoxon signed-rank test was conducted. The Wilcoxon signed-rank test performed on the text group, $z = 8.5$, $p = .847$, was not significant, like the test on the podcast group, $z = 10.5$, $p = .879$. Hypothesis 2 was therefore rejected. As no change occurred in either group, a post-hoc analysis would not yield any additional insight. An overview of the global PSQI scores can be found in Appendix I.

Discussion

Key Findings

In consideration of the first hypothesis, the present study aimed to determine whether a short podcast intervention was more effective in changing three specific behavioural patterns than a control intervention that merely provided textual information. While the behaviour of caffeine consumption could not be evaluated, the results provided interesting information about the behaviour of sunlight viewing and evening display interaction. No significant change in sunlight viewing behaviour was found in either group, thus, hypothesis 1.2 was rejected. However, the results suggest that there has been a significant change in evening display interaction in the podcast group but not in the text group. Therefore, hypothesis 1.3 was accepted. Furthermore, no significant change in sleep quality was recorded in either group. Thus, hypothesis 2 was rejected, and potential behavioural changes were not sufficient to impact sleep quality during the study period. The present findings do not provide a clear answer to the research question proposed: *To what extent can listening to an informative podcast about improving sleep hygiene motivate listeners to improve sleep hygiene better than text and therefore improve sleep quality?* While the results imply that behavioural change by podcasts can be possible and could even be more efficient than text-based information, they cannot provide a definite answer to what extent they do so. However, the findings suggest that neither intervention improves sleep quality as no significant changes were recorded.

Intepretations

Hypothesis 1 – Behavioural Change

To understand the findings, it is important to first think about why behavioural change was achieved in evening display interaction but not in sunlight viewing. If podcasts were indeed more effective, a change in both behaviours would have been expected compared to the text group. When considering the intervention in light of the ELM, it could be argued that the podcast excerpts about sunlight viewing behaviour, due to length and extensive discussions about mechanisms, primarily appealed to the central route of information processing. While one episode was entirely dedicated to this behaviour, the following episode on the third day extended the sunlight exposure discussed by an additional 9 minutes before touching on evening display interaction. In contrast, the part dedicated to evening screen interaction was considerably shorter and entailed less background information and jargon, appealing to the potential peripheral route of information processing (Petty & Cacioppo, 1986). Therefore, participants who are less involved in in-depth discussions about mechanistic information are less likely to elaborate on the provided information by way of the central route. This, in turn, leads to reduced overall persuasion and behavioural adoption. If, however, participants had generally less previous engagement with the topic, the information about evening display interaction was likely elaborated via the peripheral route, which could explain the reduction of the undesired behaviour (Petty & Cacioppo, 1986).

Another contributing factor to the difference in sleep hygiene adoption could be the simplicity of the desired behaviour. It is known that the continuous adoption of new behaviours is dependent on the complexity of the new behaviour (Gardner, 2014). Several well-established behavioural change theories like the Theory of Planned Behaviour (Ajzen, 1991) and the Health Belief Model (Rosenstock, 2000) focus on the role of self-efficacy or perceived barriers, respectively. These factors state that behavioural change occurs when individuals, on the one hand, feel capable of performing the desired behaviour and, on the other hand, are not hindered by restricting factors to perform the behaviour. In the case of the present study, the adoption of sunlight viewing behaviour can be considered a more complex behaviour in comparison to evening screen interaction. While the

latter can be easily achieved by simply turning on the blue light filter and dimming screen brightness in the settings of a device, the former behaviour requires individuals to change their morning routine, get outside, and potentially endure cold and rain for a significant timeframe of 10 to 30 minutes. All these barriers could prevent behavioural change, especially when individuals display low self-efficacy, i.e., perceive the new behaviour as too demanding for their abilities.

Additionally, it is important to note that six out of eight participants who chose to leave a comment in the closing questionnaire about any conscious behavioural changes due to the intervention noted that they tried to gain more sunlight after waking up, regardless of the intervention they received. This additional information raises the question of whether the daily behavioural questions were sensitive enough to record any behavioural changes or whether only a non-significant subset of individuals was compelled to change their sunlight-viewing behaviour.

Next, to further elaborate on the findings, it is crucial to contemplate why significant behavioural change for evening display interaction was recorded for the podcast group but not the text group. This difference suggests that behavioural change is not fully explained by the behaviour itself, e.g., its complexity, but also by how information is delivered to participants. The podcast was indeed more efficient in persuading participants to reduce evening display interaction. This effect could partly be explained by the implementation of certain BCTs that are present in the podcast but not in the text. For example, the BCT of a credible source identified by Michie et al. (2015) is present in the podcast excerpt but not in the text about evening display interaction. In fact, it is known that the number of BCTs influences the strength of behavioural change (Fritz et al., 2019).

Furthermore, audio-based information could be easier to elaborate on by participants compared to text-based information. The present findings support the theory proposed by Turner-McGrievy et al. (2009) and Ko et al. (2013) that explains podcasts greater persuasive effect based on reduced cognitive load and high control over the informative material. Similarly, the improved persuasive effect of audio-based information supports Turner-McGrievy's et al. (2009) hypothesis that podcasts increase elaboration as listeners cannot selectively scan information. Individuals, when

confronted with informational text, tend to selectively scan information, decreasing elaboration (Eveland & Dunwoody, 2002). In conclusion, it seems that audio-based information can be more persuasive, based on the way cognitive mechanisms facilitate the elaboration of information.

Hypothesis 2 – Change in Sleep Quality

Sleep quality has not improved due to the intervention, contrary to the hypothesis. Even though this finding was not expected it seems congruent with the outcomes of Hypothesis 1. When considering that behavioural change only occurred for one sleep hygiene behaviour, it can be anticipated that these small changes do not have a significant impact on sleep quality. Additionally, it must be considered that behavioural change in evening screen interaction was only recorded for the intervention group. It is therefore possible that, even if this subset of individuals experienced an improvement in sleep quality, the number of participants was too small to shift the outcome of Hypothesis 2 into a significant range.

Furthermore, it must be considered that the results of the PSQI were low (Appendix I). Buysse et al. (1989) suggest that a global PSQI score of five or higher reflects poor sleep quality and sleep problems in at least two measured areas. Most participants, therefore, display poor sleep quality and sleep problems. It is considered unlikely that screen brightness, blue light, and screen time before bed are the exclusive cause of recorded sleep problems. Even though some participants have reduced their evening screen interaction, these changes do not address other potential sleep-compromising factors. Even though it is expected that reduced evening display interaction has a positive impact on sleep quality, a reduction in this behaviour cannot be expected to improve sleep quality in a population that displays notably low sleep quality.

Limitations

The present findings have to be considered in light of the strengths and limitations of the study. Generally, a placebo-controlled randomized trial is considered one of the most reliable design choices. The effect of podcasts is directly related to a text-based intervention of a similar type as

control. The result can, therefore, be put in perspective, and the effect of podcasts can be evaluated in the light of another type of intervention. While the limitations of the sample are discussed above, the assignment of participants occurred randomly. This randomization of participants controls for individual characteristics that could have influenced the effect of the intervention. Another strength of this study lies in the within-subject design deploying repeated measurements to assess changes over time. This not only increases the expressiveness of the findings but allows for an in-depth understanding of behavioural changes at specific times in the study period. Individual differences are controlled for as every participant serves as their own control resulting in a significantly reduced risk for confounding variables.

Further, one could argue that the modifications made to the PSQI could result in compromised validity and reliability of the scale. However, other studies found similarly low outcomes in sleep quality when using the original version on a similar population (Schmickler et al., 2023) than this study did. It is, therefore, assumed that the modifications had a modest impact at most and represent sleep quality fairly accurately over one week.

It is important to note that this study is one of the first to investigate the persuasive potential of podcasts in achieving behavioural change in listeners and the first to focus on sleep hygiene, expanding the understanding of what could be a valuable resource for public health interventions. While it did not deploy a specifically theory-based or population-tailored podcast, it tested the most popular health and fitness podcast (Huberman Lab, n.d.) which is available for free to many people. Therefore, the study has acute practical relevance.

However, there are some things future studies can improve. First, the study period was short. Other studies investigating the impact of sleep hygiene on sleep quality over a greater timeframe of four weeks or more (Kakinuma et al., 2010; Morita et al., 2012; Chen et al., 2010) up to several months (Nishinoue et al., 2012). It would be insightful to see whether changes in sleep quality occurred after the first week of the intervention. Second, improvements to the study design are recommended for future studies. A double-blinded study design could reduce changes due to

placebo effects or the observer-expectancy effect. A larger and more diverse sample acquired through a random sampling procedure, as deployed by other studies (Turner-McGrievy et al., 2009; Elbert et al., 2016), could further increase the expressiveness of outcomes. Similar studies investigating the impact of podcasts on behavioural change (Elbert et al., 2016; Turner-McGrievy et al., 2009) or the importance of sleep hygiene (Kakinuma et al., 2010; Morita et al., 2012; Chen et al., 2010; Nishinoue et al., 2012) all had a significantly larger sample size. The convenience sampling method utilized in this study could have contributed to a sampling bias. Similarly, the participant distribution system Sona could contribute to a biased sample, as participants who already were concerned with their sleep, e.g., because they face sleep problems, could have been more likely to participate in this study than others.

Lastly, unexpected problems during the data collection procedure impacted the final dataset. High attrition rates and, consequently, numerous missing data points resulted in a limited dataset for analysis. Furthermore, technical difficulties during the third round of the study further contributed to the attrition rate as many participants did not receive the link for the closing questionnaire. Additionally, one item measuring caffeine consumption ("When was the last time you had caffeine yesterday […]") had to be combined with the indicated bedtime each day "When did you go to sleep yesterday?". Based on feedback, participants were unsure what a viable answer to this question was, especially when participants went to bed past midnight, which would not be considered yesterday anymore. An inspection of the related data inferred that it was not possible to determine whether the time participants stated was related to the most recent sleep cycle, which would be today, or whether it was related to the previous sleep cycle, which would be considered yesterday. As this data is crucial to successfully evaluate caffeine consumption behaviour, based on the time between the last caffeinated drink and sleep time, the behaviour of caffeine was not included in the final analysis.

Implications

The findings of the present study cannot provide a clear answer to the research question and cannot make a meaningful statement about the effectiveness of podcasts in health behaviour change.

However, this study's results align with previous research that has demonstrated the potential of podcasts in persuading listeners to adopt health behaviours (Turner-McGrievy et al., 2009; Elbert et al., 2016). While the mechanisms and other influences, which are discussed above, are still limited, past and present results do suggest that podcasts can be more persuasive than text-based interventions. If future studies continue to show this trend and further explore the best theory-driven approaches or most suitable BCTs for podcasts, this medium can be a highly valuable platform for digital health interventions. Due to its convenience and accessibility, it is an appealing medium for numerous populations, while the audio-based nature of podcasts seems to be superior to print-based or web-based interventions.

Directions for Future Research

This study follows up on initial explorations of the potential of podcasts as a platform for health intervention by Turner-McGrievy et al. (2009) and Elbert et al. (2016). While their research provided promising results for the potential of podcasts, today's study strengthens the assumption that podcasts are a suitable candidate for health interventions. However, future research is needed to validate existing findings and further explore potential mechanisms by which podcasts persuade listeners to adopt behaviours and where their limitations lie.

Similar studies or replications would benefit from more detailed measurements. Firstly, sleep hygiene behaviours can be measured differently. Instead of self-reports, objective measures, e.g., data provided by wearable sleep trackers, could offer more sensitive and reliable data. Additionally, an improved assessment of sleep quality due to the intervention can be helpful. It is recommended that changes in sleep quality are evaluated over a greater time frame than one week. Habit adoption and improving sleep could be an ongoing and long-lasting process, and an extended time frame could yield insightful data about the impact of sleep hygiene on sleep quality. Lastly, instead of investigating the impact of a podcast versus text on sleep quality, an investigation into the impact of specific sleep hygiene behaviours on sleep quality could provide new insights about the effectiveness of such

behaviours and facilitate an agreement on specific sleep hygiene behaviour recommendations for non-clinical populations.

Other studies that investigate the potential of podcasts in health behaviour change, could benefit from a different focus. First, the implementation of a different set of BCTs, which are eligible for podcast format, would shed light on the mechanisms by which podcasts achieve behavioural change. Second, the focus on different behaviour change models, like the health belief model (Rosenstock, 2000), could be useful to further explain and expand the persuasive nature of podcasts for public health interventions. As findings are generally hard to generalize for multiple health problems, a focus on different health behaviours like exercise or reducing alcohol consumption would create valuable insight into the potential of podcasts in different areas.

Conclusion

Despite the strengths and weak points of this current study, the findings connect to initial previous studies and suggest a potential for podcasts in digital health interventions. As the exploration of this topic, its mechanisms, potentials, and limitations, are still scarce, further research is needed to determine whether conventional models and theories of behavioural change hold up to this popular form of digital medium.

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Appendix

Appendix A

Informed Consent for Voluntary Participation in This Study

Informed Consent

Purpose of the Research:

The participation in this research is entirely voluntary. The purpose of this research is to investigate the potential of podcasts as a platform for delivering digital health interventions. The study aims to understand the impact of podcasts on health-related behaviours, with a focus on sleep hygiene and its impact on sleep quality.

Benefits and Risks:

Participating in this study provides an opportunity to contribute valuable insights to the field of digital health interventions. The research project has undergone review and approval by the BMS Ethics Committee/domain Humanities & Social Sciences. While there are no severe risks, it is important to note that an increased awareness of sleep may occur, which could be problematic for individuals already overly concerned about their sleep and sleep quality.

Participants in this study may benefit from by gaining useful insight about sleep and sleep health that could improve their sleep quality in the short- or long-term.

Withdrawal from the Study:

Participants have the right to withdraw from the study at any time without providing a reason. Your decision to withdraw will not lead to any personal negative consequences and will not affect your relationship with any affiliates for the University of Twente or the University as such.

Data Collection and Privacy:

As part of this study, we will collect personal information, including demographic data (age, sex, ethnicity, and occupation), as well as details about behaviours and sleep quality. Even if you choose to withdraw from the study, we will use this data, except when you explicitly request its deletion. All collected data will be anonymized to uphold confidentiality, ensuring that no participant's identity can be traced. Additionally, your name is required during the study period for participant identification across platforms (qualtrics and TIIM Application) and in case of data deletion requests. All names and identifiable data will be deleted by December 10th at the latest to guarantee full anonymity. After this date, no requests for data deletion can be accommodated, as the data will no longer be traceable to the individual making the request.

Data Usage and Safety:

The collected data will be used for research purposes to understand the potential of podcasts for digital health interventions. Data safety is guaranteed, adhering to the storage safety standards of the

faculty. All data will be anonymized and stored securely for up to 10 years based on the faculties standard procedure.

Contact Information:

If you have any questions or concerns about the study, you can contact the researcher or involved parties at any time:

- **Researcher**: Nico Hohlfeld (n.m.hohlfeld@student.utwente.nl)
- **Supervisor**: Lina Bareisyte (l.b.bareisyte@utwente.nl)
- **BMS Ethics Committee/domain Humanities & Social Sciences** (ethicscommittee-hss@utwente.nl)

Consent Form for the Study "Examining the Influence of Informative Podcasts About Sleep Health on the Development of Sleep Hygiene

YOU WILL BE GIVEN A COPY OF THIS INFORMED CONSENT FORM

Please tick the appropriate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated [17/10/2023], or it has been read to me. I have had the opportunity to ask questions, and my questions have been answered to my satisfaction.	□	□
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	□	□
Study Details	□	□
I understand that participation involves the use of my smartphone and the TIIM application. The study collects data about my sleep and behavioural changes through audio clips and daily questionnaires over one week.		
Risks associated with participating in the study		
I am aware that participating may increase awareness of my sleep, and for individuals with existing sleep anxiety, it may lead to increased discomfort.	□	□
Use of the information in the study		
I understand that my information will be used for data processing to gain insights into the potential of podcasts for digital health interventions. The data will be anonymized, safely	□	□

stored, and handled responsibly. The results will be made publicly available for those interested.

I understand that personal information collected about me that can identify me, such as my email, will not be shared beyond the study team and will be deleted December 10th latest □ □

Signatures

_____	_____	_____
Name of participant [printed]	Signature	Date

_____	_____	_____
Researcher name [printed]	Signature	Date

Study contact details for further information: Nico Hohlfeld (n.m.hohlfeld@student.utwente.nl)

Contact Information for Questions about Your Rights as a Research Participant

If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Secretary of the Ethics Committee/domain Humanities & Social Sciences of the Faculty of Behavioural, Management and Social Sciences at the University of Twente by ethicscommittee-hss@utwente.nl

Appendix B

Modified Version of the PSQI Used in This Study

P1

During the past week, what time have you usually gone to bed at night? (Please use the 24h system, e.g.: 23 instead of 11pm)

P2

During the past week, how long (in minutes) has it usually taken you to fall asleep each night? (Please use the 24h system, e.g.: 23 instead of 11pm)

P3

During the past week, what time have you usually gotten up in the morning? (Please use the 24h system, e.g.: 23 instead of 11pm)

P4.1

During the past week, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spent in bed.)

- 7 hours or more
- 6 to 7 hours
- 5-6 hours
- 5 hours or less

Add page break

P4.2

Please specify: How many hours of actual sleep did you get at night during the past week? (Same question as the previous one, but please type in the number of hours yourself)

Page Break

P5

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

P5a

Cannot get to sleep within 30 minutes

Not at all	Once	Once or twice	Three or more times
○	○	○	○

P5b

Wake up in the middle of the night or early in the morning

Not at all	Once	Twice	Three or more times
○	○	○	○

P5c

Have to get up to use the bathroom

Not at all	Once	Twice	Three or more times
○	○	○	○

P5d

Cannot breathe comfortably

Not at all	Once	Twice	Three or more times
○	○	○	○

P5e

Cough or snore loudly

Not at all	Once	Twice	Three or more times
○	○	○	○

P5f

Feel too cold

Not at all | Once | Twice | Three or more times

Add page break

P5g

Feel too hot

Not at all | Once | Twice | Three or more times

P5h

had bad dreams

Not at all | Once | Twice | Three or more times

P5i

Have pain

Not at all | Once | Twice | Three or more times

P5j

other reason

Not at all | Once | Twice | Three or more times

Page Break

P6

During the past week, how would you rate your sleep quality overall?

Very good | Fairly good | Fairly bad | Very bad

P7

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

Not at all | Once | Twice | Three or more times

P8

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

Not at all | Once | Twice | Three or more times

P9

During the past week, 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

Appendix C

Podcast excerpts used in this study.

Media Used

Master Your Sleep & Be More Alert When Awake | Huberman Lab Podcast #2

https://www.youtube.com/watch?v=nm1TxQj9IsQ

Sleep Toolkit: Tools for Optimizing Sleep & Sleep-Wake Timing | Huberman Lab Podcast #84

https://www.youtube.com/watch?v=h2aWYjSA1Jc^

Using Caffeine to Optimize Mental & Physical Performance | Huberman Lab Podcast #101

https://www.youtube.com/watch?v=iw97uvIge7c

Times for each podcast clip

Tuesday, Intro Questionnaire:

Ep. #2 00:00-01:22 | 3:22-9:00 | 11:40-13:50

Wednesday, Sunlight Exposure:

Ep. #84 15:10-23:57

Ep. #2 25:19-26:18

Thursday, Blue Light

Ep. #2 32:53-42:29 | 47:41-50:59

Friday, Caffeine

Ep. #101 42:01-45:16 | 1:27:45-1:31:44

Appendix D

Informational Text Provided to the Control Group

Tuesday Introduction

The intricate dance between sleep and wakefulness orchestrates a profound impact on every facet of our mental and physical well-being. While sleep claims a significant portion of our daily lives, providing a period of inactivity, it plays a vital role in resetting our alertness and fortifying our overall health for the times we are awake and active.

The symbiotic relationship between sleep and wakefulness becomes evident as we explore their interdependence. Sleep not only influences our wakefulness but also shapes the quality of our activities during conscious hours. This interconnectedness is governed, in part, by adenosine, a molecule whose concentration increases the longer we remain awake. As adenosine accumulates, its sleep-inducing effects intensify, highlighting the importance of regular sleep to maintain optimal functioning.

Further complicating this delicate balance is the circadian rhythm, a roughly 24-hour cycle that dictates our natural inclinations toward sleepiness and wakefulness. Melatonin, a hormone that rises in the evening and diminishes in the morning, acts as the conductor of this internal symphony. Understanding and respecting the ebb and flow of this circadian rhythm is essential for harmonizing our sleep-wake cycle.

Light emerges as the most influential stimulus in setting our inner clock and circadian rhythm. Its qualities and timing significantly impact the delicate balance between sleep and wakefulness. Acknowledging the pivotal role of light underscores the importance of mindful choices in our daily routines to promote a seamless relationship between the realms of sleep and wakefulness, contributing to enhanced mental and physical health.

Wednesday Light Exposure

Our internal circadian rhythm (also called the circadian clock) is the engine behind our sleep-wake cycle and is itself governed by light exposure. But not all light exposure is equal: the light intensity (or lux) and timing of light exposure impacts circadian rhythm quite differently.

For instance, morning light — especially the first natural light of the day — is a powerful wake-up signal due to the ratio of blue light to yellow light that is unique to sunrise and sunset. Additionally, outdoor light exposure can be upwards of ten times brighter than the brightest indoor lighting, creating a much stronger synchronization between your internal clock and the time of day.

On a **sunny morning**, get outside for **5-10 minutes.** You can do more if you have time, and feel free to use the time outside to exercise, walk, eat a light breakfast or journal in the sunlight. Even on **overcast days,** there is still enough sunlight to trigger positive effects, but you'll need to increase the time outside to **at least 15-20 minutes**.

Contacts and eyeglasses (even those with UV protection) are fine to wear when viewing morning sunlight. However, don't use sunglasses or blue blockers during morning sunlight-viewing — you won't get the maximum effects from the morning sunlight. Face toward the sun.

As always, never look directly at the sun or view the sun (or any light) in a way that causes pain; just close your eyes and blink as needed to protect your eyes.
Note: trying to do all this through a windshield or window won't work; too many of the relevant wavelengths are filtered out.

Thursday Blue Light

Exposure to bright light, particularly blue light from screens and artificial light late at night, will lead to circadian disruption. Shift work, jet lag, rapid time zone changes, and an inconsistent sleep schedule cause a misalignment between the light levels hitting the photoreceptors in our retinas and the body's other biological signals for sleepiness including increased melatonin levels and a decrease in body temperature.

UVB light exposure from artificial sources/screens at night (10 p.m.-4 a.m.) decreases dopamine levels and negatively impacts feelings of depression and anxiety. Once in a while is fine, but if you are looking at your phone or turning on bright lights between 10 p.m. and 4 a.m. on a regular basis, your health will suffer.

The effects of light on our circadian rhythm extend beyond mere sleep timing. Even mild to moderate sleep deprivation has been linked to mental health issues and temporary declines in cognitive functioning. Therefore, regulating our exposure to light sources in the evening, for example by avoiding bright lights or using blue light blockers before bed, is a key strategy in promoting overall mental and physical health and performance.

Friday Caffeine

While moderate caffeine intake can offer some health benefits, understanding how and when to consume caffeine is crucial to prevent unwanted side effects. Caffeine, known for its stimulating properties, allows individuals to remain independent of the day-night cycle, making it a common choice for shift workers. However, this independence comes with health consequences, particularly for those working irregular hours.

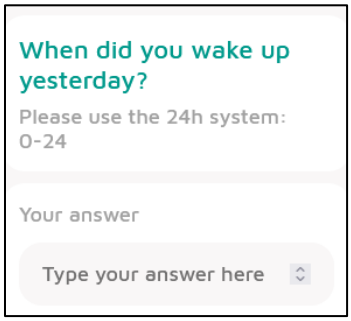
Caffeine serves as a negotiator with sleepiness, providing a temporary boost in alertness. While it doesn't eliminate the need for sleep, it helps offset feelings of sleepiness and promotes wakefulness. It is essential to recognize that sleep remains paramount for both mental and physical health.

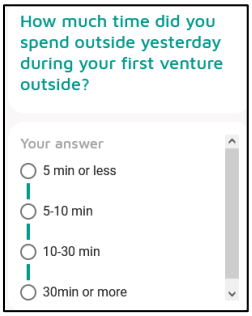
Considering the long quarter-life time of caffeine (12 hours), it is advisable to avoid caffeine intake 12-8 hours before sleep to prevent disruptions in sleep quality. For instance, if you ingest caffeine at noon, approximately 25% of its effects are still active during midnight, potentially affecting the depth and restfulness of your sleep.

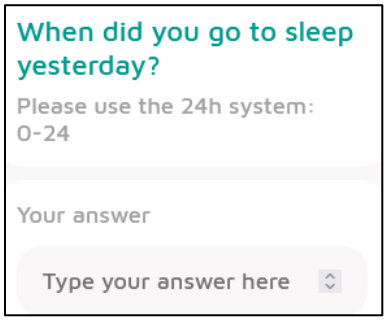
An occasional cup of coffee in the afternoon is generally not a significant concern. However, maintaining a mindful approach to caffeine intake and its timing can contribute to better sleep hygiene and overall well-being.

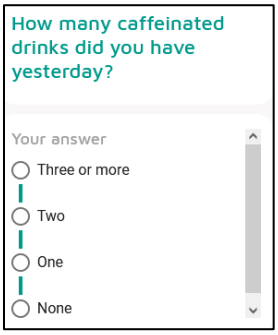
Appendix E

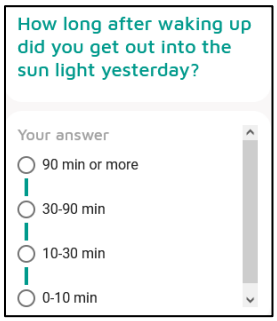
Daily Questions During the Study Period

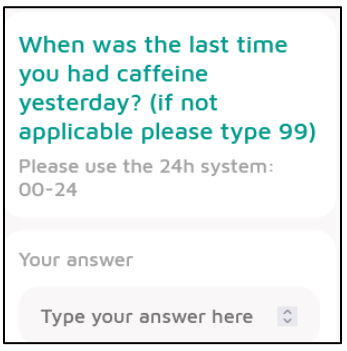


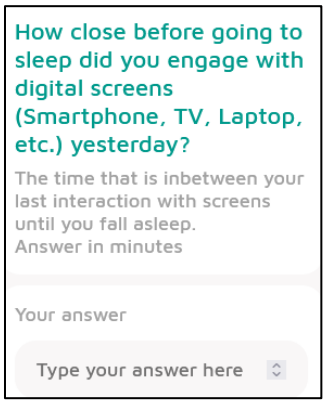


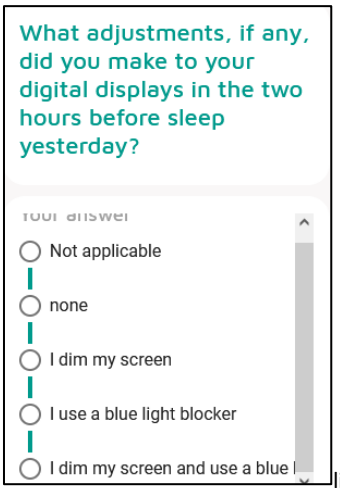












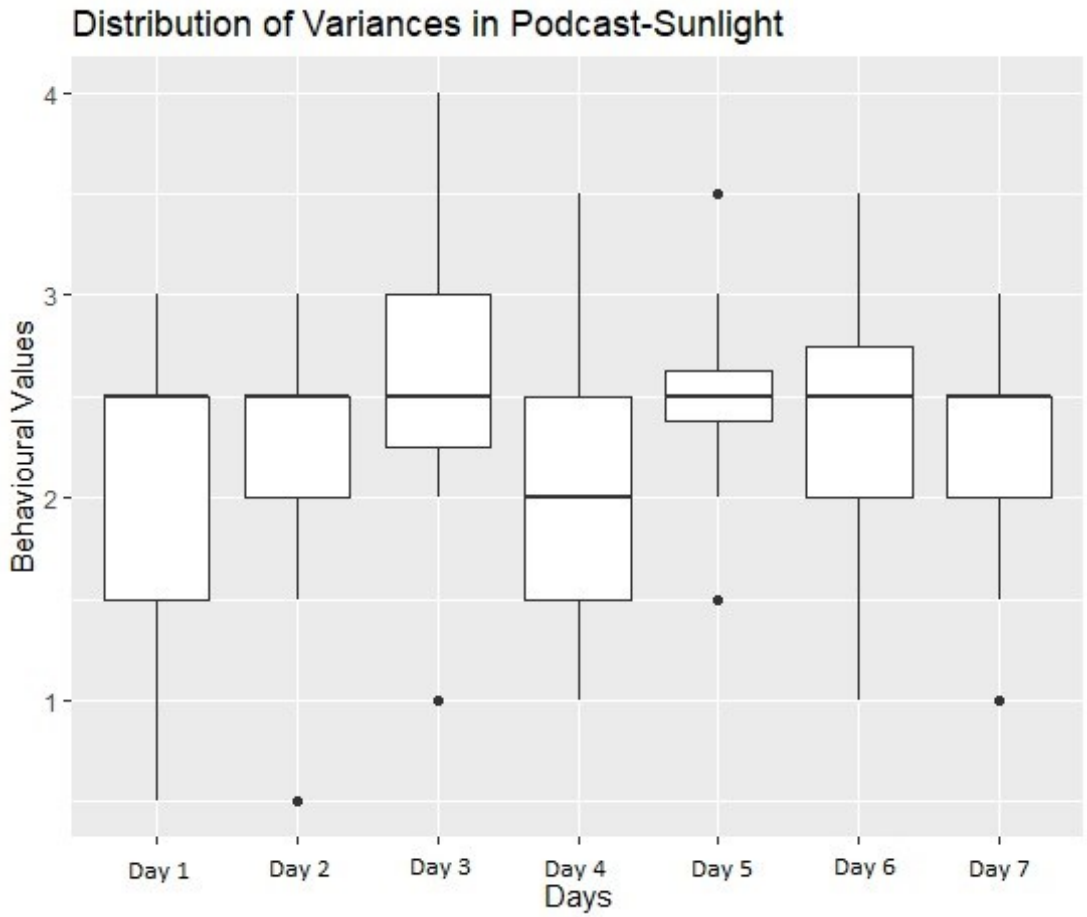
light blocker

Appendix F

Figures Used to Assess Parametric Assumptions

Figure 3

Box plot to assess the equal distribution of the Sunlight viewing scores in the podcast group



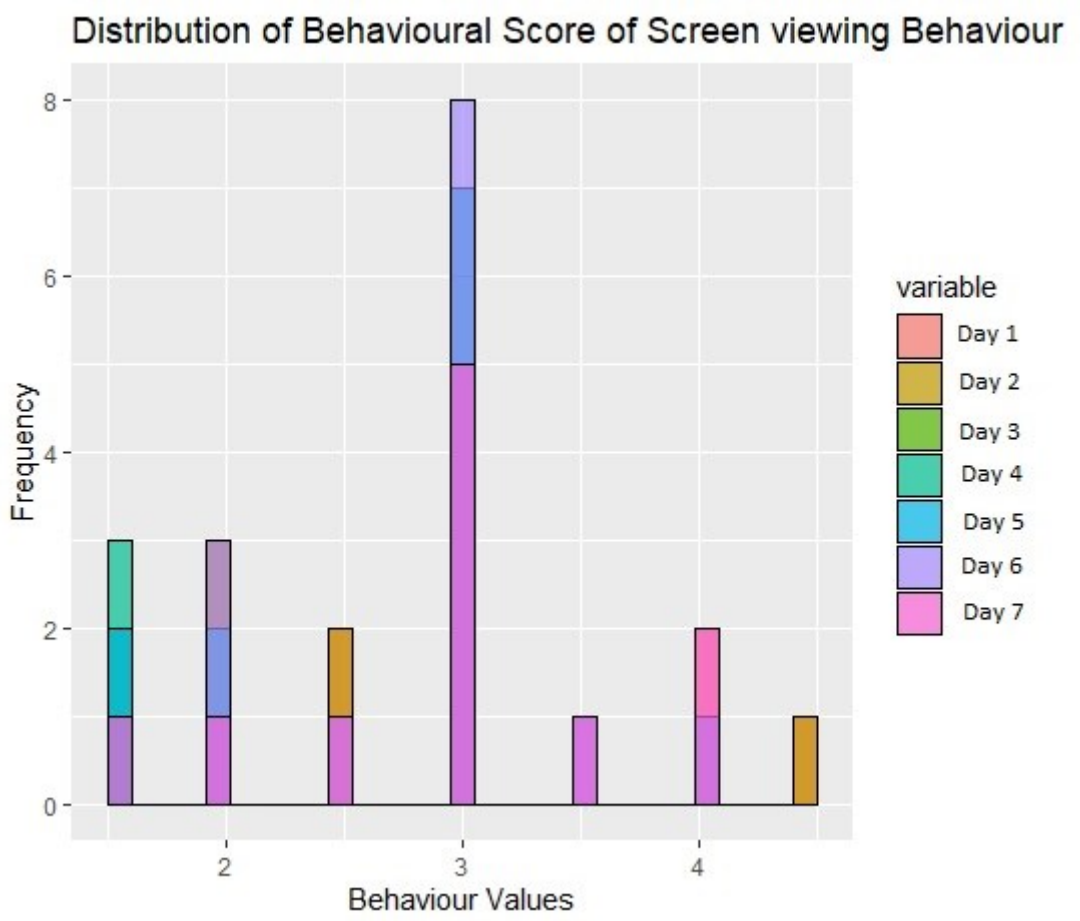
Note. This box plot plots the behavioural scores of the sunlight-viewing behaviour in the podcast group for each day. The length of each box varies drastically, indicating a violation of the assumption of equal variance. The violation of equal variance in the podcast group dictates the usage of the non-parametric Friedman test. This test will also be conducted on the sunlight viewing data of the text group to ensure a homogenous outcome eligible for comparison.

Appendix G

Figures Used to Assess Parametric Assumptions

Figure 4

Histogram to assess the normality of Screen viewing scores in the text group



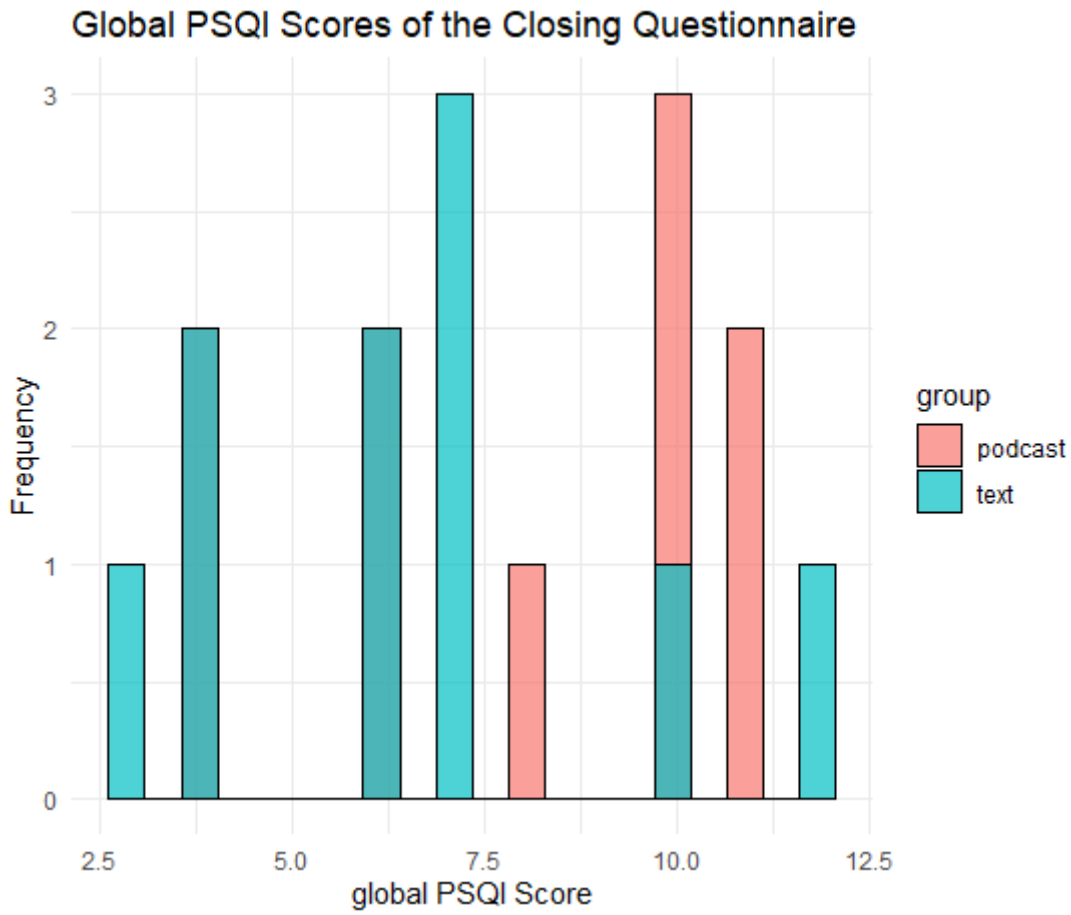
Note. This histogram plots the behavioural scores of the screen viewing behaviour in the text group for each day. The histogram does not indicate a normal distribution of data, indicating a violation of the assumption of normality. The violation of normality in the text group dictates the usage of the non-parametric Friedmans test. This test will also be conducted on the screen viewing data of the podcast group to ensure a homogenous outcome eligible for comparison.

Appendix H

Figures Used to Assess Parametric Assumptions

Figure 5

Histogram to assess normality of global PSQI scores in the closing questionnaire



Note. This histogram plots the global PSQI scores of the closing questionnaire per group. The histogram does not indicate a normal distribution of data, indicating a violation of the assumption of normality. The violation of normality dictates the usage of the non-parametric Wilcoxon signed rank test.

Appendix I

Outcomes of the Modified PSQI

Table 2

Results of the modified PSQI scale to assess sleep quality before and after the intervention

Introduction Questionnaire Score		Closing Questionnaire Score	
Podcast	Text	Podcast	Text
8	10	8	10
11	6	10	6
16	6	10	4
12	9	11	7
9	5	10	6
6	8	6	12
12	8	11	7
5	5	4	4
7	11	6	7
2	3	4	3
M = 8.8	*M* = 7.1	*M* = 8	*M* = 6.6

Note: This table illustrates the sleep quality score of the modified version of the PSQI used in this study. The values of the Introduction questionnaire represent the sleep scores of the week before the study began and the values from the closing questionnaire represent the sleep scores in the week of the intervention. The possible scores range from 0 to 21, and scores higher than 5 are usually considered to reflect poor sleep quality or sleep problems in at least two areas measured by the index.