Title	Dozier : a study into the use of virtual reality's potentials for the realm of sleep
Sub Title	
Author	Bait, L. Marsel Alfred Kunze, Kai
Publisher	慶應義塾大学大学院メディアデザイン研究科
Publication year	2019
Jtitle	
JaLC DOI	
Abstract	
Notes	修士学位論文. 2019年度メディアデザイン学 第726号
Genre	Thesis or Dissertation
URL	https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=KO40001001-00002019-0726

Master's Thesis
Academic Year 2019

Dozier: A Study into the Use of Virtual Reality's Potentials for the Realm of Sleep

Keio University
Graduate School of Media Design

Marsel Alfred L. Bait

A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
Master of Media Design

Marsel Alfred L. Bait

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Abstract of Master's Thesis of Academic Year 2019

Dozier: A Study into the Use of Virtual Reality's Potentials for the Realm of Sleep

Category: Design

Summary

Sleep is paramount to both the physical and mental health, yet it is still not treated as such. This can be seen from various examples such as statistical proof of sleep epidemics and it's relationship to the economy, and various language jargon that exist only in countries that exhibit strong sleep deprivation rates.

With napping being able to curb lack of sleep and increase worker productivity, companies are starting to focus on this topic. This study aims to empower that effort by exploring the potentials of virtual reality and it's potentially positive effects of sleep latency. Experimental results of this study point to the fact that VR technology can hasten the sleep onset latency.

Keywords:

Virtual Reality, Sleep, Nap, Sleep Onset, Innovation, Electrooculography

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Acknowledgements

It is with overflowing, immense gratitude that I acknowledge the support and help of my family for always believing in what I can do.

I cannot find the proper words to express my gratitude to my professors, Kai Kunze and Roshan Peiris who helped me keep things on the proper track get this done. Of course to my senior Yun Suen Pai for getting the boulder rolling with this project. Thank you to the GEIST members who have inspired me to focus on what to go deeper in, and to those who have helped me with the technical issues - George, and execution of the experiments - Pai and Icy.

Thank you to the thesis crew - Cody, Cendi, Yohei, Tania, etc. Ya'll MVP's. Rooms 07, 09 and 03 will forever be relevant with the smell of Hiyoshi's legendary chicken rice.

I am thankful to my friends, all my roomates (A-1920, Terence House members - Tomoki Prugger, Terence Blesin, Mari Yamachi), and Shiho Takahashi for supporting me. A huge thank you to all the participants of the experiment for this study, without you guys I would have no data.

On a closing note, if you're reading this because of your interest in sleep (I'm speaking in terms of lucid dreams, astral travel etc as well), I hope you can contribute much to this society - feel free to search and hit me up.

See you in the astral planes,
ez ggwp.

Chapter 1
Introduction

1.1. Motivation

Sleep has been under an interesting light as a topic in our society. With productivity in mind as the highest objective, most people put less importance on sleep. With two thirds of adults not being able to achieve the recommended eight hours of sleep (footnote). Lack of sleep has become an epidemic, and because of a myriad of reasons. On the physical side as an example, when done on a routine basis, sleeping only 6-7 hours per night can demolish the immune system, and increase the chances of the coronary arteries becoming blocked and brittle (Walker 2017). Mentally, lack of sleep attributes to drowsiness, with one of the most dangerous consequences, an example being driving a vehicle while still being in that state. 100,000 reports of drowsy driving related crashes, both fatal and not are reported every year [1]. Studies have shown that even for healthy adults, relatively moderate restrictions on sleep are enough to impair their neurobehavioral functions (P A Van Dongen et al. 2003) The body's general homeostasis is interrupted when a person does not sleep much. RAND corporation has shown a statistic where lack of sleep is slowly increasing the severity of the sleep epidemic. The United States for example, "sustains the highest economic loss (up to 411 billion dollars a year) due to the size of it's economy, followed by Japan (up to 138 billion dollars a year, which is 2.92 percent of it's GDP)" [2]. The study also stated that high mortality risk and sleep deprivation are linked to each other - "An individual sleeping between six to seven hours per day still has a four percent higher mortality risk.

With this in mind, from one of the surveys gathered for this study, it is shown that 77 percent of the participants are sleeping less than the proper 8 hours recommended by the National Sleep Foundation (Hirshkowitz et al. 2015). In conclusion, a sleep epidemic is a dangerous problem, as Dr. David Hillman best puts it; ”Inadequate sleep is too easily accepted into the community as a part of life, sleep is seen as an indulgence”. Historic failures of general science studies has failed to express the dire importance of sleep.

The author of this work has always been interested in sleep as a topic. How sleep has always been dethroned off of it's pedestal by society for various reasons. To the author, sleep needs to be understood more, hence the motivation to explore it deeper, and discover the possibilities to express it's importance to many, or even to just make it easier to access.

This study also explores how virtual reality technology can be used in other ways. VR is used with the idea that the visuals inside and the experience itself will be a ”stimulated” sort of activity. However, through this paper, VR would be explored more as an aid to the imagination in terms of imagery distraction (Harvey and Payne 2002).

Proper sleep in the modern environment itself has proven to be even more of an obstacle. Smart phones and other devices that we all carry emits blue light which promotes alertness, coupled with a hectic productivity focused lifestyle, it's no wonder sleep is such an issue. The perspective on sleep that society holds on to is distorted; in most work environments naps are discouraged even although it has the ability to increase productivity levels amongst workers (Davis 2199).

This study will run with the hypothesis that virtual reality technology can affect the sleep onset in a positive way - VR can improve the sleep onset

1.2. Objectives

The aim of the study is to mainly see the potentials of the relationship between sleep and VR. The objectives can be seen as;

(1) Explore the possibilities of how VR can help improve sleep onset through experiments and verify the data.

(2) To explore further the effects of different VR situations if the hypothesis is verified.

(3) To explore the possible design iteration for the device.

1.3. Contributions

The contributions of this study are as follows:

(1) Provide a proper assistance to falling asleep This study has the potential to introduce a device that has the ability to assist people in falling asleep. In a world where sleep does not have much of the dire emphasis on it, this study shines a spotlight towards the subject.

(2) Explore a different way to use VR technology This study provides a different perspective on how VR can be used. Where VR is usually a method used to amplify the waking experience, this study explores the way it can be used to lessen the wakefulness aspect whilst keeping the user's senses immersed.

(3) Contribute a data set This study has recorded data sets from a total of 24 people (14 from the initial experiment, and 10 from the recent one). The data sets include tapping data, EOG data, and questionnaire answers. These data can be used for future endeavours concerning this particular field. The EOG data, more specifically, can be used for future studies in regards to user sleep patterns.

1.4. Thesis Overview

This thesis consists of 5 chapters. Chapter 1 depicts the introduction of the thesis. The contributions of the study is expressed here. Chapter 2 is about the literature review. Chapter 3 shows the final design of the prototype, it details the design concept. Chapter 4 expresses the experiments and design iterations, while chapter 5 expresses the study of the results, the conclusion, along with future woks.

1.5. Key Terms

VR - Virtual Reality
EOG - Electrooculography
HMD - Head Mounted Device

Notes

1 nsc.org/road-safety/safety-topics/fatigued-driving

2 www.rand.org/pubs/research$_{r}eports/RR1791.html$

Chapter 2
Related Works

2.1. Sleep and The Working Society

Lack of sleep on a routine basis has the ability to demolish the immune system, double the risk of cancer, imbalance the hormonal system, and complicate the path away from cardiovascular issues and stroke(Walker 2017). It is alarming to see that some people are falling asleep less than the suggested sleep hours. Country-wise, for example On the average, taking America as an example, sleep for around 6.8 hours, an hour less from the same data collected in 1942 (**?**). Far below the average, Japan as well has an average sleeping time of 6 hours and 35 minutes per night (Roll 2018). According to the 2018 data of OECD Compendium of Productivity Indicators, when compared to the rest of the G-7 nations, Japan has the lowest level of productivity. A lot of office workers have died due to exhaustion from their work due to the country's intense work culture. The OECD data shows that the overwork capping time monthly reaches 100 hours, and the working hours per day reaches up to almost 12 hours(Nathani 2018).

World Health Organization has even declared a sleep loss epidemic on industrialized countries such as Japan, the United States of America, United Kingdom (Walker 2017). If we take a closer look at Japan, they even have specific social jargon that allude to the country's state of sleep deprivation such as; "Karoshi" which means death by overworking, and "Inemuri" which means sleeping during work - a sign of overworking. On the other hand, proper sleep boasts various benefits such as memory solidification, balancing of the metabolic state, reset of immune system armory, and lowering of the blood pressure (Walker 2017).

Figure 2.1 "Inemuri" in public transportation

Lack of sleep in even moderate levels, has the ability to impair a person's cognitive and motor performance, rendering them equivalent to them having a blood alcohol concentration of 0.05 percent or more (Williamson and Feyer 2000). The participants from that test displayed response up to 50 percent slower and significantly poorer on other tests. Longer period of sleep worsened the levels akin to 0.1 blood alcohol content. It is no surprise that 10 000 reports of car accidents, both fatal and not are reported annually [1]- Drowsy driving is as fatal as drunk driving in this regard.

Naps can be seen as another way to curb lack of sleep - a 2018 study compared the effectiveness between extended sleep, coffee and naps in terms of the relinquishing of sleep debt, with naps deemed as the best option. Naps have been proven to be the most effective way to getting more night time sleep (Horne et al. 2008). Taking naps are biologically hardwired into our systems, with our circadian rhythms generally dipping in the middle of the day (Ph.D. 2016). Napping and the working culture has been a new venture spotlight recently, albeit being newly introduced, some companies have created devices and efforts that can help people take a naps within their office spaces.

Energypod, for example, is a brand of a line of chairs that were specifically designed for naps in the office. Created by the company called Metronaps, these pods have a zero gravity position, boasts a gentle wake systems making use of lights and vibrations, and aesthetically visually pleasing. The pods operate for a 15 - 20 minute nap time. These pods have a privacy visor that helps people feel secure and in that way, helps them fall asleep. Google is one of the companies that makes use of these energy pods for their offices.

Figure 2.2 The Energypod by Metronaps

Big companies seem to be catching up with the knowledge of the importance of sleep. Google for example, have sleeping pods in their offices for workers to use when they feel like napping. Ben and Jerry's offices have sleeping spaces as well for the same purpose. Some companies in Japan including "Nextbeat.co"(McCurry 2019) and property developer "Mitsubishi Estate.co" (Kyodo 2018), provide sleeping rooms for their employees. A wedding planning company called "Crazy" has a program where the employees are given incentives if they are able to fulfill six hours of snooze every night through an application that monitors their sleep. The founder of the company, Kazuhiko Moriyama mentioned that the well rested workers are the more productive workers. (McCurry 2019).

With sleep possibly being given the proper attention that it deserves in the future, more work places will take part in helping their employees get more sleep - with productivity and economical sustainability as the main focus. The angle that this paper will tackle would be the ways that will aid just that, in the sense of virtual reality technology and it's possible capabilities in reducing the sleep onset time.

2.2. Sleep Detection

Sleep can be verified through three main readings; brainwave, eye movements, and muscle activities - the collective term for this being known as "Polysomnography" (PSG 1999).

Sleep Detection in History

Eugene Aserinsky and Professor Nathaniel Kleitman, two professors from the university of Chicago, were amongst the pioneers for sleep research. It was through their study that we see the fact of how sleep has more layers to it than it seemed. Sleep stages are comprised of two general layers namely the "Non-Rapid eye" (nREM) sleep phase and the "Rapid-Eye movement" (REM) phase. REM sleep is characterized by eye movements and brainwave activities similar to being awake, while nREM sleep would be characterized by less eye movements and brainwaves. nREM itself is divided into 4 further phases. These sleep stages take turns approximately every 90 minutes. It is this discovery that paved the way for researchers to probe deeper into sleep.

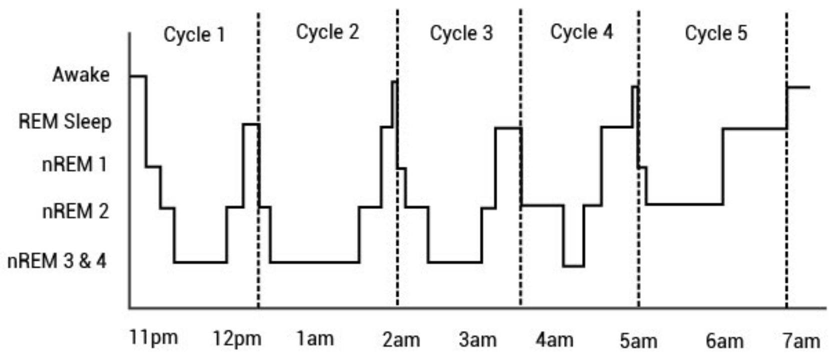

Figure 2.3 Sleep cycle

Methods to detect sleep falls into two categories; physiological and behavioral type methods(Lack et al. 2019) . Physiology methods make use of devices such as EOG, PSG and EEG. Behavioral wise, this is divided into active and passive methods. Active method makes use of a task that requires minimal effort for the participant while trying to fall asleep. Once these actions are recorded to be halted, then we can assume that the participant has fallen asleep. This was first proposed by Blake et all (Helen Blake and Kleitman 1938) Active method makes use of experiments that require reaction times as well (Liberson 2199). Passive methods include ones that do not disturb the participant too much such as recording the user's data through the use of a pressure mattress. Another way to detect sleep onset would be through the use of wearable heart rate sensors (Okamura et al. 2016a). A different approach includes a non-invasive technique that makes use of pressure mattress to evaluate the user's sleeping pattern (Metsis et al. 2012)

Researchers and experiments requiring sleep detection usually make use of complicated and costly equipment such as the Polysomnography machine (PSG) . There are though, some related works that make use of simpler methods, one of them is the use of Electroencephalography (EEG) [2]. In that particular study that tried to determine the accuracy of the use of EEG to detect sleep onset, the signal was derived from a single frontal electrode inside a wireless headband used by the subject. The EEG has proven to have an accuracy of 87.5 percent.

Other long term studies also make use of a method to recognize rapid eye movements called Electrooculography. The corneo-retinal standing potential that exists in the back and front of the human eye are measured in this technique though pairs of electrodes that are placed near the eyes. One electrode sees the positive side, while the other sees the negative side of the retina. This study will make use of EOG for the collecting of data through the Jins MEME glasses (M Boukadoum and Ktonas 1986).

2.3. Virtual Reality in Meditation and Therapy

Virtual reality technology has been especially trending in the recent years. The technology offers a virtual environment that the user could immerse themselves into, as it gives them a different taste for their visual and auditory senses. Virtual reality, although rarely associated with sleep, has an undeniable effect on the human mind - this is proven by it's application to therapy and meditation.

Virtual Reality Mindfulness

One example of how VR has revolutionized an industry would be the study "Virtual Reality Mindfullness"(Navarro Haro et al. 2017) .The study focused on testing the usage of VR as a way to facilitate mindfullness practice. Traditional Dialectical Behavioral Therapy (DBT) mindfullness skills training is designed for people who have issues with focusing their attention. Several patients though, usually have issues concentrating and losing their motivation fast. VR was used in this study in the way that the user floats down a river while the DBT instructional audio plays.

Figure 2.4 VR version of Dialectical Behavioral Therapy (DBT)

The results of the study showed that improvements in state of mindfullness took place, along with reduction of negative emotions. The VR aspect created a strong feeling of presence that hindered them from being distracted. In this scenario, VR technology has stepped up the levels of the traditional DBT technique, and has solved most of the issues related to the traditional DBT.

Relaworld

Meditation is similar to sleep as it requires the user to be in a calm state of mind. Relaworld(Kosunen et al. 2016) for example, can be used to induce a deeper sense of relaxation for the user via VR combined with neurofeedback technology.

Basically, Relaworld is a neuroadaptive virtual reality meditation system that merges VR and neurofeedback technology. The device makes meditation easier for novices, while still being able to add a new layer of experience for the more experienced meditation practitoiners.

Figure 2.5 The Relaworld set up

Through Relaworld, the user's brain activity, measured by EEG, is mapped into the virtual reality environment. This reflects the user's levels of relaxation and concentration levels. The Relaworld user study showed that their subjects were able to express that Relaworld does promote a deeper relaxation, a deeper level of meditation, and a better feeling of presence in comparison to meditation sessions without the use of the HMD or Neurofeedback.

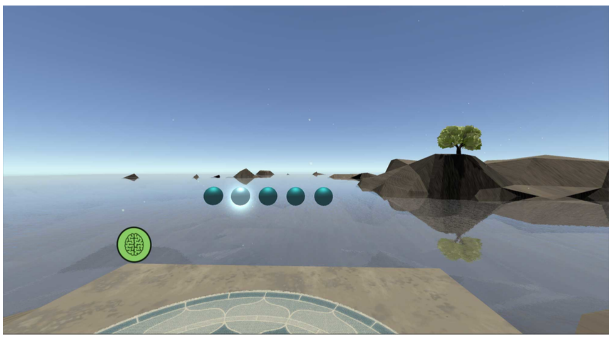

Figure 2.6 The Relaworld virtual reality environment

The Meditation Chamber

The Meditation chamber(Shaw et al. 2007) is a combination of Virtual Reality and biofeedback technologies aimed to help the user relax through the means of meditation and muscle relaxation. The secondary goal is for the device to be able to help people who rarely meditate to immerse themselves deeper into the art of meditation via the biofeedback technology. With the device, they are able to sense when they are truly lowering their physiological states through galvanic skin response and heart rate. A possible negative issue with this device is the fact that the heavy weight of the device my distract the user's full experience.

Virtual Meditative Walk

VR technology has been relevant in the medical field as well. As a form of pain distraction, the technology has proven to be quite indispensable. The Virtual Meditative Walk (Gromala et al. 2015) makes use of biofeedback sensors, stereoscopic sound, and an immersive VR environment.

Figure 2.7 The Relaworld set up

The device helped the users learn how to utilize the mindfullness based stress reduction technique (MBSR) - a sort of meditation. Through the use of sonic and real time visual feedback, the users can learn to manage their pain.

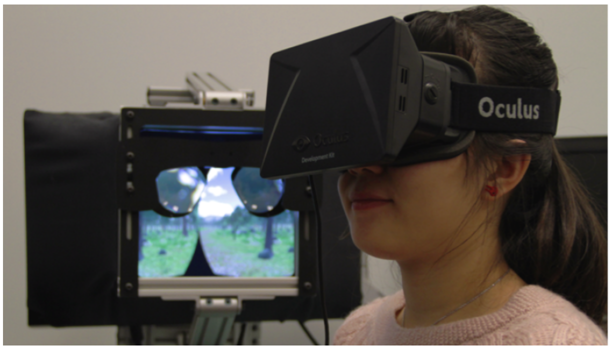

Figure 2.8 The Virtual Meditative Walk set up

A user study was conducted to determine the effectiveness of the VMW in a clinical setting. The results show that the VMW was effective in comparison to the non-VR control condition.

Treatment of phobias

Therapy-wise, as an example,VR has been proven to be an effective treatment to people with arachnophobia. A study explored the potentials of VR technology as an exposure therapy to the treatment of spider phobia (Garcia-Palacios et al. 2002). The study compared a waiting list condition to a treatment condition between 23 participants. The VR treatment group, on average received 4 hours of sessions spread out. Through questionnaires such as the "Fear of Spider Questionnaire" and the "Behavioral Avoidance Test", plus severity ratings made by a clinician, it was confirmed that up to 83 percent of the participants who went through the VR exposure treatment exhibited clinically significant improvement in comparison to the 0 percent from the other group.

The virtual reality's effect on the mind id largely attributed to the sense of presence that the technology stimulates. The reality ahead is not real, yet one feels, behaves, and acts like it is real. The concept of "Presence" is what makes VR so appealing. When using VR, there is nothing in front of the user cognitively speaking, but they will respond both unconsciously and consciously (Sanchez-Vives and Slater 2005)

2.4. Imagery Distraction

Unwanted thoughts, concerns and worries are often the biggest culprits that hinder people from getting a proper good night's sleep. Imagery distraction is a technique where the individual's cognitive space is kept occupied and distracted from re-engaging with the aforementioned issues during the pre-sleep period (Harvey and Payne 2002). This is done by having the individual imagine themselves to be in another place, as detailed as they visually and tangibly can.

The study looked into whether the engaging task of practicing the elaboration of imagery could reduce both the pre-sleep cognitive activity and sleep onset latency. The subjects of the test, all who have insomnia, were divided into three groups where one were instructed to make use of imagery distractions, the other one used general distractions, and the last group had no instructions whatsoever. The study concluded that shorter onset sleep latency along with less frequent pre-sleep cognitive activities was the case for the group that were asked to make use of imagery distraction as a means to get to sleep.

Imagery distraction is proven to be quite a powerful tool. In a study where imagery distraction was used as a technique to distract children from the pain during medical procedures, the technique was shown to give the children lower anxiety scores (BROOME et al. 1994). VR technology, in this case - can be paralleled to imagery distraction in the way that the user can be placed virtually into another space.

Chapter 3
Concept

This chapter will focus more on the reasoning behind the selected prototype decisions, and also introduce the main prototype.

3.1. On the use of Virtual Reality

We hypothesize that VR technology is the superior choice to pair with the effort to shorten sleep latency because of the way that it relates with the technique of imagery distraction. In the technique, the participants were asked to make use of their imagination in order to exhaust themselves off the usual mental load that usually comes with sleep difficulties. VR can be seen as the next step, potentially in the way that it gives them the visual aid to imagine things easier and faster. VR also seems to have a strong correlation with drowsiness levels which may help the sleep onset.

3.2. On the use EOG as the main sensor

In relation to the study, the use of EOG is the best option as the device can easily fit into the VR headset. EOG is also quite non-invasive and can be considered as the more accurate option in general. In the experiments, the purpose of the EOG here is to collect the real time data from the user that can be used in future studies mainly in correlation to the user's tap data.

3.3. Design concept and artifact

With the various related works listed in the previous chapter, a possible prototype was thought of. A potential device that makes use of the powerful effects of VR technology along the lines of relaxation, in addition to the potent effects of imagery distraction. Two experiments will be run to validate the hypothesis; "Virtual reality technology can help in hastening sleep onset."

Figure 3.1 Default Dozier view

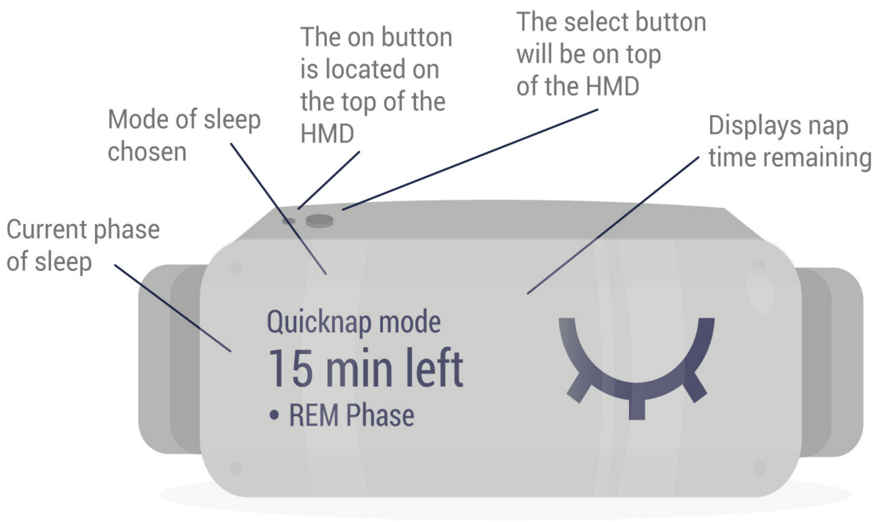

Figure 3.2 The front display of the HMD when used

Dozier is the final result of this study. Dozier is a comfort focused virtual reality HMD that users can use to fall asleep easier. This wireless, chargeable and lightweight VR HMD transports the users to a different environment that they can choose to fall asleep in. The name Dozier comes from the combination of two words that highlight the purpose of this study; "Doze" and "Easier". The author also wanted to come up with a sort of name that is easy to remember, and easy to pronounce.

The front part of the HMD is a digital screen that displays the logo, brand name, and battery levels when not in use. It will then display the information such as the sleeping mode, the time of sleep left, and the user's current sleeping phase at the time. These information are especially relevant in busy office environments, an example could be in cases where their coworkers need to be able see how much more time the user will take to sleep before they wake them up for both emergency and non emergency office related issues. This feature also helps the users fall asleep easier without thinking too much, as the people who need to approach him/her will get informed right away about the duration of the user's sleep time. The information of the user's sleeping phase is also very useful, as it expresses the user's current state of mind. If one is waken up during the REM phase, it will be much more difficult in comparison to nREM phases. This information will also be relevant for future studies that can take place with this technology.

The Dozier will be gazed focused, and the select button will be on the top beside the power button. The Dozier is also equipped with soft cushioning in the back for the comfort of the eyes, and also for the built in earphones.

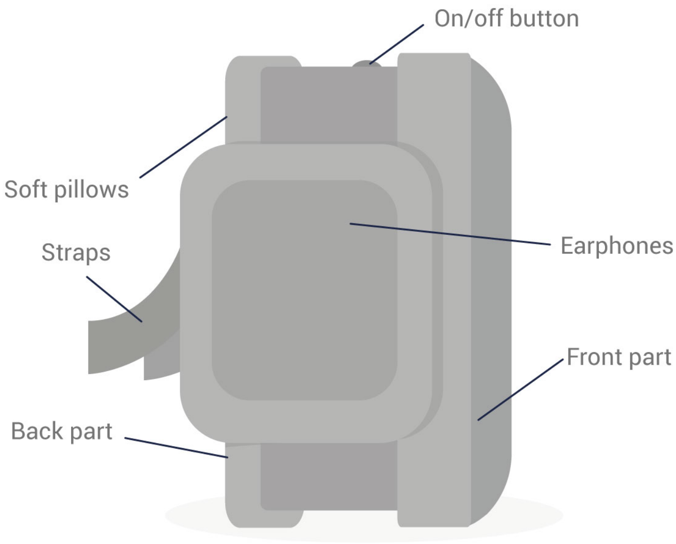

Figure 3.3 Side view of Dozier

Figure 3.4 Dozier used on a sleeping employee

The design done for this study was focused on two things; the physical HMD and the visual design of the software within the Dozier. The design of the physical HMD is sleek and clean. Minimalism and clarity is the main focus in mind when designing the Dozier. The color chosen was gray for the sake of simplicity, and as a metaphorical statement; the mask may look somewhat dull, but when worn, the visual design inside is vibrant - akin to how unnecessary sleep may seem to many, and yet it is the most important thing that is needed to keep our mental and physical states functioning optimally.

Figure 3.5 The color palette for the application

Figure 3.6 One of the main pages seen when the Dozier is turned on

Figure 3.7 One of the main pages seen when the Dozier is turned on

Figure 3.8 One of the main pages seen when the Dozier is turned on

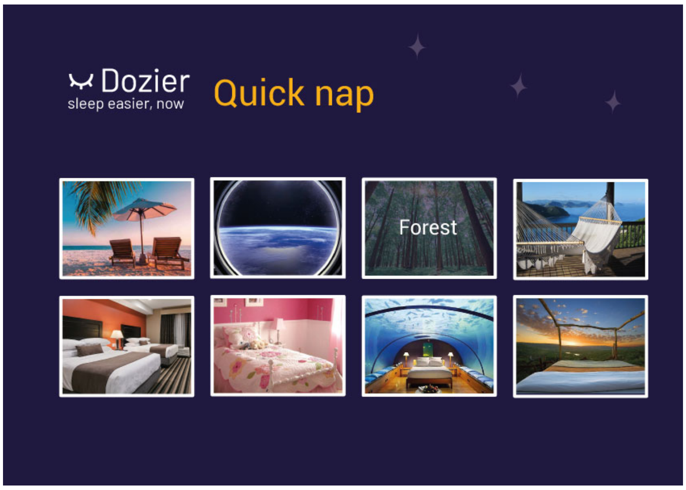

Figure 3.9 The selection page for the VR environments

The design of the Dozier UX makes use of the color palette shown in figure 3.5. The color was chosen because those colors are bale to display both dark and light environments without too much difficulties. These colors are also calm and not too attention grabbing. The illustration style chosen is pinned on the theme of dreamy and wispy shapes. The effect of a fantasy setting is further emphasized by the use of translucent clouds.

3.4. Vision and philosophy

Healthy sleeping habits are very important. If the body does not receive ample amounts of sleep, the path to various diseases and mental illnesses can be easily uncovered. Hectic sleeping schedules are not uncommon with today's society - especially the working society. Lack of sleep is damaging the society in terms of physical and mental well being and even economically. Naps are seen as the best way to curb lack of sleep from improper sleeping schedules, and yet it is still very common for companies to not endorse naps to their workers. In this study, the author of this work focuses on the research of the possibilities of how VR can help users fall asleep faster, and in what ways that solution can be implemented easily in office environments. The proposed solution is a VR HMD device called the Dozier, which helps users fall asleep faster through having them use VR to imagine themselves being in different environments - basically imagery distraction realized through VR. The goal of the product is for offices to have more productive and yet healthy workers through the use of this device. To the author, this device is amongst the easier and faster way to promote the importance of individual worker productivity and well being without having to invest too much into things such as sleeping pods etc. The focus on simplicity as an aspect of the brand is also expressed in the logo design. The Dozier logo is a basically a closed eyelid, an expression for rest. The tagline "Sleep easier, now" is very direct and short, an allusion to the ideal sleep onset that the Dozier should be able to give the users. The font used was Barlowe as it is a plain and clear font.

3.5. Target audience

The target audience for this work can be generally classified as people who could greatly benefit from having their bad pre-sleep habits diminished for faster sleep onset.

The main target audience that the study would be tailored to are office workers. With productivity being the main focus of companies as to what makes an employee a functional one, it comes as no surprise that a large amount of them both knowingly and unknowingly suffer from sleep deprivation. The people who thrive in an environment where sleep may be the most misunderstood - where burnouts and lack of any form of rest is seen as the proper way to be, is the perfect environment to target for this study. The age range for this study would then be around 20-50 year old males and females.

The second experiment would focus more on exploring the study in terms of an office environment.

Chapter 4
Experiments

4.1. Experiments

Two experiments were carried out to verify the purpose of the study. In this scenario, we used a combination of different materials to form a sort of prototype for the Dozier, the main components being the Google Daydream HMD, and the Jins meme glasses for the sensor. The first experiment was run to see if VR does have an effect on sleep onset, and the second experiment was run to further explore the effects of VR on sleep in situations that are closer to the target audience's lifestyle, and also to see if there is something to the users ability of being able to choose their preferred environment to sleep in.

In these experiments, data was extracted and that included the heart rate, finger tapping data, and the JINS meme data. The devices that was be used for the experiment were therefore be as follows: a VR HMD, one phone used as the VR screen, one phone used as the tapping phone, one Apple watch that recorded the heart rate data, and one iPhone that transcribed the heart rate data. In terms of the VR headset, there exists a lot of variations such as the HTC Vive, the Samsung Gear VR, the Oculus Go etc. We did though, go with the one that we believed to be the most comfortable to sleep with - the Google Daydream VR HMD. The reason is because it is much lighter than the aforementioned devices, and it is made up of fabric that should not be too much of a bother to the users.

Figure 4.1 The Google Daydream HMD

4.2. FTT as Manual Drowsiness Detection

While sleep can be detected through the use of various techniques, drowsiness and sleep onset is something that professional labs can achieve easily with their specialized devices and algorithms. Finger tapping method though, can be used as a potential solution for this study. An example would be the study "A Method to Detect Accurately Falling Asleep and Awakening Time" (Okamura et al. 2016b) where tapping was utilized tapping during a beep or a vibration. If the user does not respond after a number of counts, they will be considered to have fallen asleep. This study makes use of a similar method used by the experiment ran by M Casagrande (Casagrande et al. 1997) , the only thing about the method used there is that it may be less of a non-invasive technique.

An app therefore, was been developed for the purpose of this study where it records the user's taps. If the user does not tap within the next 300 seconds (5 minutes), then we can assume that the user is asleep. In terms of the drowsy onset detection, we see each user's average taps by looking at the data of the first 50 taps. We then determine the drowsy onset time by multiplying the average tapping speed by 10. this value is suitable because it falls into the range of time for stage 1 (Casagrande et al. 1997). The highest number for millisecond between a tap with no interruptions can be considered as the sleep duration.

Figure 4.2 The FTT application logging the time stamp, tap number and tap rate

EOG was used in this study as a way to record data from the users. The EOG in this study will store the data from the users that can be used in terms of machine learning for future studies in this field.

With EOG as the main choice of sleep detection, the device used would be JINS MEME, a smart glass. Logging of the data will be sent through the use of blue tooth to the MacBook running a python script. The participants will also wear a smart watch that has an accelerometer and a heart rate sensor. In totality, the EOG and heart rate sensor will be the prototype that will detect the sleep onset.

The JINS Meme glasses is then taken apart in order for it to be able to be mounted into the Daydream HMD. This way, the device operates both as a viewer for the users, and also as a recorder for the EOG data.

Figure 4.3 The Daydream HMD with Jins meme set up inside

4.3. Effects of VR on sleep experiment

The experiment procedure was done by the author and a senior who also carried out the final analysis of this experiment. It took place in a studio recording room with the purpose of having less public distractions as the room absorbed sounds pretty well. The room had a constant temperature of 25 - 28 degree Celsius at all times, and the participants were not barred from wearing anything they preferred. In the room we had a couch for them to sleep on with a pillow for the head, and a blanket. Both the couch and the pillow have a layer of disposable sheets for hygienic purposes. The participants were all instructed to have at least 8 hours of sleep the night before, and also that they do not ingest anything 3 hours prior to their experiment session - especially foods that contain caffeine, alcohol and sugar. the participants are all given an hour to sleep. Initially, the plan was to ask the participants to attend the study 4 times so they could fulfill the data for the 3 virtual realities + 1 condition where the user only wears the HMD without any VR video playing. In the end though, due to participant related difficulties, we settled with only two conditions namely;

a.) VR condition: The condition where we play a VR scene on the HMD for the participant along with the environmental sounds (Beach condition)

b.) HMD only condition: The condition where the user sleeps with the HMD on but it doesn't play any videos, and sound-wise only white noise is played. In this scenario, the HMD condition is treated as the baseline.

Before the start of the experiment, we asked the participant to fill up the Epworth questionnaire. The purpose of this was to find out how susceptible to sleep each of the participants were to different scenic conditions.
The questionnaire scenes;

1.) Sitting and reading
2.) Watching TV
3.) Sitting inactive in a public space
4.) A passenger in a car for an hour without a break
5.) Lying down to rest in an afternoon
6.) Sitting and talking to someone
7.) Sitting quietly after lunch without alcohol
8.) In a car while stopped for a few minutes in the traffic
9.) Relaxing by the beach side

To each of these conditions, participants are to answer the to a 4-point likert scale. The last option being "Never doze", and the highest one being "Highest chance of dozing".

4.4. Experimental process

The overall process is as follows, on the first meeting, the user is given the instructions as to what to do and what not to do.They later on are asked to sign a consent form. After all that, they will fill up the Epworth questionnaire. They will then go on to nap on the couch with the HMD showing either the VR condition or the HMD only condition as figure 4.4 depicts.

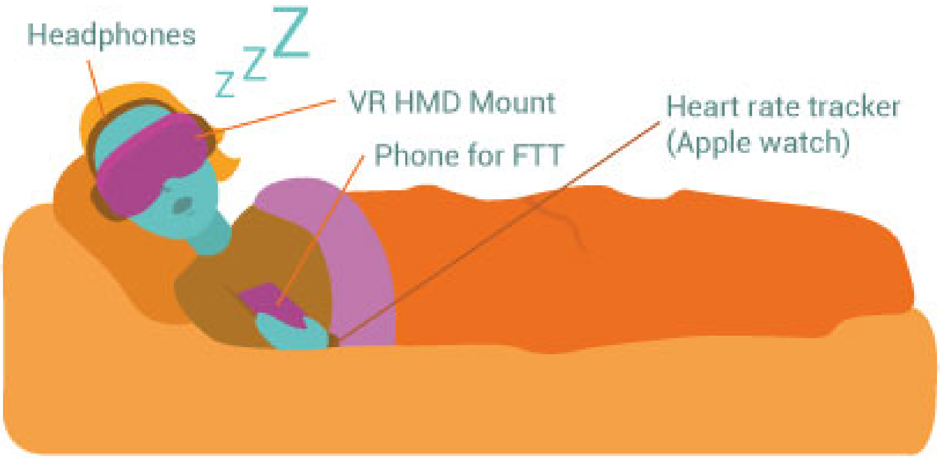

Figure 4.4 The general setup for experiment 1

The Daydream HMD with the jins meme inside will record the data from the participants (Figure 4.4). They will be tapping on the phone as we monitor the taps in a separate room. The participant repeats the process again but without the Epworth questionnaire, and with the next experimental condition. At the end of every session, the participant will be asked to fill up a NASA TLX (NASA Task Load Index Assessment) to asses the experiment done in terms of the received work load from participating in the experiments.

Figure 4.5 A participant undergoing the experiment

4.5. Questionnaire Results

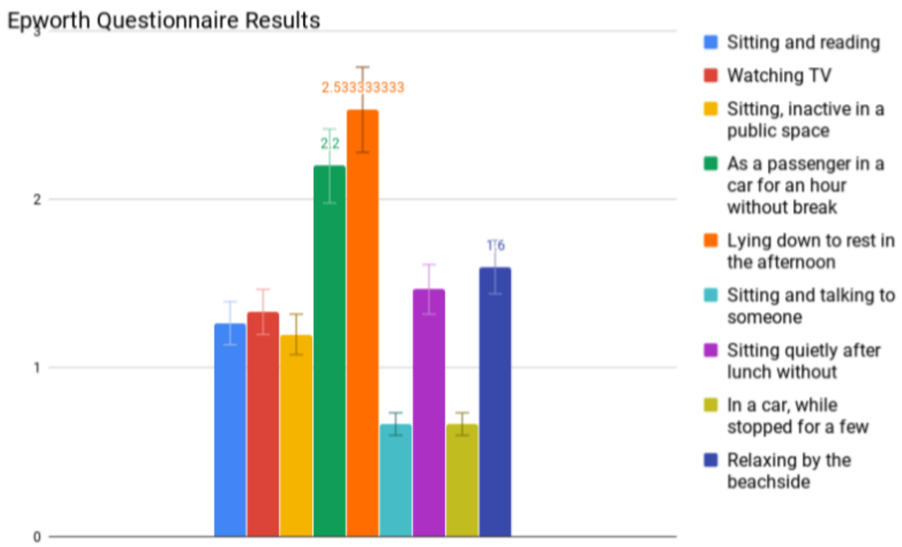

Figure 4.6 The Questionnaire results

Lying down to rest in the afternoon was chosen to be the situation in which the participants would sleep the easiest. This is alright to use as a reference but is not quite specific as a scenery. The second highest one would be "as a passenger in a car for an hour without break". We cannot use this though as the rocking and the vestibular stimulation could be the biggest contribution to this answer(Omlin et al. 2018)(Bayer et al. 2011). For this particular study, we wish to see the perceived environment that has the best effect. We therefore, chose the "relaxing by the beach side". This helped us decide to prepare the Beach side environment - which is a 360 degree video recording. It is to be noted that a blue light filter was always added to the VR environment videos to negate the effects of blue-light.

We begin with the first experiment where the focus is on finding data on whether VR can in any way influence the sleep onset.

4.6. Effects of VR on sleep experiment - Tapping data analysis

A total of 14 participants took part in this initial study. 8 males and 6 females aged between 23 - 35 years old (mean 26.43, standard deviation 3.11).

Figure 4.7 shows the sleep onset latency data, figure 4.8 shows the drowsiness onset latency data, and figure 4.9 shows the sleep duration for all the participants.

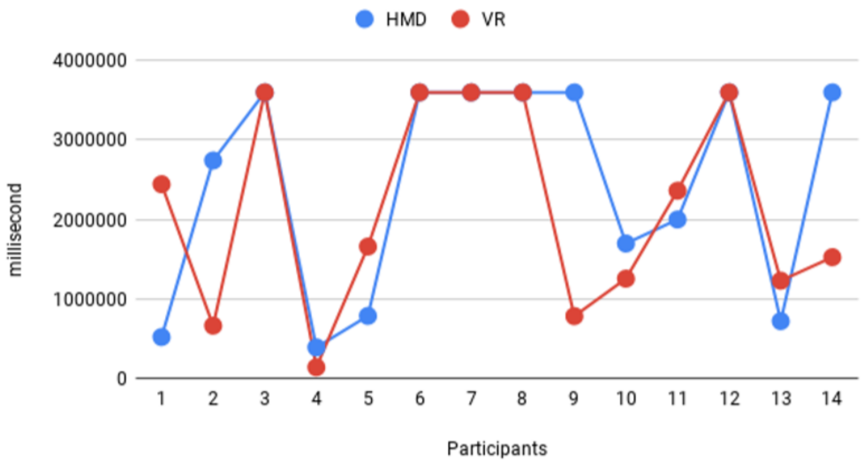

Figure 4.7 Sleep onset latency data

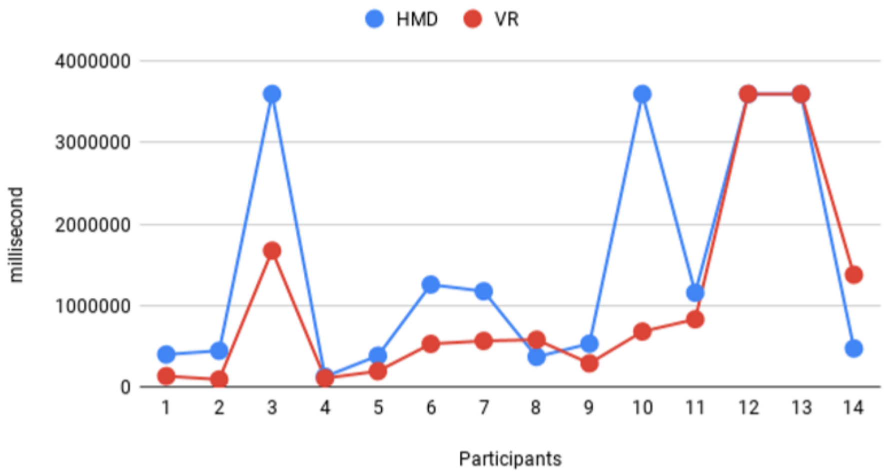

Figure 4.8 Drowsiness onset latency data

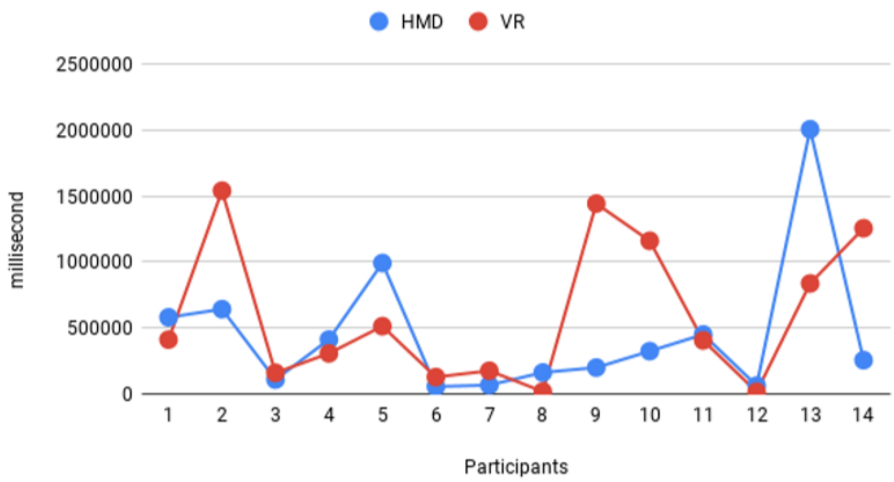

Figure 4.9 Maximum sleep duration data

The average time that the participants fell asleep while presented with the VR data turned out to be 2,174,000 milliseconds (35 minutes and 45 seconds). This is 4 minutes and 45 seconds faster than the data for the participants falling asleep under the HMD only condition; 2,432,000 milliseconds (40 minutes and 53 seconds). We then ran the data under a Shapiro-Wilk to determine the result's normality. The results turned out to be significant (p is less than 0.05). We therefore cannot assume normality in the data. The Wilcoxon Signed-Rank test was ran to check if the two sleep onset time data are of significantly different rates. With this in mind, we cannot reject the hypothesis that VR environment can assist in decreasing the sleep onset latency compared to the one without the use of VR) as the result is not very significant (Z=-0.652, p is more than 0.05)

We did receive a lot of feedback in regards to the comfort levels of the experiment. One of the most common ones was that a lot of the participants felt that the HMD was heavy on their face. It was also difficult for some people to sleep properly as they usually slept on their sides - which was difficult to do with the HMD. Most people more or less had different ideals for comfort. 1 participant mentioned that he/she preferred the HMD only condition because of the quietness, while 3 other participants preferred the one with the virtual reality as the HMD only condition felt unnatural to them. Each participant had their own specific preference to comfortable levels. Some mentioned that the looping of the VR video distracted them from sleeping easily. They noticed the looping of the video and the sound, and this made them over-think. 4 participants expressed feeling uncomfortable because of how the JINS meme metallic sensor inside the HMD pressed up against the bridge of their nose, especially if they had taller nose bridges.

On the drowsiness onset; With the HMD only conditions, the participants became drowsy in 1,479,000 milliseconds (24 minutes 39 seconds) on average. This is 7 minutes and 42 seconds longer than the one with the VR conditions, which was 1,018,000 milliseconds (16 minutes and 58 seconds). The Shapiro-Wilk test yielded a significant P value (p is smaller than 0.05), this means that we cannot assume normality. As for the Wilcoxon Signed-Rank test, a significant drop in drowsiness time (Z=-2.04, p is less than 0.05) for the beach environment in comparison to the HMD only condition. We can therefore state that VR can assist in reducing drowsy onset latency by 31.21 percent. The virtual imagery in the VR environment was ample enough to make the participant feel like they are at the beach regardless of their personal preferred sleep preference.

The same procedure was carried out for the sleep duration time. For the HMD only condition, on average, the participants took 452,000 milliseconds (7 minutes and 32 seconds). This was 2 minutes shorter than the average time for the VR condition which was around 598,000 milliseconds (9 minutes and 58 seconds).

The Shapiro-Wilk test data ran on these data showed that the data was non-parametric (p is less than 0.05). The Wilcoxon Signed - Rank test, the result was non significant ($Z = -0.471$,p is more than 0.05). Overall up to 4 participants were able to sleep for over 15 minutes for the VR condition, in the HMD condition, only 2 participants were able to do so. One participant though was able to sleep for 33.5 minutes when using the HMD only condition, the longest sleep duration recorded in this study.

4.7. NASA TLX Data Analysis

The figure above shows the six parameters; mental demand, physical demand, temporal demand, performance, effort and frustration. Except for efforts, which was normally distributed, significant results are produced from the Shapiro-Wilk test for all the factors (p is more than 0.005). The Wilcoxon Signed -Ranked tests was used on each factors except for performance. From this, only "Frustration" seemed to show significant results (Z= -2.11, p is less than 0.05). This points to the probability that the participants found the use of HMD without VR content to be more frustrating to sleep with in comparison to the one with VR content.

4.8. Correlation Matrices

To find out if there is any correlation between the participant's tapping data, Epworth Sleepiness Scale, and their TLX score, we use the Spearman's Rank Correlation Coefficient. We generated a correlation matrix (figure 4.11) for HMD with no VR, and (figure figure 4.12) for the beach content. T1, T2, and T3 represent the tapping data for sleep onset, drowsy onset and sleep duration. TLX 1 to 6 represents the six TLX parameters. E1 to E9 represents the Epworth scale results in sequence. The values in the green cell represents a correlation significance of p¡0.001, and yellow cells represent a correlation significance of p is less than 0.05.

	T1	T2	T3	TLX1	TLX2	TLX3	TLX4	TLX5	TLX6	E1	E2	E3	E4	E5	E6	E7	E8	E9
T1	1																	
T2	0.311	1																
T3	-0.8	-0.331	1															
TLX1	-0.116	-0.019	-0.007	1														
TLX2	-0.236	-0.185	0.223	0.86	1													
TLX3	-0.301	-0.498	-0.036	0.64	0.625	1												
TLX4	-0.149	-0.218	-0.153	0.589	0.362	0.631	1											
TLX5	0.123	0.24	-0.347	0.72	0.646	0.518	0.422	1										
TLX6	-0.047	-0.143	0.145	0.728	0.83	0.361	0.422	0.613	1									
E1	0.331	-0.309	-0.375	0.417	0.294	0.379	0.32	0.299	0.423	1								
E2	0.02	-0.012	-0.087	-0.209	-0.295	-0.135	-0.042	-0.071	-0.171	0.343	1							
E3	0.07	0.121	-0.244	-0.151	-0.385	0.012	0.322	0.059	-0.209	0.245	0.532	1						
E4	-0.099	-0.242	0.121	0.041	-0.065	0.111	0.243	-0.091	0.123	0.47	0.483	0.359	1					
E5	-0.019	0	-0.089	-0.428	-0.303	0.018	-0.143	-0.339	-0.479	-0.181	0.164	0.2	0.266	1				
E6	-0.198	-0.426	0.089	0.31	0.366	0.244	0.139	0.24	0.432	0.458	0.497	-0.098	0.137	-0.291	1			
E7	-0.133	0.209	0.155	0.263	0.191	0.092	-0.078	0.024	0.09	0.145	0.204	-0.063	0.169	0.051	0.05	1		
E8	0.554	-0.015	-0.504	0.097	-0.09	0.067	0.262	0.075	0.208	0.465	0.023	0.368	0.343	0.187	-0.068	0.091	1	
E9	-0.663	-0.134	0.521	0.068	0.228	0.162	-0.013	-0.093	0.037	-0.208	0.319	-0.154	0.031	0.231	0.435	0.548	-0.406	1

Figure 4.10 Correlation matrices for HMD condition

	T1	T2	T3	TLX1	TLX2	TLX3	TLX4	TLX5	TLX6	E1	E2	E3	E4	E5	E6	E7	E8	E9
T1	1																	
T2	0.403	1																
T3	-0.793	-0.308	1															
TLX1	0.437	0.109	-0.334	1														
TLX2	0.436	0.089	-0.389	0.911	1													
TLX3	0.631	0.157	-0.514	0.879	0.927	1												
TLX4	0.369	0.029	-0.292	0.658	0.6	0.601	1											
TLX5	0.036	-0.156	-0.146	0.808	0.776	0.63	0.621	1										
TLX6	0.194	0.043	-0.022	0.82	0.786	0.723	0.449	0.728	1									
E1	0.192	-0.522	-0.199	0.159	0.032	0.122	-0.193	0.07	0.226	1								
E2	-0.119	0.005	-0.13	-0.138	-0.257	-0.336	-0.399	-0.021	-0.108	0.343	1							
E3	-0.005	0.195	-0.338	0.152	-0.009	-0.062	-0.017	0.31	0.184	0.245	0.532	1						
E4	-0.304	-0.387	0.021	-0.289	-0.39	-0.261	-0.287	-0.083	-0.158	0.47	0.483	0.359	1					
E5	0.272	0.266	-0.549	-0.377	-0.215	-0.109	-0.179	-0.393	-0.516	-0.181	0.164	0.2	0.266	1				
E6	-0.288	-0.629	0.277	0.09	0.054	-0.138	-0.182	0.16	0.077	0.458	0.497	-0.098	0.137	-0.291	1			
E7	0.301	0.135	-0.062	0.203	0.022	0.162	0.117	0.019	0.048	0.145	0.204	-0.063	0.169	0.051	0.05	1		
E8	0.394	-0.148	-0.252	0.15	0.007	0.198	0.134	0.045	0.201	0.465	0.023	0.368	0.343	0.187	-0.068	0.091	1	
E9	-0.209	-0.066	0.144	-0.034	-0.018	-0.157	-0.008	0.009	-0.21	-0.208	0.319	-0.154	0.031	0.231	0.435	0.548	-0.406	1

Figure 4.11 Correlation matrices for VR condition

These figures show that between sleep onset and sleep durations for both conditions, we found a significant negative correlation. Since we have proven that VR does make a participant drowsy faster, this can be useful. Participants who are more likely to fall asleep in a beach or in a car are more likely to fall asleep in an HMD condition. VR condition wise, two correlations with the Epworth scale are discovered. One being; participants who are likely to feel sleepy when they are sitting and talking to someone else are more likely to feel drowsy in the VR environment only. Secondly, participants who felt that they fall asleep easier when lying down, have a shorter duration of sleep latency within the VR condition. For perceived workload, sleep latency and temporal demand correlates with sleep latency - shows that the pressure to fall asleep in the VR may have made it harder for the participants to actually fall asleep.

4.9. Evaluation on the EOG

We discuss more about one of this study's contributions. With the initial experiment carried out, we focus on the use of EOG sensors to automatically detect the user's sleep onset. With the EOG data, paired along with the user's tap data, a data set can be figured out through the use of machine learning to create automatic responses. One possible scenario as an example, would be for the prototype to dim itself as soon as it detects that the user has fallen asleep already in order to lessen potential distractions. The data from the JINS meme includes EOG sensors on the nose pods, 3 axis accelerometer, and a 3 axis gyroscope. A 10 second sliding window is the generated for each of these features. The mean, standard deviation, and variation is then calculated for each of these features for 24 features. The principal Component Analysis (PCA) is then run until only 6 figures remain. The test results of the model show an 82.88 percent accuracy. Some slight issues that may have happened could be the users adjusting the HMD mid experiment. The tighter the device on the contact point, the more accurate - but this may cause a discomfort on the user. In the next experiment, we focus on comfort as well. The main classification metrics are shown in figure 4.12.

	Precision	Recall	f1-score	support
awake	0.80	1.00	0.89	596752
asleep	1.00	0.43	0.60	256894
average/total	0.86	0.83	0.80	853646

Figure 4.12 Results of the main classification metrics

4.10. Conclusion

With VR (In this case more specifically the beach environment) being able to influence sleep by reducing drowsiness onset and frustrations during naps by improving the perceived environment of the user, this study has taken a step in using VR as a technique to improve / affect sleep. The hypothesis has not been fully satisfied as it is more of the drowsiness onset that is improved. We move on to a new experiment that will dig deeper into this and is to answer questions such as; "Can we improve the sleep onset time - make it faster somehow perhaps?", "Could customization of environments to the user's preference somehow affect the data?". We also decided to change some parts of the experiment for the purpose of making it more "office friendly", and use better devices for the quality of the experiment.

4.11. Effects of different VR scenarios on sleep experiment

For this second experiment, we improved the prototype with the feedback from the participants from the previous experiments. The HMD was improved by removing the frames of the JINS meme glasses so that the sensor is more adjustable - the user can move it around themselves.

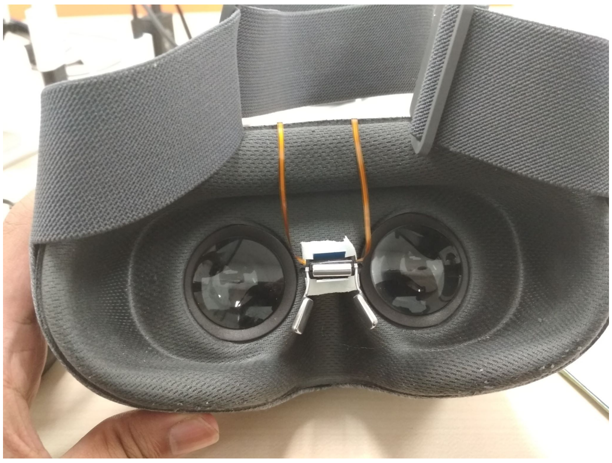

Figure 4.13 Movable sensors for comfort

Overall, a lot of things were changed mostly to fit the initial idea of making the device usable in the office environment. Instead of using the couch as we did the first experiment, we used a gaming chair that was able to recline all the way to 40 degrees, which is enough to assist people in inducing sleep(Nicholson and M.Stone 1987). This was decided also due to the realization that with the 40 percent angle, the VR shows more things in comparison to the previous experiment of having the participant lay flat on the surface of the couch. We also changed the setting of the experiment to take place in an area that resembles more of an office environment instead of a sound proof studio. The NASA TLX aspect has also been removed as it seemed to not properly fit the experiment - we will focus on a more qualitative feedback on the comfort aspect.

We have decided that overall, the experiment will be more of a qualitative one. The hypothesis will still be the man focus, but this second one will also focus more on the design and the prototype's potential. This experiment will also answer the further research questions developed after the conclusion of the previous experiment; "in terms of future applications of the findings, could customizabilty of different VR scenarios give better sleep onset?", and also, could the VR version of the room give better sleep data in comparison to a non-VR (physical) version of the room?

We also conducted a wider questionnaire to get a general consensus on the topic of sleep habits and the proper environments in order to have a better grasp. The questionnaire was also made to understand better which improvements to bring upon to this experiment. In terms of conditions, the environments have become more specific;

Nothing- The user sleeps in the room with nothing but the Apple watch on to read their heart rates, and the Asus phone to read their tapping data.

Sleeping mask - The user sleeps in the room with a sleeping mask on, plus the Apple watch on to read their heart rates, and the Asus phone to read their tapping data.

Current room VR - The user sleeps in the room with the HMD on playing the VR video of the room they are in (The experiment room). They also wear a noise cancelling headphone that plays the sounds of the current room that was recorded along with the video. They are strapped with the Apple watch on to read their heart rates, and the Asus phone to read their tapping data.

Preferred environment to sleep in - The user sleeps in the room with the HMD on playing their preferred VR video. They are strapped with the Apple watch on to read their heart rates, and the Asus phone to read their tapping data. They also wear a noise cancelling headphone that plays the sounds of the VR environment chosen. The choices that they can choose from are the top 4 highest chosen ones from the newly made questionnaire - which are;
a.) Beach environment
b.) User's own room
c.) By the lodge (Woody area)
d.) By the clouds (Floating among the clouds)

4.12. The application

With the ability to choose the environment that the user may prefer to sleep in taken into account, the application to view the VR videos was further improved with such feature. On the home page, 6 VR rooms are shown, one button for the toggling of blue light filter, and one more button for returning to the main menu. The VR videos that were used for this particular experiments were a combination of self shot 360 degree videos (by the use of a Ricoh Theta S), and Youtube videos. For special cases where the participants choose their preferred VR to be their own room, they were given the 360 camera to take home so they were able to record and submit their videos to be put into the app. This application was developed for the specific use of being utilized in the experimental conditions, but in the final product that this experiment can lead to, the concept will more or less be the same.

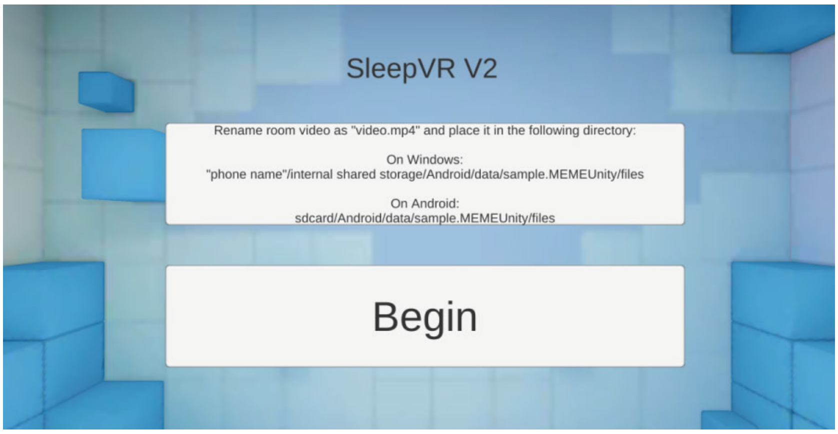

Figure 4.14 The beginning page as the app is opened

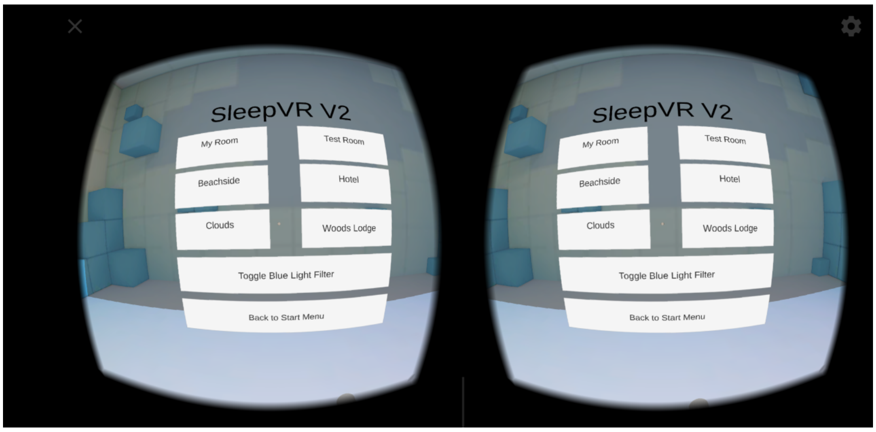

Figure 4.15 The main menu page

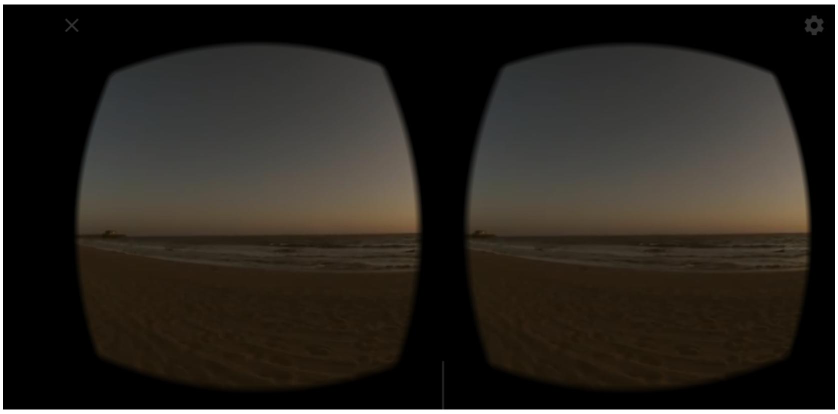

Figure 4.16 Beach VR video

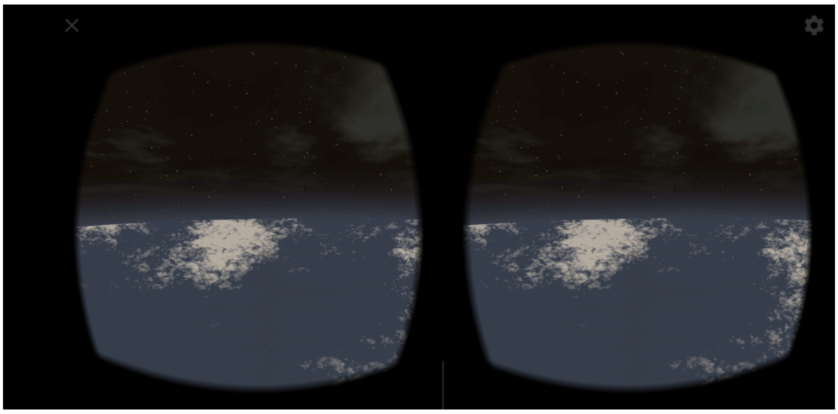

Figure 4.17 By the clouds VR video

Figure 4.18 Hotel room VR video

Figure 4.19 By the lodge VR video

Figure 4.20 An example of one of the experiment participant's room in VR video mode

4.13. The experimental process

They are asked to sign a consent form after being explained about the experiment and the rules. Unlike the previous experiment, we do not give them a questionnaire before or after. They are then asked to sleep according to the conditions. For the Nothing condition", they sleep on the gaming chair with the apple watch and the tapping phone, with the lights on - simulating a proper office environment (figure 3.15). For the "eye mask condition", they do the same as the "nothing condition", but with an eye mask on (figure 3.16). For the "VR of the room condition", the participants will sleep exactly like in the previous conditions, but with the daydream HMD on, displaying a VR of the room itself (figure 3.17). Lastly, the "preferred VR condition", will be the same as the "VR of the room condition", but with the user's preferred environment as the VR displayed in the HMD. After the experiments, the participants are asked about the experiences for feedback. Each participant sleeps for a total of 4 times, going through each conditions once.

Figure 4.21 A participant of the second experiment, going through the "nothing" condition

Figure 4.22 A participant of the second experiment, going through the "Eyemask" condition

Figure 4.23 A participant of the second experiment, going through the "Preferred HMD" condition (Experiment room setup will be the same)

4.14. Questionnaire results

A survey was carried out in order to understand the general issues on sleep, and to further clarify the people's perception on the topic. The survey was done online with 157 participants, the link was shared to people with the age range of 20 to 50 years old. The questionnaire aimed to understand a couple of things including; the sleep health of the subject pool, the most prevalent sleep issue, their personal rituals to be able to sleep properly, and the most ideal situation that they imagine they can sleep the best in. The survey was taken by 104 females, and 52 males from countries including Japan, Indonesia, the Philippines, South Korea, Germany and America.

From the data received, only 22 people out of the 157 have a proper, constant 8 hour sleeping schedule. Most of the participants, 73 of them, have the average of 6 hour sleeping schedule. This data already shows a sleep deprived sample (Hirshkowitz et al. 2015). 89 of the participants felt that the quality of their sleep can be improved. In terms of ease of falling asleep, 73 people answered that they found it difficult to sleep while the next majority (60 people) found it quite easy to fall asleep. This shows that the majority of the issue is still the problem of falling into the sleep, and that while many people are able to fall asleep easily - they do not necessarily fulfill the 8 hour sleeping window that is considered healthy (possibly because of busy schedule and an unhealthy or incomplete perspective on sleep).

When asked whether the participants had any sort of sleeping ritual, majority of them (94 people) said that they had none, while the rest of the 63 people said that they do have a sort of ritual. When asked on the type of ritual that they administered on themselves in order to fall asleep, the most mentioned technique was "Falling asleep to background noise", with "meditating or praying" as the second highest, "reading books" as the third highest, and "visualizations" as the fourth highest. This data shows that there is potential still for visualizations to be used as it is still within the top 4 methods used, albeit not being the top highest. When asked about how heavily they relied on the rituals to fall asleep, most of them said that they did not rely on it much - which is expected as most of them do not have any sort of sleeping ritual at all. Also, this shows that there is space for a prototype to be used to help people fall asleep, keeping in mind that it has to be as none invasive as possible for people to use them in their busy schedules.

79 of the participants answered that they have a constant sleeping schedule. Majority (149 people) of the participants answered that their sleeping schedule can be improved to some degree - this shows an interest in a change of pace, and that they are aware of their unhealthy sleeping habits. When asked what the participants think prevents them from getting proper sleep, most of them mentioned "over thinking and worrying" as the main issue. This shows that imagery distraction as a technique might be a proper solution for this issue as it aims to inhibit the over thinking part of the mind.

The survey also shows that 109 of the participants do know, or at least have a sort of idea as to the devastating effects of sleep deprivation(Fang et al. 2015). A majority of the participants (140 people) do not wear eye masks to go to sleep. 91 people mentioned that they did not often take naps, and 31 people do not take naps at all. From a general perspective, this expresses that a majority of the participants are truly sleep deprived. When asked as to why they do not take naps, the majority answered that they did not have the time to do so, and that if they did nap, they would feel like they needed more sleep time than permitted as they feel like they lack sleep.

When asked to imagine a room where they find themselves to fall asleep the easiest, the highest amount of people (114 people) mentioned that they preferred sleeping in their own room. 56 people mentioned "hotel rooms", 27 people mentioned "by the clouds", 24 people preferred "the beach", and 22 people preferred "lodge by the woods".

The last part of the questionnaire was the Epworth questionnaire. This was inserted to asses the general replies, and see the general sleep state of the participants. They had to choose between 4 options; 0 being the lowest chance to fall asleep, and 3 being the highest. When asked " When you are seating and reading, what are the chances of you falling asleep?", the majority answered 2. When asked " When you are watching TV, what are the chances of you falling asleep?", the majority answered 1. When asked " When you are seating inactive in a public place, what are the chances of you falling asleep?", the majority answered 0. When asked " When you are a passenger inside a car for an hour without a break, what are the chances of you falling asleep?", the majority answered 3. When asked " When you are lying down to rest in the afternoon when circumstances permit, what are the chances of you falling asleep?", the majority answered 3. When asked " When you are seating and talking to someone, what are the chances of you falling asleep?", the majority answered 0. When asked " When you are seating quietly after a lunch without alcohol, what are the chances of you falling asleep?", the majority answered 1. When asked " When you are in a car, stopped for a few minutes, what are the chances of you falling asleep?", the majority answered 1.

The overall analysis of the answers shows that the participants are busy people who lack sleep, and are aware of it. The participants are generally aware of how unhealthy their sleep lifestyle is and what causes it, but do not do much effort to curb the issue. As mentioned earlier in this paper, the importance of sleep is heavily under emphasized within the minds of the society. The questionnaire reflected just that. The questionnaire shows potential success for some for some sort of solution that will help the participants fall asleep easier without altering their sleep schedule too much. Ideally, a prototype that has the ability to keep the user informed about their sleep score, and something that they can use in order to eliminate over thinking. From this questionnaire, we also found the top 4 sleeping environments that we used for the second experiment.

4.15. Tapping data analysis

A total of 10 participants took part in this second study. 5 males and 5 females aged between 23 - 29 years old (mean 25.27, standard deviation 2.20). Each of them had to sleep 4 times, one time for each condition.

First of all, in terms of tapping data, in both the conditions of "Nothing" and "Sleeping mask", some of the participants were not able to sleep at all. To be more specific, 5 participants were not able to sleep in the "Nothing condition", and 3 participants were not able to sleep in the "Sleeping mask" condition. In the other conditions, all VR related, all 10 of the participants were able to sleep.

The first image shows the sleep latency graph, the second shows the drowsiness latency graph, and the third shows the sleep duration graph.

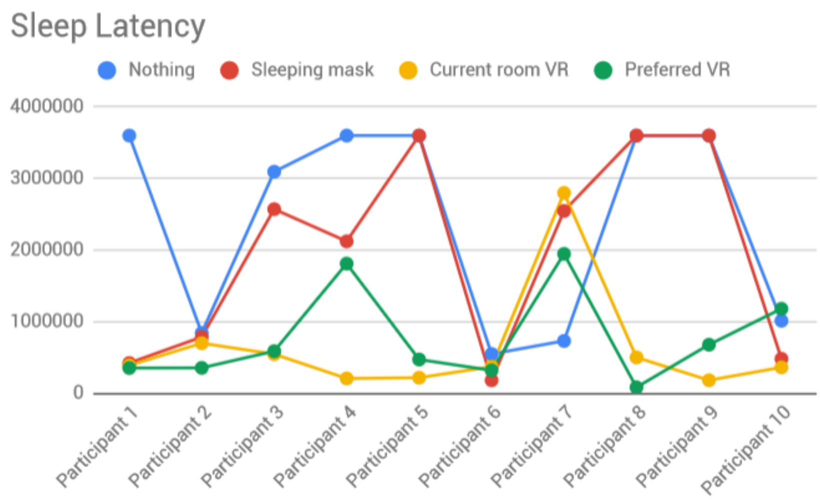

Figure 4.24 Tap data - Sleep onset latency graph

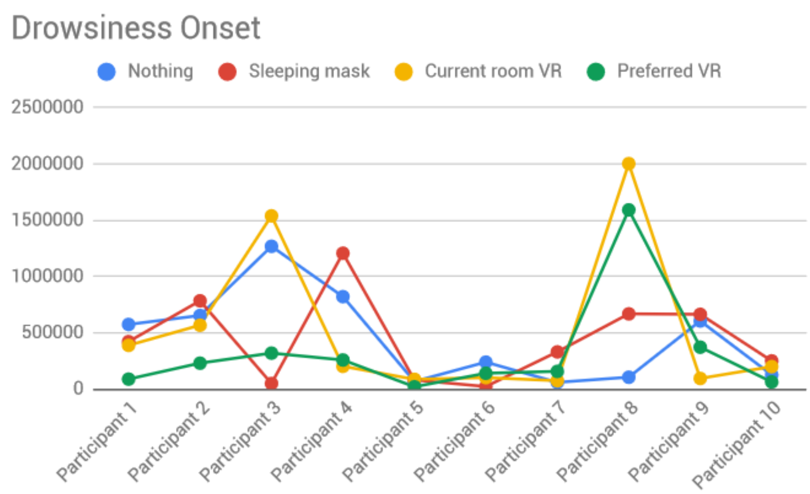

Figure 4.25 Tap data - Drowsiness onset latency graph

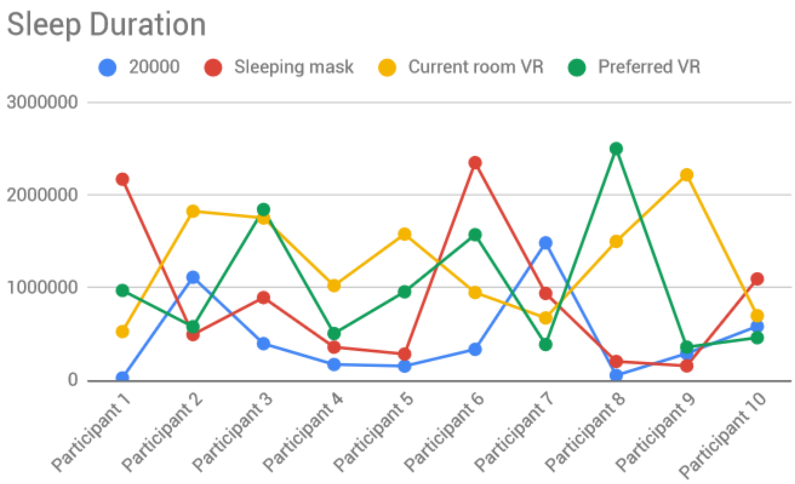

Figure 4.26 Tap data - Maximum sleep duration graph

Sleep Latency

In terms of sleep onset, on average, the condition "Current room VR" resulted in faster sleep onsets. Current room VR has an average sleep latency onset of 625,800 ms (10 minutes, 25 seconds). The condition of "Preferred VR" came in second with 777,100 ms (12 minutes, 57 seconds). the condition of "Sleeping mask"came in third with 1,990,400 ms (33 minutes, 10 seconds) and finally the "Nothing condition" came in with 2,422,400 ms (40 minutes and 22 seconds). When we take a closer individual look at the results, 4 out of the 10 participants had their fastest sleep onset (compared to the other conditions) under the "Preferred VR" condition. "Current room VR" condition came in next, with 4 out of the 10 participants having had their fastest sleep onset there, but with 2 other participants having their lowest sleep onset within the condition as well. "Sleeping mask condition" and "Nothing" conditions each recorded one data with a participant having their fastest sleep latency there.

Drowsiness Onset

On average, "Preferred room VR" condition has the fastest drowsiness latency of 323,900 ms (5 minutes, 33 seconds). "Nothing" condition followed next with 451,700 ms (7 minutes, 31 seconds). "Sleeping mask" condition had the next fastest drowsiness onset with 447,500 ms (7 minutes, 27 seconds), and finally

”Current room” condition had the longest drowsiness onset with 525,300 ms (8 minutes, 45 seconds). When observed closer, ”Preferred room VR” condition had the most number of fastest drowsiness latency records from each participants (5 out of 10). All the other records have 2 fastest records of sleep onsets each, with ”Nothing” condition being the condition with the least of the worse performing drowsiness onset data.

Sleep Duration

On average, the ”Current room VR” was the condition with the highest sleep duration recorded ,being 1278044.4 ms (21 minutes 18 seconds). Second highest was the ”Preferred room VR” with 1016603.4 ms (16 minutes, 56 seconds), third highest was sleeping mask with 897376.1 ms (14 minutes, 57 seconds), and the lowest being ”Nothing condition” with 462690.8 ms (7 minutes, 42 seconds). On a closer look at the data set, ”Current room VR” has the highest amount of longest sleep durations recorded, 5 of them out of the 10. ”Sleeping mask” condition was the second one with 3 longest sleep data recorded of the 10 participants. ”Preferred room VR” condition had 2 of those, and finally ”Nothing” condition had 1.

Discussions on the prototype

An interview with each of the participants was carried out at the end of the experiments with the final conditions. Overall, most of the participants expressed preference to the ”preferred room VR” condition, with the next highest being the sleeping mask condition. In terms of the comfort levels, 2 participants found the combined weight of the HMD and the VR viewing phone to be too heavy. 2 participants also had difficulty in terms of sleeping for a long time due to the tight pressure of the JINS meme metal sensor on their nose bridges.

Experiment conclusion

Overall, the data set strengthens the main hypothesis, VR does quicken sleep latency. The data from the second experiment shows that both the conditions that make use of VR technology show relatively faster sleep onset times in comparison to non-VR conditions. The ”Current room VR” condition, the fastest sleep latency on average, is 29 minutes and 57 seconds faster than the slowest sleep latency condition, which is the "nothing" condition, quite a wide time gap.

If we look at the average drowsiness onset of the 4 conditions, the gap between the conditions onset are quite low. The fastest drowsiness onset being 5 minutes and 33 seconds of the "preferred VR" condition, and the longest being 8 minutes and 41 seconds of the "current VR room" condition. The difference is merely a total of 3 minutes.

Sleep duration wise, "Current room VR" condition shows the highest sleep duration with 21 minutes and 18 seconds of average snooze time. Both the VR conditions, again, rank higher than the non-VR conditions. The difference of the highest and the lowest sleep durations, ("Current VR" to "Nothing" conditions) is 13 minutes and 36 seconds, which is quite a significant amount of time. This reflects the need for the EOG technology. Several of the participants complained that they would be woken up as time passed by due to the VR display. If the EOG is fully integrated with the prototype, and is functional - the VR display can curb this effect by dimming down the screen in order to not create any possible disturbances to the user's sleep duration.

The questions raised earlier in the conclusion of the initial experiment are also answered by the results. The first question asked if customizability of different VR environments could give better sleep onset. The answer is yes. "Current room VR" condition showed the highest average sleep onset, but not far different from "preferred VR environment" condition. "Current room VR" and "preferred VR environments" conditions have an average of less than 13 minutes of sleep latency while the non-VR conditions have more than 30 minutes of sleep latency. VR has proven to give a faster sleep latency, further solidifying the hypothesis. On average, "Current room VR" and "preferred VR environments" conditions have less than 13 minutes of sleep latency while the non-VR conditions have more than 30 minutes of sleep latency. The other question concerning the potential improvement of sleep data when one is presented with a VR version of the room is also answered. Sleep latency wise, the condition of "current room VR" expressed the fastest sleep onset on average. In terms of drowsiness onset, ”current room condition” took the longest, but only with a gap of a few minutes in comparison to the others. The data set does not have too wide of a gap between each other. Lastly, in terms of sleep duration, ”current room VR” condition also topped the other conditions with an average of 21 minutes and 18 seconds. In conclusion, VR version of the room does better the participant’s sleep sleep data (sleep onset, drowsiness onset, and sleep duration) of the participants.

Chapter 5
Results and Discussions

5.1. Evaluation summary

Throughout the study, a total of two experiments have been carried out, with the final design executed from the findings. This section highlights the key findings and then explains the general evaluation of the study.

The first experiment was carried out with the purpose of finding out whether VR technology has the ability to improve sleep onset. The experiment compared the sleep data between a VR and a non-VR condition. The results showed that VR has successfully hastened the drowsiness onset and reduced the pre-sleep frustrations by augmentation of the user's perceived environment.

The next experiment carried out was set to answer the hypothesis again, but also to see if different, user preferred environments have the ability to give better sleep data. The result showed that sleep latency amongst all the conditions was best with the VR condition, and so was the drowsiness onset and sleep duration. Overall, analysis of the three sleep data prove that VR condition does give the user a faster sleep experience. The two experiments overall verifies the theory that people could generally sleep faster due to the reduction of the cognitive load.

A prototype was designed as a result of these findings, coupled with the response of the experiment participants for the comfort aspect.

We take another look at the study's objectives. The two experiments have justified the first and second objectives, with the second experiment focusing on the second objective.The final objective was satisfied by the culmination of the prototype design.

In summary, Dozier as a concept has been verified through this study. Dozier has the ability to give users a faster sleep onset. Now that the core of the prototype has been backed, the future potentials of this study can be focused on.

5.2. Design limitations

The design limitations from this study would be based off the experiments conducted. One limitation could be how hot the screen gets when the VR viewing phone was let on for more than 45 minutes or so. The hot screen may, at times, have affected the participant's sleep. This is also another reason why the study is best focused on short naps instead of longer sleep. Another limitation was the accuracy levels of the apple watch data. The data collected is not very detailed, so it is not always on time. Ideally, the apple watch data can be used as a backup for the taps data, but it is not a very reliable one.

5.3. Conclusion and future works

This study proposes a prototype with the ability to hasten the sleep onset through the use of VR as a visualized form of imagery distraction. Two experiments were carried out to verify the hypothesis. In terms of the future works, since we have established the hypothesis, the author would say that VR in relation to full night's sleep would be a possible path especially if the EOG sensor aspect has been fully fused into the project.

Another interesting path would be down the topic of lucid dreaming. Lucid dreaming is basically when one is aware that they are dreaming - imagine a mental VR. Lucid dreaming occurs when one is woken up during the REM (Rapid eye movement) sleeping phase. There is a possibility that Dozier can be used to induce lucid dreams. An example would be having the Dozier play audio cues that prompts the users to perform a reality check as soon as it recognizes that they in the proper stage of sleep for the possibility of a lucid dream. Overall, the future studies that stem from this study would be greatly emphasized by not only the legitimization that VR technology can improve the user's sleep life, but also from the data collected from the EOG sensor.

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Appendices

A. Questionnaire results for ”Effects of different VR scenarios on sleep” experiment

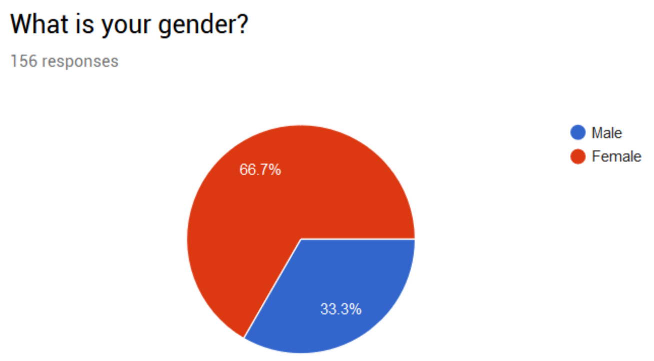

Figure A.1 Gender of the participants

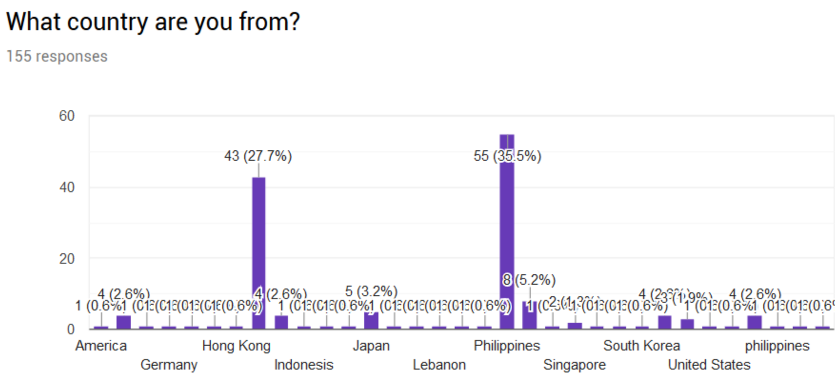

Figure A.2 Countries the participants come from

Figure A.3 Hours of sleep the participants get per night

Figure A.4 Participants rating their own sleep quality

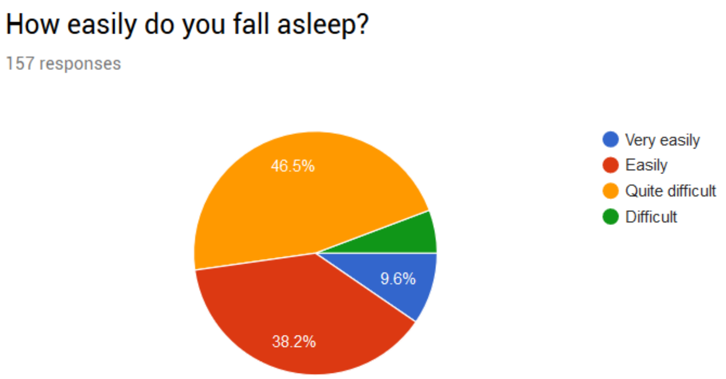

Figure A.5 Participants on how easy they fall asleep

Do you have any sort of "ritual" for you to fall asleep? (Count sheep etc)

157 responses

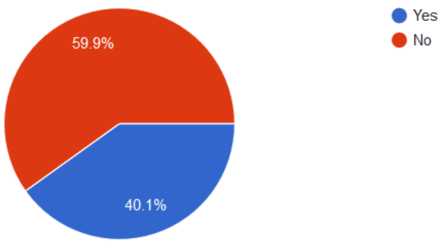

Figure A.6 Participants on their sleep rituals

If you do have a ritual, could you please describe it?

77 responses

- Use my mobile phone to check on my fb or youtube or even watch movie on netflix
- Playing online games or reading books just to make me feel sleepy
- N/A
- Imagine situations and things, sometimes environments.
- YouTube/Netflix
- count sheep, listen to music, change my body position
- I start to envision my goals in life.
- I watch twitchTV or youtube and fall asleep on it
- Take a deep breath and hold it for 6 seconds and then release, after that my breath will be slower and just like that i will let my mind drift off
- breathing deeply or thinking of what happen today
- No

Figure A.7 Participants describe their sleep rituals

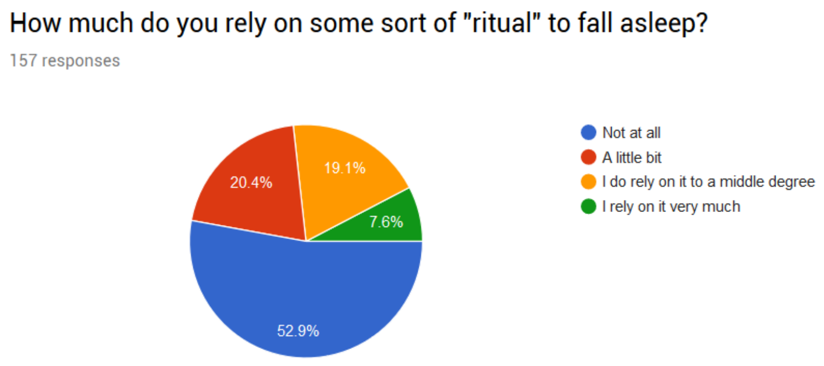

Figure A.8 Participants on their reliance on the rituals aforementioned

Figure A.9 Participants on how constant their sleeping schedule is

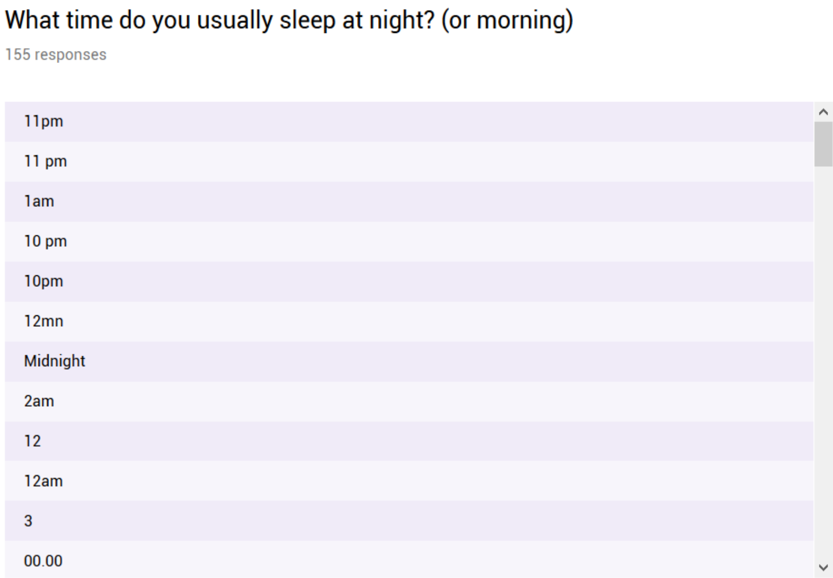

Figure A.10 Participants on their sleeping time

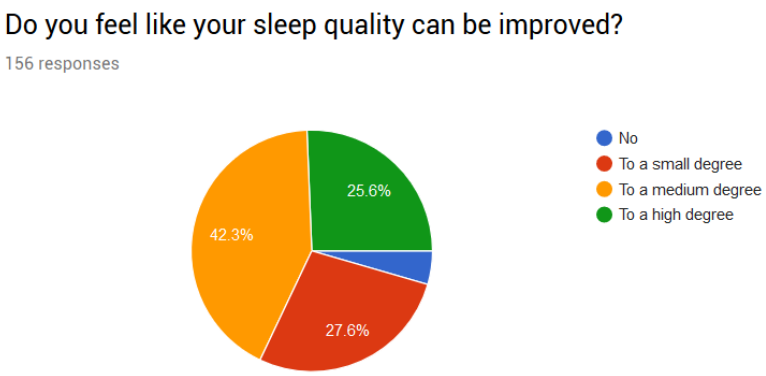

Figure A.11 Participants on whether their sleep quality can be improved

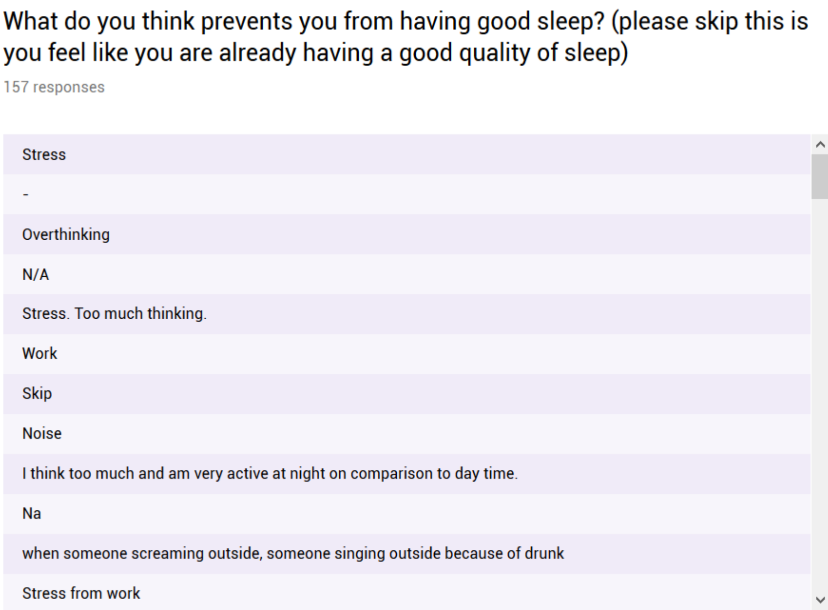

Figure A.12 Participants on what prevents them from having good quality of sleep

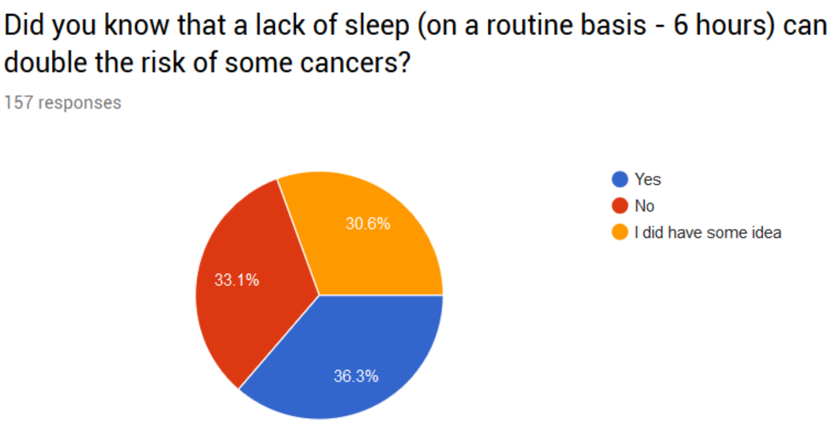

Figure A.13 Participants on their sleep knowledge

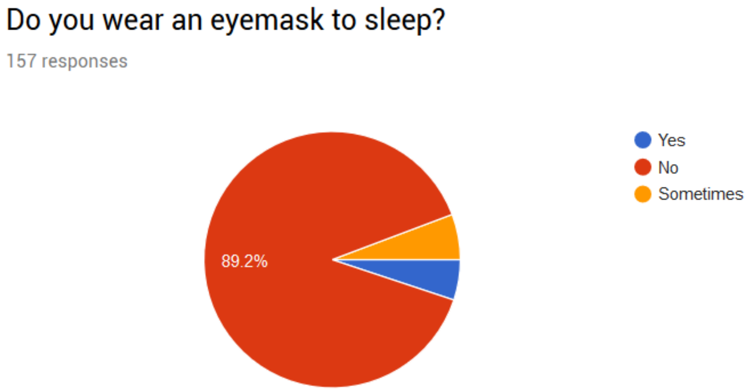

Figure A.14 Participants on their sleeping mask usage

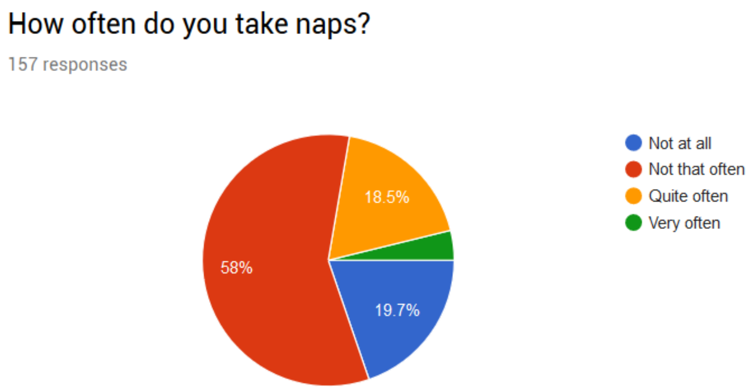

Figure A.15 Participants on how often they take naps

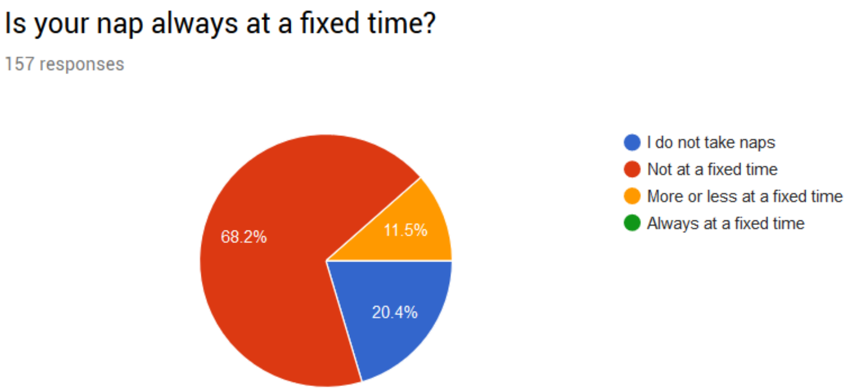

Figure A.16 Participants on their nap time

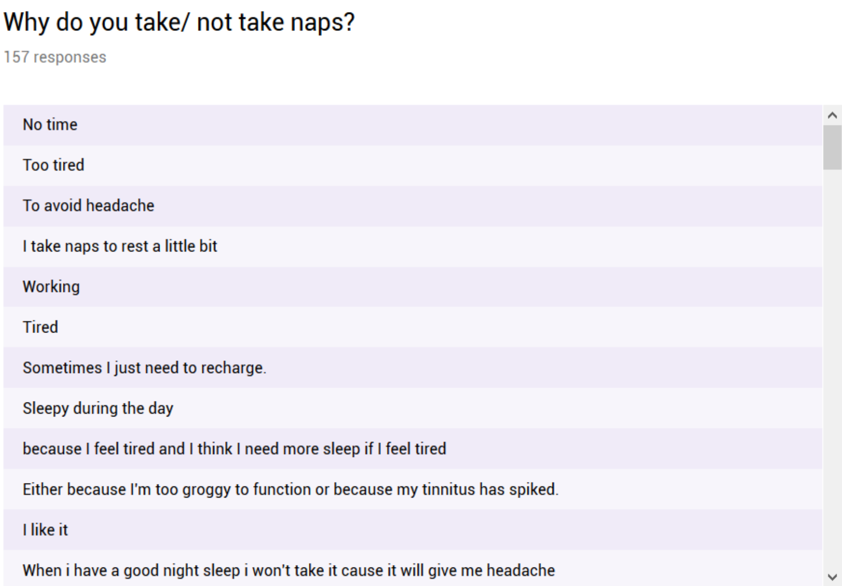

Figure A.17 Participants on why they do or do not take naps

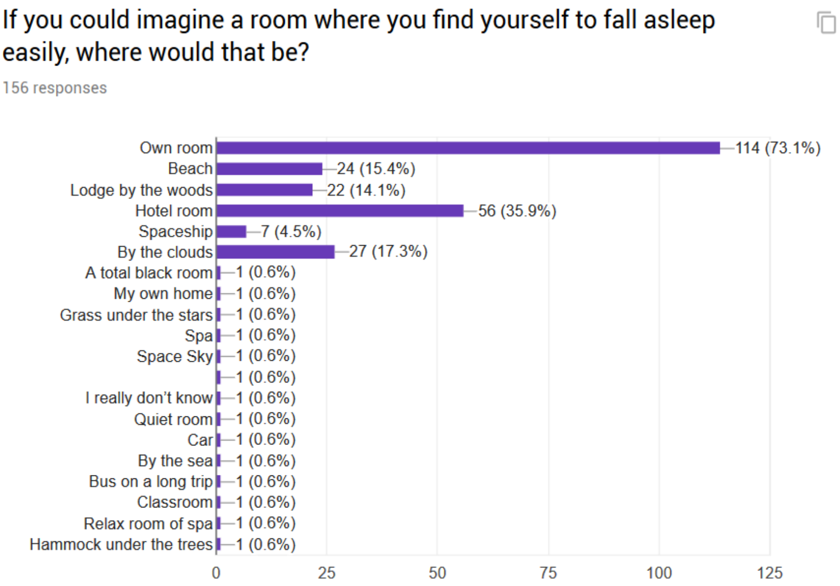

Figure A.18 Participants on their ideal sleeping envionment

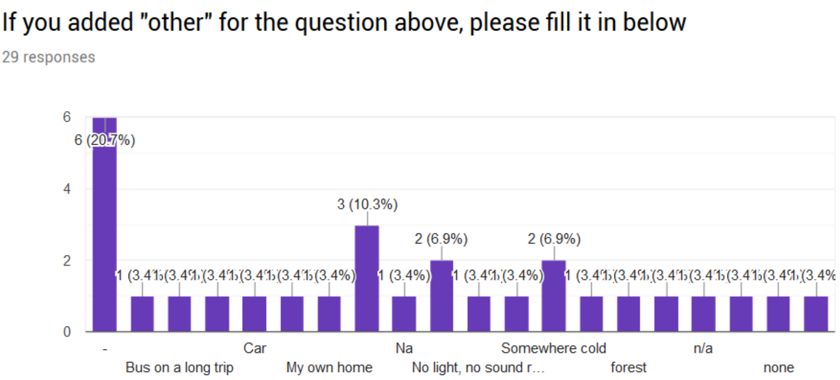

Figure A.19 Participants on more of their ideal sleeping environments

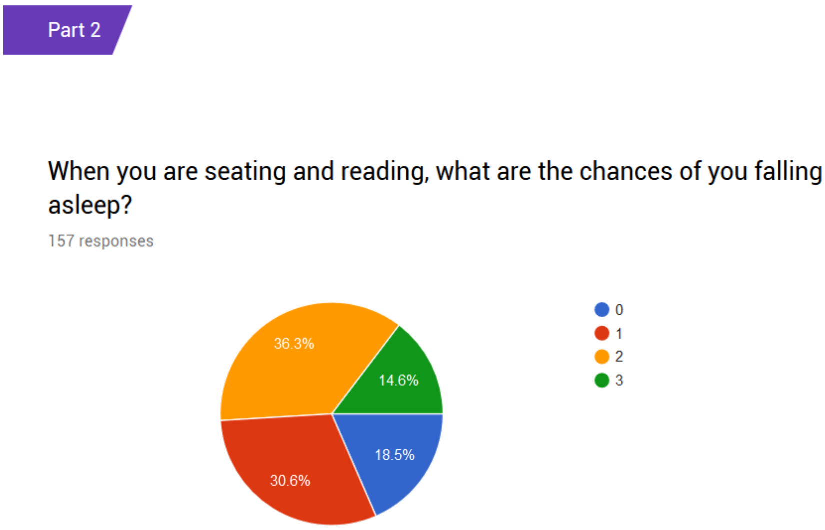

Figure A.20 Epworth questionnaire

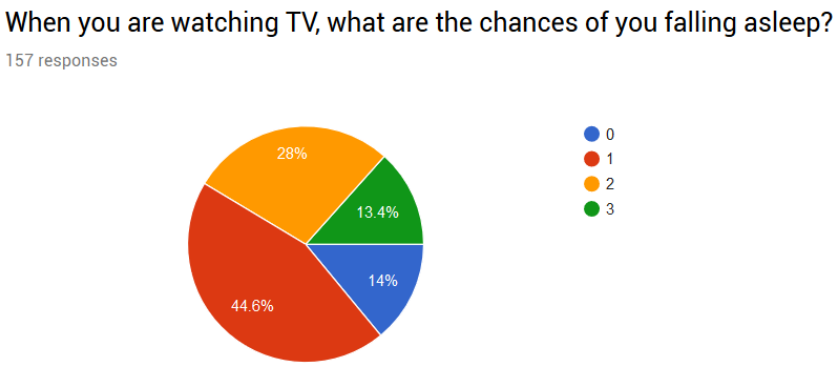

Figure A.21 Epsworth questionnaire

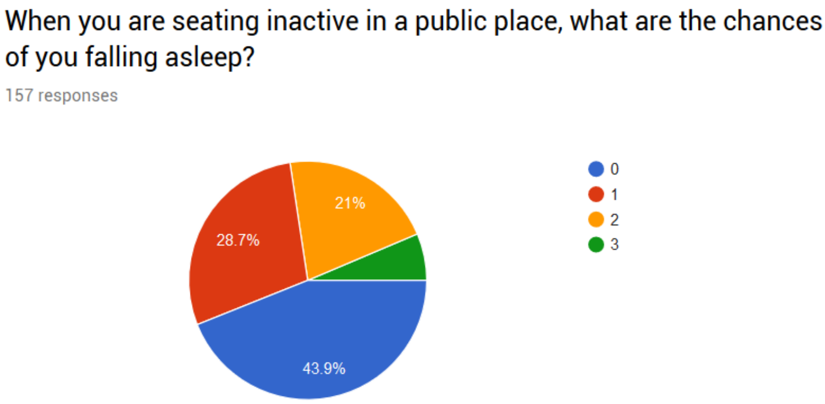

Figure A.22 Epworth questionnaire

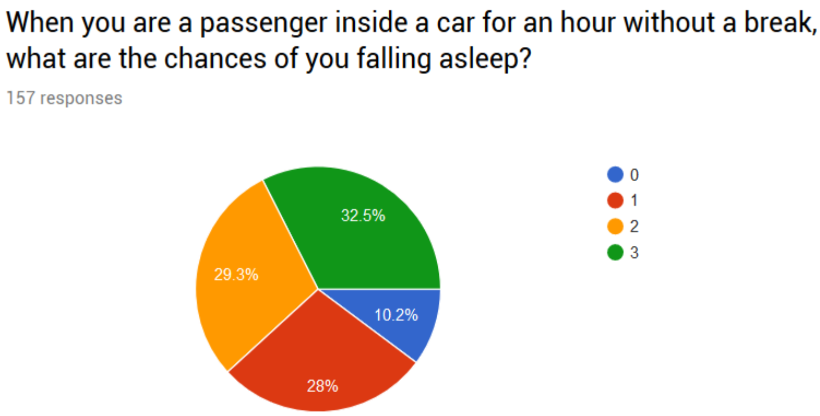

Figure A.23 Epworth questionnaire

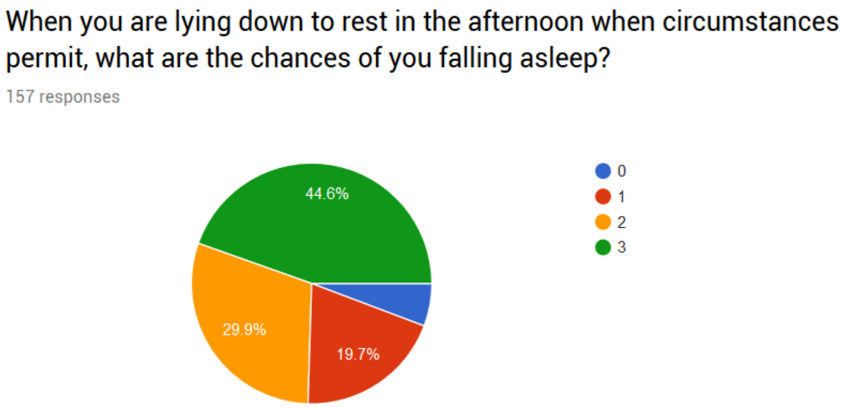

Figure A.24 Epworth questionnaire

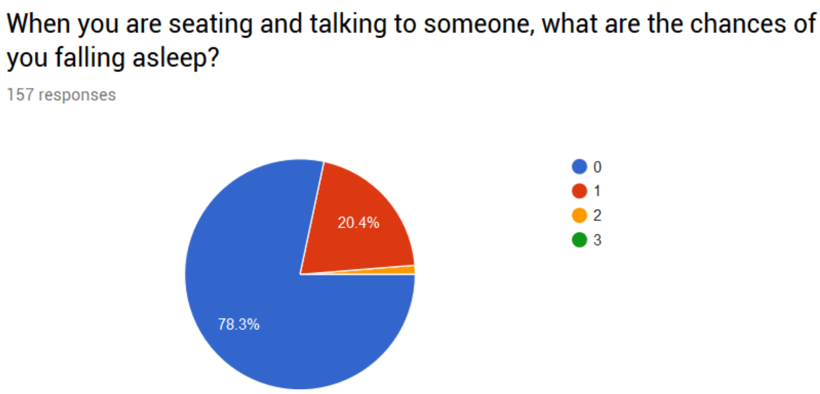

Figure A.25 Epsworth questionnaire

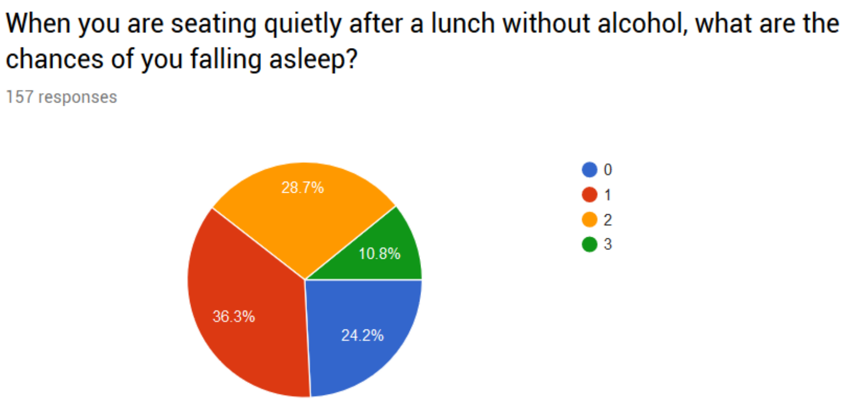

Figure A.26 Epworth questionnaire

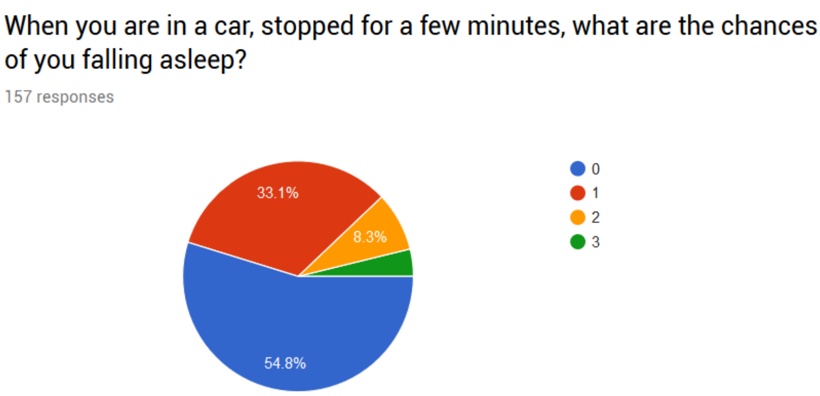

Figure A.27 Epworth questionnaire