CONCENTRO SHOOK PROTOTYPE: A DEVICE MADE FOR REDUCING CONCENTRATION LOSS

A Honors Thesis

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Abstract

The ability to concentrate on a task is crucial for productivity and success, yet it is a common struggle for many individuals. During my honors thesis, I aim to investigate the question "How can technology assist with concentration?" by exploring the potential of existing computer systems, such as smartphones and Raspberry Pis, to improve concentration and enhance weaker functioning related to concentration. As we increasingly rely on technology to augment our human capabilities, I believe that technology can play a significant role in supporting concentration. To this end, I proposed the development of a device prototype of a pad that transmits vibrations to a person when they have stopped focusing on a task, and a smartphone application that blocks distracting notifications and alerts the user when they want to stop concentrating. In addition to these devices, I plan to measure concentration levels using EEG data collected through a DIY EEG sensor built with various materials. By working with these devices, I hope to gain insights into the underlying factors that contribute to reduced concentration levels and identify potential technological strategies for improving concentration. Ultimately, my thesis seeks to explore whether the development of such technology can aid the brain in concentrating on a task, and if not, what alternative approaches can be taken to support concentration. By shedding light on the complex nature of concentration and the potential for technology to assist in this area, I hope to contribute to the growing body of research on how technology can improve our cognitive abilities and enhance our overall well-being.

1. Introduction

Technology has been an integral part of human life for centuries, and its advancements have continuously transformed the way we live, work, and interact with each other. In today's fast-paced and ever-evolving world, the ability to concentrate and focus is more important than ever. However, distractions are everywhere, and it can be challenging to maintain a high level of concentration for extended periods of time. That's where my project comes in: I aimed to investigate how technology can assist with concentration and help individuals improve their cognitive functioning. By utilizing affordable EEG technology in conjunction with readily available computer systems, such as smartphones and Raspberry Pis, I aimed to develop a solution that could enhance concentration in individuals struggling with this vital skill. While we have become accustomed to using technology to augment our physical abilities, such as storing and retrieving information, we have yet to explore its potential to enhance our mental capabilities. My project aimed to bridge this gap and investigate the possibility of using technology to improve concentration, ultimately contributing to a more productive and efficient society.

In today's fast-paced world, the ability to concentrate and maintain focus is more important than ever. Unfortunately, distractions are everywhere, and it can be challenging to maintain a high level of concentration for extended periods of time. That's where my project comes in: I aimed to develop a device that can assist individuals in maintaining focus and staying on task. The device consists of a pad that transmits vibrations to the user when they have stopped concentrating on a task, such as solving a math problem. The device should be placed on the user to ensure it does not interfere with their daily activities, while also allowing for easier reach to the human brain to measure EEG. Drawing inspiration from past research and utilizing several known methods for reducing concentration, my aim was to create a device that could augment the user's natural abilities and help them maintain focus. As a researcher limited to certain fields of study, I saw this as an opportunity to test the boundaries of what can be explored and contribute to the ongoing development of technology-assisted cognitive enhancement. Ultimately, my goal was to create a device that could help individuals improve their cognitive functioning and lead to a more productive and efficient society.

In today's digital age, it can be challenging to maintain focus and concentration, especially when there are countless distractions competing for our attention. With this in mind, I set out to develop a device prototype that can assist individuals in staying focused on their tasks, either by reducing distractions or by making them aware of when they have lost concentration. I chose to use a smartphone as the interface for the device due to its widespread popularity and frequency of usage. By developing a smartphone application, my aim was to help individuals reduce their cognitive load when using other apps, receiving notifications, keeping track of tasks, or memorizing information. The app could achieve this through various features, such as app and notification blocking, scheduling tasks, and keeping track of information through reminders and notifications. One unique feature of the app would be its ability to predict when a user has become distracted, such as when attempting to open an app, and alert the user through a vibration. This innovative approach to cognitive enhancement could help individuals stay focused and productive, ultimately contributing to a more efficient and successful society. By combining technology and cognitive psychology, my project aimed to explore the boundaries of what can be achieved and pave the way for future developments in this exciting field.

In the pursuit of enhancing cognitive performance, it is essential to have a precise measure of when an individual is losing concentration. This is why I am incorporating an affordable EEG with a Raspberry Pi to my project. The EEG will measure the brain's alpha and beta waves and, through some algorithm, identify the percentage of how concentrated a person is towards a task. However, the challenge lies in ensuring that the readings are not confused with other brain wave variations. To mitigate this, I have decided to keep the device focused on certain tasks that do not have too much variability. The Raspberry Pi will also include a vibration sensor that will work in tandem with the mobile application and the EEG to alert the user when they are losing focus. The vibration sensor will not only wake the user up but also do so without causing any annoyance. The ultimate goal of this feature is to help users regain their concentration without creating any added distractions. By utilizing innovative technology such as affordable EEGs and Raspberry

Pi's, I aim to develop a device that will take cognitive enhancement to new heights. This approach not only opens up new avenues of research but also has the potential to change the way we approach cognitive functioning and productivity.

Enhancing concentration is a task that many of us face daily, and technology can play a significant role in helping us achieve that. The Concentro Shook prototype aims to address this by utilizing a user-friendly interface and advanced sensors that keep track of your concentration at all times. The device is designed to ease the demanding task of concentration and reduce the cognitive and external distractions that could potentially affect it negatively. Unlike other anti-distraction apps that work in the background, the Concentro Shook device will be more interactive with the user, as it will be more physically present. This feature will create a more immersive experience and help users stay engaged in their tasks. Moreover, the Concentro Shook prototype will utilize some algorithms like the fast fourier transform to directly measure the user's brain waves, which will help provide more accurate readings. The device will also be equipped with a vibration sensor that will alert the user when they are losing focus, prompting them to take action and regain their concentration. Through innovative technology and a user-focused approach, the Concentro Shook prototype has the potential to revolutionize the way we approach concentration, productivity, and cognitive enhancement.

In today's digital age, the way we interact with technology has become increasingly important, and the development of human-computer interfaces (HCI) has become essential in improving user experience. The Concentro Shook prototype is a prime example of an HCI that focuses on concentration, providing users with a more interactive and engaging experience. By attaching the device to the user's body, the Concentro Shook interface has the potential to increase the user's receptiveness to the device's feedback, making them more likely to take action and improve their concentration. Moreover, the device's vibration mechanism is a novel way of alerting the user to refocus their attention, similar to how someone might snap us out of daydreaming. The device acts as a self-contained system, making it a more effective and reliable solution than traditional anti-distraction strategies. In essence, the Concentro Shook interface has the potential to revolutionize the way we approach concentration and productivity, while also improving the user's experience when interacting with technology.

The Concentro Shook device aims to tackle the pervasive problem of concentration lapses, which can hinder productivity and performance. While there are numerous techniques and tools that can help users stay focused, such as Pomodoro timers, noise-cancelling headphones, and meditation apps, Concentro Shook offers a more personalized and responsive solution. By using a vibration motor to signal when a user's concentration has dropped, Concentro Shook can alert the user in a non-intrusive way and provide them with the opportunity to regain their focus. Moreover, by combining this vibration feedback with EEG measurements, the device can offer a more accurate and objective assessment of the user's concentration level. Through the use of a Raspberry Pi and an affordable EEG, Concentro Shook can capture alpha and beta waves to determine the user's level of engagement with the task at hand. The goal of the device is not only to measure the user's concentration but also to encourage them to maintain a high level of focus. By providing timely notifications and feedback, Concentro Shook can help users stay on track and avoid distractions that might interfere with their work or study. The unobstrusive device aims to be a discreet and convenient tool that can be used in various settings, such as the workplace, classroom, or home. In summary, Concentro Shook is a novel device that combines vibration feedback and EEG measurements to assist users in maintaining their concentration. By offering a more interactive and accurate approach to concentration training, the device has the potential to help individuals overcome the challenges of distraction and improve their cognitive performance.

As a student, I became increasingly aware of the challenges and limitations of concentration. While we may have hours in the day to work, many of us struggle to maintain focus and productivity. This led me to consider what could be achieved if we could overcome these challenges and unlock our true potential. While there are various approaches to improving concentration, such as drugs, discipline, and training programs, I wondered whether technology could offer a more immediate solution. Just as devices like Google Maps have helped us navigate to our destination more efficiently, I believe a device designed to support concentration could provide a similar benefit. By reducing distractions and minimizing cognitive load, such a device could help us maintain focus and maximize our productivity. This idea inspired me to explore the potential of the Concentro Shook prototype and to develop a human-computer interface that supports concentration in a new and innovative way.

Imagine being able to work without the frustration of losing concentration. With the increasing demands of modern work and study, it can be challenging to maintain focus and achieve optimal productivity. This is where a device like Concentro Shook could make a significant impact. By addressing the numerous reasons why people lose concentration, such a device could help users complete tasks faster and meet deadlines with greater ease. But it's not just about efficiency. Concentro Shook has the potential to unlock new levels of creativity and engagement, helping users to stay engaged and present even in the most tedious or challenging situations. For example, during a lecture or meeting, the device could detect when the user is daydreaming or losing focus and provide a gentle vibration to bring their attention back to the task at hand. This could save users valuable time and reduce the need to ask for clarification or repeat information, leading to greater academic and professional success.

Concentro Shook aims to be a unique device that combines ideas from various fields to provide an effective solution for enhancing concentration. Drawing from previous psychological and neuroscientific research, the device aims to measure the user's concentration level through the use of EEG waves. Additionally, it integrates concepts from human-computer interaction (HCI) by reducing cognitive load and designing applications that are easier to use. By utilizing a vibration sensor, the device can provide a tangible signifier that the user needs to be concentrating at a given moment, similar to operant conditioning. Furthermore, it borrows ideas from existing anti-distraction applications such as Forest, which can block notifications and set up an easy scheduler, and a timer to keep track of the user's work. Concentro Shook aims to be a comprehensive and effective solution to help users achieve their concentration goals.

Concentro Shook has the potential to be a valuable tool for not only improving concentration, but also for furthering our understanding of what helps people focus. By testing various combinations of features, such as vibration sensors, EEG measurements, and anti-distraction techniques, we can gain insight into what works best for enhancing concentration. With this information, we can refine and improve the design of future devices, making them more effective for a wider range of people. Additionally, the data gathered from Concentro Shook could provide valuable insights into concentration issues, giving individuals struggling with concentration a better understanding of why certain aids may or may not be effective for them. As technology advances, we may also discover new and innovative ways to measure and improve concentration, furthering the development of tools like Concentro Shook.

2. Summary of Work of Previous Researchers

2.1. Concentration: Staying Focused in Times of Distraction Summary

In previous research, working memory has been defined as the part of the brain responsible for executing complicated tasks, with a limit on the amount of information that can be effectively processed and stored (Stigchel 23). Maintaining a minimal amount of information in working memory is crucial for efficient task execution, especially during periods of concentrated effort. However, unwanted information can also enter working memory and disrupt concentration, as can happen when a distracting pop-up appears on a device screen. Previous studies have suggested that engaging in specific activities, such as playing memory games, can increase working memory capacity and improve overall cognitive function (Stigchel 23-24, 27, 29). These findings highlight the importance of understanding working memory and the impact of external factors on cognitive performance, in order to develop effective strategies and technologies for improving concentration and productivity.

Baddeley's working memory model is a useful framework for understanding the three components that make up working memory. The central executive, the visuospatial sketchpad, and the phonological loop work together to enable us to carry out complex tasks (Stigchel 32). The phonological loop is responsible for holding onto auditory and linguistic information, such as sounds and spoken text. However, it has limitations, such as the fact that we cannot read and comprehend text while thinking about something else simultaneously (Stigchel 32). Additionally, the phonological loop can help us control our impulses, such as when we use our inner voice to calm ourselves down when we are angry (Stigchel 32). On the other hand, the visuospatial sketchpad stores visual information and information about the locations in the world, and it is used when imagining things (Stigchel 36). These two storage systems work independently of each other, and we often convert verbal information into visual images to better understand them, such as when we receive directions to a destination (Stigchel 35, 38). Understanding the different components of working memory can help us design interventions to improve our concentration and cognitive performance.

The central executive, as part of Baddeley's working memory model, is crucial in helping us ignore unnecessary information and focus on the relevant information needed to complete a task efficiently. This ability is often referred to as "cognitive control," and it is necessary for tasks that require sustained attention and the ability to switch strategies when necessary. However, children and the elderly may have more difficulties with cognitive control than young adults. This is because the prefrontal cortex, which is responsible for cognitive control, either has not yet reached maturity in children or has deteriorated due to age in the elderly (Stigchel 38, 41). This is important to consider when developing technologies to aid concentration, as different age groups may require different approaches to improve their ability to concentrate.

Attention is a crucial aspect of concentration, and the ability to direct it voluntarily is essential for efficient task execution. However, reflexive attention, which is not under our control, plays a critical role in maintaining our awareness of our surroundings. While this type of attention can be useful, it can also be a source of distraction during desk work, where it is crucial to minimize environmental stimuli to maintain focus. In addition to external distractions, internal stimuli, such as worrying about an upcoming exam, can also divert our attention and diminish our working memory capacity. For individuals with post-traumatic stress disorder (PTSD), involuntary alertness to potential danger in their environment can make it challenging to concentrate, contributing to concentration problems. Therefore, it is important to consider strategies such as turning off device notifications and managing anxiety levels to optimize attentional resources for concentration tasks (Stigchel 42-45).

The concept of multitasking has become increasingly prevalent in today's society, with many individuals believing they can complete several tasks simultaneously. However, research has shown that our brain cannot perform two tasks that require our working memory simultaneously. Instead, our brain rapidly switches between tasks, causing a cost to our productivity, leading to a decrease in performance when compared to concentrating on one task. The switch costs are even higher when the previous task is more complicated, and the brain requires time to declutter before starting a new task. This process takes more time, leading to mistakes or longer completion times. In a study conducted at Stanford University, researchers found that individuals who spend more time using various media, such as smartphones or laptops, have higher switch costs, highlighting the detrimental effect of media usage on cognitive abilities (Stigchel 48-50).

These findings have significant implications for how we manage our daily activities, emphasizing the importance of focusing on one task at a time to maximize productivity and minimize the time required to complete tasks.

The detrimental effects of interruptions and task-switching on employee productivity have been further studied. The constant interruptions can lead to employees taking longer to complete their work and make more errors. In one study, researchers found that after a worker was interrupted, it took an average of 25 minutes for them to fully return to their original task. Moreover, employees who were interrupted more often had a higher level of stress and produced more cortisol, a hormone associated with stress. The researchers noted that the negative effects of interruptions were not limited to their duration but also the fact that they caused employees to have to restart their work. Furthermore, even small interruptions, such as a brief phone call or email notification, were found to have a significant negative effect on productivity (Stigchel 52-55).

In an attempt to combat the negative effects of interruptions, some employers have implemented strategies such as setting aside specific periods of uninterrupted work time or creating a designated quiet zone. Additionally, some researchers have suggested that workers may benefit from learning how to manage interruptions by setting aside specific times to check their email or return phone calls, for example, rather than allowing them to interrupt their work throughout the day (Stigchel 55). Overall, it is clear that minimizing interruptions and task-switching can have a positive impact on employee productivity and well-being.

Music has been shown to have a positive impact on our cognitive performance, particularly in tasks that require sustained attention. When we listen to music that we already know, it can increase our arousal and help us concentrate on the task at hand, as it can block out distractions from the external environment. In contrast, unfamiliar music or music with lyrics can be distracting and reduce our concentration, as it requires additional mental processing that competes with the task at hand. Moreover, the level of arousal can influence our reaction time, where higher arousal leads to faster reactions. However, if the level of arousal is too high, it can lead to stress, negatively impacting our concentration (Stigchel 65-66).

The duration of our concentration on a particular task is limited, and the length of time we can concentrate decreases as the difficulty of the task increases. This can be explained by the Yerkes-Dodson law, which suggests that we need a balanced level of arousal to perform optimally. Too much or too little arousal can lead to decreased performance (Stigchel 68-69). High levels of arousal, such as those experienced when we are anxious, can lead to stress, which further reduces our concentration levels. The production of stress hormones, such as cortisol and adrenaline, associated with high levels of arousal, further exacerbates the negative impact of stress on our cognitive performance (Stigchel 72-73). Therefore, it is important to strike a balance in our arousal levels to optimize our cognitive performance.

To further enhance concentration, it is important to consider the individual's cognitive style. For instance, some individuals benefit from a structured environment with clearly defined tasks, while others are more creative and prefer an open-ended approach. Furthermore, some individuals are more sensitive to noise or visual distractions, which may impact their concentration. It is therefore important to tailor the work environment to the individual's needs, for example, by providing noise-canceling headphones or assigning tasks that match their strengths. In addition, breaks are crucial to maintaining concentration over a prolonged period. Studies have shown that taking short breaks, even just a few minutes, can enhance productivity and reduce stress levels. During these breaks, it is important to engage in activities that are relaxing and enjoyable, such as taking a short walk or engaging in light conversation with colleagues. Technology breaks, such as putting away devices and disconnecting from social media, can also be beneficial for restoring attention and focus. Overall, maintaining concentration requires a combination of factors, including individual preferences and needs, environmental factors, and the use of breaks and technology breaks. By understanding and addressing these factors, individuals can optimize their work performance and reduce the negative effects of distractions and multitasking. (Stigchel 77, 79, 81).

While video games are designed to grab the player's attention and maintain their interest, they can also have negative effects on concentration. A study found that while playing a video game, participants showed decreased activity in the prefrontal cortex, the area of the brain responsible for attention and concentration. This means that while video games can be engaging, they may not be the best way to improve concentration in a work or study environment (Stigchel 84). However, some elements of video game design, such as immediate feedback and a clear goal, can be helpful in maintaining concentration. This is because feedback and goal-setting provide a sense of achievement and progress, which can motivate the user to continue working. Another way to improve concentration is through the use of positive affirmations, which have been found to increase self-esteem and reduce anxiety, leading to improved concentration and productivity (Stigchel 85-86). It is also important to note that different types of tasks require different levels of concentration. For example, tasks that are repetitive or involve memorization may require less concentration than tasks that involve problem-solving or critical thinking. Understanding the nature of the task at hand can help determine the most effective methods for maintaining concentration and productivity (Stigchel 89).

The article "A Wandering Mind Is an Unhappy Mind" sheds light on how our thoughts tend to wander during mundane tasks, and this wandering often leads to negative thoughts, causing us to feel unhappy. Interestingly, the study also showed that we tend to be happier when we are engaged in work compared to when we are daydreaming. This suggests that staying focused on a task may be beneficial for our well-being. Daydreaming can also be detrimental to our concentration since it diverts our attention from the task at hand and makes us less aware of our surroundings. In a study, participants were less likely to daydream when they were offered a reward for their good performance, which emphasizes the importance of motivation and incentives in maintaining concentration (Stigchel 91-93). In conclusion, the findings suggest that having a clear incentive and reward system can be an effective strategy to keep individuals focused and motivated, thus reducing the likelihood of daydreaming and promoting positive mental states.

2.2. Reducing academic procrastination: Designing an artifact to aid students Summary

Procrastination is a common issue that affects many individuals, especially college students. According to Jacobsen (1), procrastination refers to delaying an intended task despite expecting to be worse off for the delay. The negative impact of procrastination is far-reaching, and it can lead to decreased performance, learning, self-esteem, and increased stress and anxiety, ultimately affecting academic success. In fact, studies show that around 70% of college students regularly procrastinate, with 50% doing so problematically (Jacobsen 1).

Several intervention strategies exist to address procrastination, including cognitive-behavioral therapy (CBT), which focuses on changing an individual's negative thoughts and behaviors. However, CBT may not work for everyone, and half of the participants drop out before it becomes effective (Jacobsen 1). Other interventions include self-regulatory training, which teaches individuals how to identify their goals, plan their tasks, and monitor their progress. In addition, structured time management and study skills training may help individuals prioritize their tasks and develop effective study habits. By implementing these interventions, individuals can better manage their time and ultimately improve their academic performance and well-being.

Designing effective environments and tools that counteract the negative effects of procrastination is an important consideration for designers. Researchers have explored the use of digital aids to help individuals overcome procrastination, particularly in academic settings. For instance, Jacobsen's study focused on designing a mobile app to help students overcome academic procrastination. The app was designed to promote positive behavioral change and was aimed at helping students avoid common procrastination traps. By providing a structured approach to tackling academic tasks, the app aimed to help students develop effective study habits and reduce procrastination. The app also provided a range of tools to help students manage their time and avoid distractions, such as goal-setting features and reminders. While the effectiveness of such digital aids is still being explored, the potential for these tools to help individuals overcome procrastination and improve their academic performance is promising (Jacobsen 2-3).

The development of the mobile application mentioned earlier is based on an understanding of the factors that lead to procrastination. By breaking down tasks into smaller, more manageable steps, the app helps to reduce the daunting nature of the task and make it easier for users to begin. The app also provides a clear overview of deadlines and important tasks, which can help to reduce procrastination by providing an easy visualization of what needs to be done. Another important feature of the app is the focus mode, which allows users to eliminate distractions from their smartphone. This can be particularly useful for students, who may find themselves constantly checking social media or responding to notifications while they are trying to study. By blocking these distractions for a set period of time, the app helps to increase productivity and reduce procrastination. It is worth noting that the mobile app is a minimum viable product and not yet fully complete. However, it has been designed with a positive behavioral change approach, which aims to create long-term change in user behavior. This approach focuses on creating an app that is easy and enjoyable to use, with the hope that users will continue to use it over time and see a reduction in their procrastination. (Jacobsen 4).

In the field of behavioral psychology, the concept of procrastination is a common area of study. However, the author of this research paper has made an important contribution by defining procrastination more concretely in the context of developing a mobile application to address it. By adopting Piers Steel's definition of procrastination such as that it is “the act of voluntarily delaying an intended course of action despite expecting to be worse off for the delay”, the author has provided a clear framework for understanding the problem that the mobile app is designed to address. This definition captures the essence of the negative effects of procrastination, and it is useful to have a clear understanding of the problem that the mobile application is attempting to solve. By using this definition, the author has avoided any potential subjectivity in understanding what problems the app attempts to address and has instead provided a more objective and evidence-based approach (Jacobsen 6).

Academic procrastination can have a significant impact on a student's academic performance as well as their health. In addition to poor grades, students who procrastinate may experience stress, fatigue, and emotional consequences. Procrastination can also lead to a short-term reduction in stress during the early stages of a project, but an increase in stress as the deadline approaches. These effects can be both short-term and long-term. The mobile application developed by the researcher focuses on addressing the negative consequences of procrastination to avoid any confusion with the possible benefits of procrastination. By using the app to reduce procrastination, students may experience improved academic performance, reduced stress and anxiety, and improved emotional well-being (Jacobsen 7-8).

Procrastination is a complex phenomenon that can be influenced by many factors beyond just poor time-management or laziness. For instance, regulatory failure, a body's attempt to avoid negative emotions such as stress or anxiety, can contribute to procrastination. Internal factors such as neuroticism, extroversion, and conscientiousness can also affect procrastination. Neuroticism, which is the proneness to psychiatric disorders, self-doubt in one's ability to do well, and low self-esteem, can lead to task aversiveness. Extroversion, one of the strongest predictors of procrastination, is often associated with impulsiveness, making people prefer immediate rewards without too much thought about the future. Low conscientiousness is another personality trait that can affect procrastination and is associated with being not well-organized, unambitious, careless, and non-achievement oriented. External factors, such as the timing of rewards and punishments and task aversiveness, can also influence procrastination. The longer away the deadline is, the more likely that a student will see it as less impactful in their decisions as they won't reap the benefits until it is closer. In addition, tasks perceived as more unpleasant or difficult are more likely to be avoided due to humans' natural tendency to avoid aversive stimuli (Jacobsen 9-13).

While there are various applications that attempt to address procrastination, the three apps mentioned in the previous paragraph are among the most popular ones available. The Forest app, for example, incorporates a focus timer and app blocking features that help users stay on task and avoid distractions. As the user stays focused on their work, a virtual tree will grow on the app. On the other hand, if the user gets distracted and opens another app, the virtual tree will die (Jacobsen 15). The Hold app, meanwhile, offers an indefinitely ongoing timer that rewards users with points every 20 minutes of not using other apps. These points can be redeemed for special rewards offered by the app, providing users with an extra incentive to stay on track (Jacobsen 16). Finally, the Todoist app offers a comprehensive task management system that includes functionalities designed to increase productivity. With its user-friendly interface and customizable features, it can help students prioritize tasks, set reminders, and manage deadlines more effectively (Jacobsen 17). Overall, these three apps represent just a few of the many mobile applications available that aim to address the problem of procrastination.

Zimmerman's RtD Model highlights the importance of designers' contribution to research through the design process. In terms of the evaluation criteria, the first criterion is process, which refers to designers' work being reproducible and their research methods being transparent and well-explained (Jacobsen 19). The second criterion is invention, which requires designers to introduce something new that can advance the current research field (Jacobsen 20). The third criterion is relevance, which means that the research should have a meaningful impact on the world or a specific group of people in order to be considered valid and not just a personal project (Jacobsen 20). Finally, extensibility is the fourth criterion, and it involves providing documentation that allows other designers to build on the research in the future, making it knowledge that is applicable to other design research (Jacobsen 20).

In the RtD model, designers must carefully consider each criterion in order to make a meaningful contribution to research. By ensuring that their work is reproducible and that their research methods are transparent, designers can increase the reliability of their findings and help advance the research field. Invention is also crucial, as it encourages designers to think outside the box and introduce new concepts or ideas. Moreover, designers must ensure that their research is relevant and has a positive impact on the world or specific groups of people. Finally, extensibility ensures that the knowledge gained from the research can be applied to future design projects and help further advance the field. By considering each of these evaluation criteria, designers can create work that makes a valuable contribution to research (Jacobsen 20).

Jacobson's research on mobile app design included a diary study that involved recruiting three bachelor student participants in their 20s to keep a diary of their mobile application usage. The researcher also conducted several post-study semi-structured interviews with the participants to gather more detailed information (21-23). In designing the mobile app, Jacobson utilized several design principles that are known to enhance usability and user experience. One of the principles is visibility, which entails making interface elements more visible to users in order to enhance usability. Feedback is another important principle, and it involves providing immediate feedback to users after an action has been taken. Constraints are also used in order to restrict certain actions and encourage users to interact with the application in an appropriate manner. Mapping controls to natural-like interactions with the app improves ease of usage, and consistency in interface design helps users to avoid confusion. Finally, affordances play an important role in ensuring that objects in the app are easily perceivable and that users can interact with the user interface with ease (Jacobsen 23-25).

Development

In addition to a loose form of agile methodology and inspiration from the Forest app, the app development process also included the use of focus groups to gather feedback from potential users. Based on this feedback, some modifications were made to the original design of the app. For instance, participants suggested that the anti-distraction feature, known as Focus Mode, should be turned off after some time. This input was taken into consideration and implemented in the app design. On the other hand, although participants did not like the idea of breaking down tasks in the app, the feature was not removed due to evidence from psychological research suggesting its importance. Overall, the app development process involved multiple iterations and gathering feedback from potential users, which allowed for the incorporation of user feedback and the creation of a more user-friendly and effective app (Jacobsen 27-30).

Technical Development

To improve the development of the app, the researcher utilized the Android Studio IDE and Kotlin programming language, which provided an efficient way to build an Android native application that can integrate with the required features, such as Focus Mode. The iterative approach to app development allowed the team to build a prototype, test it with participants, and gather feedback to improve the next iteration. The final version of the app was built from the ground up and tested on a Samsung Galaxy S8 device. To keep track of the changes made during development, Git was used to maintain a backup of the codebase. This allowed Jacobsen to track the evolution of the app and revert to earlier versions if necessary (Jacobsen 34-36). By utilizing these tools and processes, Jacobsen was able to efficiently build a robust and functional mobile application that met the needs and preferences of the target user group.

The app development phase resulted in a well-designed application with various features that can help users with their assignment discomfort. One of the essential features is the ability to add assignments, which involves breaking down the assignment into smaller, more manageable tasks and setting task deadlines. This feature can significantly aid in task organization and tracking, which can ultimately lead to reduced assignment discomfort. The app's Focus Mode feature is also useful, providing users with the ability to block and silence notifications for a specified period. This feature can help users avoid distractions, and with the use of phone permissions, it can provide an effective way to enhance productivity. Additionally, the app's home screen is a central hub that displays important information to the user, such as a message box that informs the user of the next upcoming task, a weekly progress bar, and a weekly calendar displaying upcoming tasks. With this information readily available, users can quickly assess their progress and make adjustments to their schedules accordingly (Jacobsen 28-30).

Results

After performing data analysis on the diary study data collected from the participants, it was revealed that the app's Focus Mode was beneficial for one of the participants who struggled with impulsive behavior while studying. This participant found that the app prevented them from accessing other distracting applications and helped them stay focused. The task adding and breakdown feature of the app proved to be useful for another participant, providing them with a clearer structure and organization to their study routine. However, for the third participant, the app was deemed redundant as they had already established phone usage routines and found the app's features did not align with their needs. These findings are in line with previous studies, which have shown that different individuals have varying needs and preferences when it comes to productivity applications (Jacobsen 49, 59). Understanding such individual differences and preferences can be valuable when designing and developing productivity apps, as it can help ensure that the app caters to the user's specific requirements and maximizes their chances of success.

2.3. Want My App That Way: Reclaiming Sovereignty Over Personal Devices Summary

Dark patterns in mobile apps have been shown to negatively impact user experience by exploiting psychological weaknesses and promoting addictive behavior (Kolling et al. 1). These patterns are particularly harmful to vulnerable populations such as children, the elderly, and the disabled, who may be more susceptible to such manipulations due to cognitive or physical limitations. To mitigate the negative effects of dark patterns, researchers have developed a mobile app called GreaseDroid (Kolling et al. 1). GreaseDroid is designed to identify and block instances of dark patterns in mobile apps, providing users with greater transparency and control over their digital interactions. By empowering users to make more informed decisions about their app usage, GreaseDroid may help to reduce the harmful effects of dark patterns and promote a more positive user experience.

GreaseDroid is a user-scripting app that allows users to remove dark patterns from mobile apps in a personalized manner (Kollnig 3-4). Through its interface and control flow patches, users can alter the UI of apps to reduce distracting components, such as Facebook stories, and remove gamification token mechanisms that may contribute to addictive behavior (Kollnig 3-4). This level of customization provides users with a tool that empowers them to design their digital experience in a way that promotes their well-being.

By allowing users to apply patches to mobile apps, GreaseDroid provides a flexible and adaptable solution for combating the negative effects of dark patterns (Kollnig 3-4). Users can choose to apply patches selectively to individual apps or across their entire device, providing them with a high degree of control over their digital interactions. The app's expert-level functionality requires some technical knowledge, making it more suitable for advanced users who are comfortable with scripting and programming. However, the potential benefits of the app may be significant, especially for individuals who struggle with addictive behavior or are otherwise vulnerable to the negative effects of dark patterns.

Overall, GreaseDroid is a promising tool for mitigating the harmful effects of dark patterns in mobile apps. By providing users with a customizable solution that empowers them to take control of their digital interactions, the app may help to promote healthier and more productive technology use.

2.4. A Cognitive Design Space for Supporting Self-Regulation of ICT Use Artifact Used Research Methodologies Summary

In today's digital age, users face a constant barrage of notifications, alerts, and other distractions that can make it difficult to maintain focus and self-control over their devices (Lyngs 1-2). To address this problem, virtual tools have emerged that aim to promote healthier and more intentional technology use by removing distractions from UIs, blocking apps, tracking usage, and rewarding intentional behavior (Lyngs 1-2). While these tools have been shown to support self-regulation, they often rely on basic theory from behavioral neurosciences and may not fully leverage the potential of cognitive science.

To address this limitation, researchers have sought to develop anti-distraction tools that incorporate a more nuanced understanding of the mechanics of self-regulation (Lyngs 1-2). By drawing on insights from cognitive science, these tools can provide users with a more effective and tailored approach to managing their digital interactions. For example, anti-distraction tools may leverage principles of cognitive load theory to simplify UIs and reduce the cognitive burden of using apps (Lyngs 1-2). Similarly, these tools may use techniques from positive psychology to encourage intentional behavior and promote a sense of achievement and well-being (Lyngs 1-2).

Through their integration of cognitive science principles, anti-distraction tools have the potential to significantly enhance users' ability to self-regulate their technology use (Lyngs 1-2). By providing users with a more personalized and adaptive approach to managing digital distractions, these tools may help to promote healthier and more productive technology use across a broad range of contexts. However, further research is needed to fully understand the potential of cognitive science-based anti-distraction tools and to identify the most effective strategies for implementing these tools in practice.

Self-regulation is a key aspect of managing digital distractions, and researchers have sought to gain a deeper understanding of the mechanisms underlying this process (Lyngs 3). According to the behavioral neuroscience of self-regulation, there are two distinct systems involved in behavioral control: System 1 processes and System 2 processes (Lyngs 3).

System 1 processes are fast and largely unconscious, responding to environmental stimuli and shaping our long-term goals (Lyngs 3). This system is thought to play a critical role in helping individuals navigate complex and unpredictable environments by providing rapid and automatic responses to incoming information.

In contrast, System 2 processes are slower and more conscious, involving personal goals and working memory rules (Lyngs 3). Unlike System 1 processes, System 2 processes require effortful attention and can be influenced by rewards and the belief in one's ability to succeed

(Lyngs 3). This system is thought to play an important role in more deliberate and intentional forms of behavior, such as sustained concentration or long-term goal pursuit.

By gaining a deeper understanding of these underlying mechanisms, researchers may be better equipped to develop anti-distraction tools that can effectively support self-regulation and promote healthier technology use. For example, tools that leverage System 2 processes may be particularly effective in helping users maintain focus and resist distractions, while tools that target System 1 processes may be more effective in promoting more automatic and habitual forms of behavior (Lyngs 3).

In sum, the behavioral neuroscience of self-regulation provides a useful framework for understanding the complex processes involved in managing digital distractions. By developing a more nuanced understanding of these processes, researchers can design anti-distraction tools that are better tailored to users' needs and more effective in promoting healthier and more productive technology use.

The issue of self-regulation of ICT use can be further understood through the three points described by Lyngs (4). Firstly, when there is a mismatch between ICT use and a goal, System 2-level detects it. This means that users may feel like they are not achieving what they want, leading to feelings of frustration and inadequacy. Secondly, a general mismatch can happen when System 1-level is not aligned with a goal, and goals may not be in working memory. This can be exacerbated by distractions from social media apps, which can limit working memory capacity. Finally, the design of apps themselves can contribute to difficulties in self-regulation of ICT use. The availability and accessibility of app functionalities can be tempting to use nonstop, leading to addictive behaviors and distractions. These issues demonstrate the need for effective anti-distraction tools and proper design space to support self-regulation and well-being.

2.5. Self-Control in Cyberspace: Applying Dual Systems Theory to a Review of Digital Self-Control Tools Summary

In addition to the integrative dual systems model for self-regulation, this research also employs the concept of the "expected value of control" to measure effective self-control. The expected value of control is the amount of value an individual expects to gain from engaging in self-control, and it can be used to predict whether an individual will successfully regulate their behavior or not. This approach has been used successfully in previous research, where some users have limited their time on social apps due to feeling upset about time conflicts and effective self-control.

To further evaluate the design of apps and browser extensions for digital self-control, the researchers identified 17 HCI papers that had a novel design intervention or evaluated interventions. They analyzed these papers to identify which regulation theories and design interventions were used. One of the authors of these research papers has stated that the dual systems theory can guide research that forms long-term behavior based on breaking and forming habits. This suggests that the dual systems theory may be a useful framework for designing interventions that help individuals develop better habits around their use of ICTs (Lyngs et al. 1-2).

To further clarify the concept of the expected value of control, it is the prediction of the success probability of a self-regulatory action. This is essential in digital self-control tools as it helps users understand the potential benefits of their self-regulatory actions. A higher expected value of control can increase users' motivation to exert self-control in the moment, even if it requires effort or sacrifice. Moreover, design interventions that increase the expected value of control can be effective in helping users sustain their self-control in the long term.

It is also important to consider the context in which self-control is exerted. The emotional state and fatigue level of a user can significantly impact their self-control abilities. Negative emotions can reduce self-control, leading to more impulsive behavior and a higher likelihood of succumbing to distractions. Thus, digital self-control tools should not only focus on enhancing users' cognitive abilities but also consider emotional regulation techniques.

Furthermore, the design of apps and other digital technologies can be a significant factor in users' struggles with self-control. With numerous features accessible at all times, users may find it challenging to resist the temptation of using these apps continuously. Therefore, digital self-control tools should aim to limit distractions and make it easier for users to focus on their goals. This could be achieved through app blocking features or by removing irrelevant notifications.

Overall, a better understanding of dual systems and the expected value of control can aid in the development of effective digital self-control tools. By considering the contextual factors affecting self-control and designing interventions that increase the expected value of control, designers can help users sustain their self-control over time. (Lyngs et al. 3-4)

To further extend the analysis of self-control interventions and their relation to the dual systems model, it is important to note that the blocking or removal of distractions feature can be helpful for both System 1 and System 2 levels of control. This feature helps to limit the automatic response of System 1 by removing the environmental stimuli that trigger the user's attention towards non-work-related activities. By blocking access to social media apps or other non-essential websites during work hours, System 2 can focus on the long-term goals that have been set.

In addition, self-tracking time spent on tasks can be helpful for both levels of control as well. This feature provides System 2 with a tool to monitor and control its progress towards long-term goals. It can also help to manage the limited working memory resources of System 2 by allowing users to set specific time limits for tasks, which in turn helps to minimize the cognitive load on working memory.

Furthermore, the goal advancement feature can be used to enhance the conscious goal setting and planning abilities of System 2. Reminders for important tasks or deadlines can help users stay on track and maintain focus on their goals. This feature can also help to activate System 1 in a positive way by providing a sense of achievement and satisfaction when goals are completed.

Lastly, the reward/punishment feature can be useful in activating System 1's desire for immediate gratification. Gamifying interventions can provide a sense of enjoyment and accomplishment for the user, which can lead to an increase in motivation and focus on tasks. By incorporating this feature, self-control interventions can be designed to help balance the automatic response of System 1 with the more deliberate and intentional actions of System 2. (Lyngs et al. 7-8).

2.6. Does breaking up prolonged sitting improve cognitive functions in sedentary adults? A mapping review and hypothesis formulation on the potential physiological mechanisms

Studies have shown that sedentary behavior at work can have negative impacts on various aspects of health, including cardiovascular and metabolic health, as well as mental health. Additionally, prolonged sitting can negatively affect cognitive performance, such as memory and attention, which can have implications for job performance. To combat these negative effects, research has demonstrated the importance of breaking up prolonged sitting by incorporating standing and light-intensity exercises into daily work routines. For example, some studies have suggested taking short walking breaks or doing simple exercises, like leg lifts or squats, every 30 minutes to reduce health risks associated with prolonged sitting (Chandrasekaran 1-2, 13). By incorporating these simple activities into the workday, individuals can potentially improve their physical and cognitive health, which may lead to better job performance and overall well-being.

2.7. Imagining, Studying and Realising A Less Harmful App Ecosystem Summary

The use of browser anti-distraction interventions in mobile apps has been explored by several researchers. One approach that has been investigated involves modifying existing apps to add extensions, similar to browser extensions. This approach was taken by Kolnig et al. (1-3, 6), who developed an extension app that extracts another app and modifies it to add extensions. While it is not always possible to use the same functionalities as browser extensions, due to limitations in the mobile app ecosystem, some apps such as Lucky Patcher and GreaseDroid have attempted to implement similar ideas.

Browser extensions have been found to improve the user experience in various ways. For example, they can remove malware from websites, make browsing easier for people with disabilities, and help prevent the use of dark patterns. However, the same functionalities cannot always be replicated in mobile apps due to the limitations of the platform. To address this issue, Kolnig et al. developed an extension app that modifies existing apps to add extensions. By doing so, they were able to implement anti-distraction interventions in mobile apps and improve the user experience.

Researchers have explored various approaches to implementing anti-distraction interventions in mobile apps. While the limitations of the mobile app ecosystem can make it challenging to replicate the functionalities of browser extensions, extension apps and other approaches have shown promise in improving the user experience and reducing app harms.

2.8. ECG-Based Concentration Recognition With Multi-Task Regression Summary

Recent advancements in wearable sensors and smartphones have enabled researchers to accurately measure and recognize human activities and mental states. One particular application of this technology is the prediction of a person's level of concentration. While alpha rhythm around the occipital lobe is traditionally used to measure concentration, the study by Kaji et al. (2018) focused on using the Fm theta rhythm, which represents the frontal lobe activity and correlates with cardiac autonomic activities.

The research by Kaji et al. faced the challenge of variability among test subjects. To address this challenge, they employed a multitask learning (MTL) method that allowed them to simultaneously predict the degree of concentration for multiple subjects. This approach resulted in a high prediction rate for a person's concentration level.
In addition to the work by Kaji et al., other researchers have also explored the use of wearable sensors and smartphones for measuring and predicting mental states. For example, a study by Park et al. (2018) used heart rate variability (HRV) to predict stress levels. Their results showed that HRV-based stress prediction was accurate and reliable, suggesting that this approach could be used in practical settings.

Overall, the use of wearable sensors and smartphones has opened up new possibilities for accurately measuring and predicting mental states such as concentration and stress levels. While challenges such as subject variability need to be addressed, the development of new techniques such as MTL and HRV-based prediction holds promise for advancing this field.

2.9. A Context-Aware IoT-Based Smart Wearable Health Monitoring System Summary

Advances in wearable technology have led to the development of low-cost, high-quality multipurpose smart devices that can monitor and track athletes' heart health and fitness. Kassem et al. (2020) developed such a device using a Raspberry Pi and an open-source microcontroller, along with a HealthyPi hat to connect biomedical sensors such as temperature, ECG, pulse, and oximetry. This device enables continuous monitoring of an athlete's health status, with the data being transmitted via the MQTT protocol to an IoT dashboard where it can be accessed by a physician or other healthcare provider.

The proposed method for measuring an athlete's health status involves using the ECG sensor to collect heart rate data, the temperature sensor to collect temperature readings, and the SPO2 sensor to collect oxygen levels and respiratory rate. The Raspberry Pi then transmits this data to the selected IoT dashboard via the MQTT protocol. The output data generated can then be used to further evaluate and identify the patient/athlete's physical and health states.

In addition to the work by Kassem et al., other researchers have also explored the use of wearable technology for monitoring athletes' health and fitness. For example, a study by O'Reilly et al. (2018) used a wearable device to monitor physiological responses to exercise in a group of professional soccer players. The results showed that the wearable device was able to accurately measure heart rate, skin temperature, and activity levels, demonstrating its potential as a tool for monitoring athlete health and performance.

Overall, the development of low-cost, high-quality multipurpose wearable smart devices holds great promise for monitoring and tracking athletes' health and fitness. While challenges such as data management and analysis need to be addressed, the use of such devices has the potential to significantly improve our understanding of athlete health and performance.

2.10. Frequency-based EEG Human Concentration Detection System Methods with SVM Classification

The article describes a system for detecting human concentration by observing the electroencephalography (EEG) signals generated by the human brain using a non-invasive brain-computer interface (BCI) device. Two frequency-based feature extraction methods, power spectral density (PSD) from Fast Fourier Transform (FFT) and energy from Discrete Wavelet Transform (DWT), were used and compared, with DWT found to be better and more accurate, showing an 18% improvement in accuracy compared to the system with FFT. The system employed an RBF kernel support vector machine (SVM) classifier, which demonstrated a 91% accuracy in recognizing human concentration, with the best parameter settings for $C=1$ and $\gamma=0.1$. The system has potential applications for detecting a driver's concentration level or a student's concentration during cognitive activities (Dewi et al. 32-33).

The paper provides theoretical background information on EEG, its uses in medical industries, and BCI devices. EEGs are used to monitor patients with epilepsy and other brain-related diseases, while BCI devices are consumer-based devices used to obtain brain signals from humans for a wider range of applications. EEG signals can be differentiated by the frequency band, and two human conditions related to concentration are detected: full-concentration mode and distracted attention/less-concentration mode. Various methods for EEG-based systems are discussed, including Event-Related Potentials (ERP), Wavelet Transformation, Autoregressive, Fourier Transformation, and Neural Network (Dewi et al. 29-30).

The article also presents a methodology section that discusses the EEG used, the Neurosky Mindwave BCI device, the FFT and DWT algorithms, and the SVM classifier used in the study. The experiment and its results are discussed in detail, with DWT found to be more effective in recognizing the degree of human attention based on EEG signals. The article concludes by suggesting that the system has potential applications in detecting concentration levels for drivers and students during cognitive activities (Dewi et al. 29-30).

2.11. Raspberry PI Shield - for measure EEG (PIEEG)

The paper discusses the development of a shield for Raspberry Pi called PIEEG that can be used to measure EEG signals from the brain. EEG signals are commonly used in neuroscience research and clinical applications. The cost of commercial EEG devices is high, and the authors propose a Raspberry Pi-based device for reading EEG signals that is lower in cost. The proposed device was tested and shown to successfully resist the effect of electromagnetic interference, detect the alpha brain wave, and detect the P300 paradigm. The paper provides details on the components of the device, the experimental setup, and the results of the testing (Rakhmatuiln et al. 410-411).

The paper notes that advances in artificial intelligence have allowed for practical uses of electroencephalogram signals in various fields of engineering. The paper also provides general information about electroencephalography, including different types of sensors that can be used to record brain signals, such as wet versus dry electrodes. The authors choose dry electrodes as one of the easiest ways to measure EEG due to the lack of a need to apply gel. However, high contact resistance due to the insufficient electrical connection at the electrode-scalp interface can be a significant problem for the measurement process. The cost of commercial EEG signal recording devices is often high, making it difficult for researchers to use them, although the cost does not necessarily correlate with manufacturing difficulty. Thus, there is an increasing interest in low-cost devices for recording EEG signals (Rakhmatuiln et al. 410-411).

The authors note that invasive methods for measuring bio signals, such as microelectrode arrays implanted directly into the brain, are not convenient, expensive, dangerous, and require a highly qualified person and special equipment. Low-cost devices for recording EEG signals receive more attention in this field. The most popular low-cost BCI manufacturer is OpenBCI, whose devices have a price range within a thousand dollars. However, a few authors have pointed out the shortcomings of OpenBCI devices, including instability in EEG signals. The PIEEG aims to provide a low-cost, high-accuracy device for recording EEG signals by using Raspberry Pi as the microcontroller and avoiding the need for expensive data transmission adapters (Rakhmatuiln et al. 411-412).

3. Explanation of current methodology and goals

3.1. Plans

My thoughts behind the development of this device were on creating some technology that transmits vibrations to a person when they have ceased focusing on a task such as reading. The proposed device aims to improve users' concentration by utilizing various techniques known to enhance focus. For instance, studies have shown that regular breaks can improve productivity and prevent mental exhaustion (Wickersham, 2016). Therefore, the device would incorporate timed vibration alerts to prompt the user to take breaks when necessary. In addition, ambient noise has been found to have a significant impact on an individual's focus and performance (Cantor et al., 2019). To this end, the device would include a noise-canceling feature that minimizes distracting sounds and promotes a calm environment.

Moreover, studies have demonstrated that physical exercise and movement can improve concentration and cognitive performance (Basso & Suzuki, 2017). Hence, the device would be designed to promote physical activity by vibrating more intensely during periods of prolonged inactivity. This feature aims to encourage the user to move around, stretch, or take a short walk to promote blood flow and refresh the mind.

The device's form factor aims to minimize user discomfort and distractions. It would be designed as a small, lightweight pad that would not impede the user's daily activities, and its vibration alerts would be discreet and subtle. The device's vibration motor placement on a location like a shoulder so that it would also make it easily accessible to the user's head.

The device aims to enhance users' concentration by incorporating various techniques and features, such as timed vibration alerts, noise-canceling, and physical activity promotion, while minimizing user discomfort and distractions. While this device serves as a prototype for further exploration, it has the potential to pave the way for the development of more advanced and effective concentration-enhancing devices.

The device also aims to enhance user productivity by reducing distractions and keeping the user aware of their focus level. The smartphone interface allows for a more seamless integration with the user's daily routine and reduces the cognitive load associated with managing multiple devices. One potential use case for the device is to help users stay focused during work hours by blocking unnecessary apps or notifications. For example, the device could block social media apps during designated work hours to minimize distractions and help the user stay on task. Additionally, the device could schedule tasks and reminders to help the user manage their time effectively and reduce the cognitive load associated with keeping track of tasks and deadlines.

Another feature of the device is its ability to predict when a user has become distracted. This could be achieved by analyzing various user inputs, such as app usage and touch patterns, and detecting when the user's attention has shifted. Once a distraction is detected, the device could send a vibration alert to the user to remind them to refocus on their task. Furthermore, the device could also provide suggestions to the user on how to regain focus, such as taking a short break or practicing a mindfulness exercise.

The proposed device aims to enhance user productivity by utilizing a smartphone interface to reduce distractions and keep the user aware of their focus level. The device could achieve this through app and notification blocking, scheduling tasks and reminders, detecting distractions, and providing personalized suggestions. While the prototype device is a stepping stone for further development, it has the potential to revolutionize how we manage our daily tasks and improve our overall productivity.

In addition to utilizing a smartphone interface, the proposed device also aims to incorporate EEG data to further enhance its ability to monitor the user's concentration level. The use of EEG technology will allow for a more accurate measurement of the user's alpha and beta waves, which can be used to determine their level of concentration on a given task. By measuring the alpha and beta waves and comparing them to a baseline value, the device can determine when the user has lost concentration and provide a vibration alert to help them refocus.

However, one challenge with EEG technology is the potential for the readings to be affected by other brain electrical variations, which can result in inaccurate readings. To address this challenge, the device will be designed to work with tasks that have relatively low variability, such as reading or studying. This will help to ensure that the readings are as accurate as possible and that the device can provide meaningful alerts to the user when they lose focus.

To implement the EEG functionality, a Raspberry Pi will be used in combination with other materials to measure and analyze the data. The Raspberry Pi will also include a vibration sensor, which will work in conjunction with the EEG readings to alert the user when they should try to regain focus. The vibration sensor will be designed to be non-intrusive, providing gentle reminders without disturbing the user's workflow.

Overall, the inclusion of EEG technology and a vibration sensor will greatly enhance the device's ability to monitor and improve the user's concentration level. By incorporating both the smartphone interface and EEG data, the device will be able to provide a comprehensive solution for reducing distractions and enhancing productivity.

3.2. Raspberry PI Setup

One of the primary goals of this project is to establish a reliable communication link between the Raspberry Pi 4B, the Android phone, and the various sensors used in the device. To achieve this, the first step was to ensure that the Raspberry Pi was set up and functioning properly. This involved connecting the Raspberry Pi to a monitor using an HDMI cable and attaching a keyboard and mouse to control the device. You can also use VNC Viewer to connect to the Raspberry Pi through a phone or computer, which requires the Raspberry Pi username and password. For example the default username and password for my Raspberry Pi is “pi” and “raspberry” respectively.

After completing the hardware/connection setup, several command line instructions were typed in to set up the Raspberry Pi and ensure that it had essential functionalities, such as a Wi-Fi connection. Establishing a stable Wi-Fi connection was particularly important, as it allowed the Raspberry Pi to communicate with the Android phone and other devices without relying on a physical connection. My Raspberry Pi would not connect to the Wi-Fi so after surfing the web I figured out that you can edit the “ /etc/wpa_supplicant/wpa_supplicant.conf” file to add a connection.

Once the Raspberry Pi was set up and connected to the Wi-Fi network, the next step was to integrate the various sensors into the device. This involved programming the Raspberry Pi to read data from the sensors and transmit it to the Android phone for processing and analysis.

To facilitate communication between the Raspberry Pi and the Android phone, a dedicated app was developed. This app served as the interface between the user and the device, allowing them to monitor their concentration level and adjust the device settings as needed.

Overall, the process of setting up the Raspberry Pi and establishing communication between the various components of the device was a critical step in achieving the goals of the project. By ensuring that the hardware and software components were functioning properly, I am able to create a reliable and effective device for improving concentration and reducing distractions.

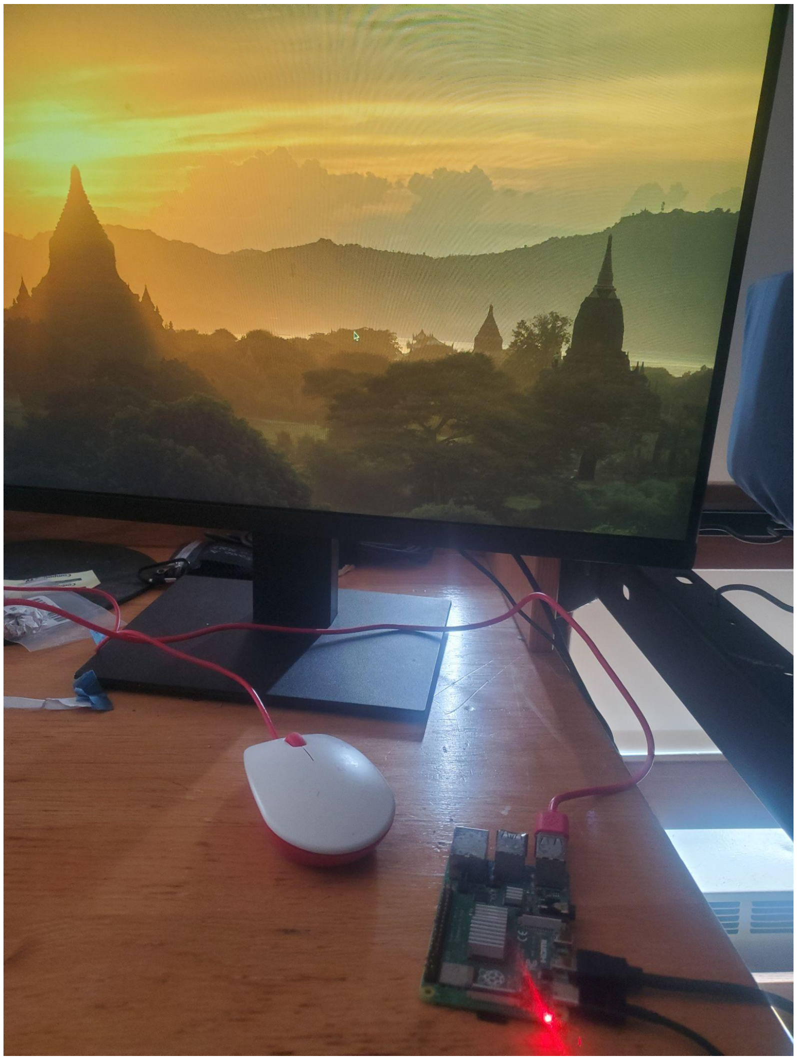

Figure 1. Raspberry Pi Setup (Source: Wilson Neira, 2023).

3.3. Alerting Sensor

The next step is to decide which sensor to use as a user alerting system. I had several options, such as active or passive buzzers. I tested each buzzer to see how they worked, each made sounds but did not vibrate or shake. I then decided not to choose either sensor since both sensors are easily listened to by a surrounding person and the buzzing sound would likely annoy the person. After failing to choose a buzzer I decided to go with a vibration sensor since it makes it possible for only the user to notice. The vibration motor would be placed on the user and make contact with the skin through a pad. I then proceeded to learn about the vibration sensor and read a short tutorial on how to run it on the Raspberry PI. I then tested the sensor by coding some Python programs to run on the Raspberry PI. These Python programs would make the sensor vibrate and then stop, working similarly to turning off and on an LED.

To further enhance the vibration sensor, I decided to experiment with different vibration strengths. I wanted to create a distinct vibration pattern that would help the user differentiate between a regular notification and the user alerting system. After some research, I discovered that certain vibration patterns are more recognizable to the human body than others. I programmed the vibration motor to be set as high as possible using different Raspberry Pi GPIO inputs and durations of vibration. I did not go with the highest vibration since it actually overheats my vibration motor making its wire connections melt and then completely disconnect.

In addition to programming the vibration sensor, I also started to explore ways to integrate the sensor with the mobile application. I experimented with using Bluetooth to connect the Raspberry PI to the phone, allowing the application to send commands to the vibration sensor. This would enable the user to customize the vibration pattern or turn off the user alerting system altogether if desired. However, I had technical difficulties attempting this as it required libraries and programs that were not working with my Raspberry Pi 4B. Which is when I decided to go with MQTT as the standard message protocol due to its more available documentation and tutorials.

Overall, the use of a vibration sensor as a user alerting system has proved to be a promising solution. With the vibration motor and integration with the mobile application, it can effectively alert the user without causing unnecessary distraction to others in their surroundings.

3.4. MQTT

In the process of developing a mobile application for this thesis, I installed Android Studio, a widely-used Integrated Development Environment (IDE) for mobile app development. A crucial aspect of the project was the data transfer between the mobile phone and a Raspberry PI, which is responsible for signaling when the vibration motor turns on. This alert is designed to notify the user that their concentration has lapsed. To facilitate this phone-Raspberry PI connection, I employed the Message Queuing Telemetry Transport (MQTT) protocol, a broker that enables devices to publish or subscribe to data through a client/server connection.

The choice of MQTT as the data transfer mechanism was motivated by its lightweight nature, specifically tailored for Internet of Things (IoT) devices. Its publish/subscribe messaging model promotes efficient and reliable data transfer between devices, making it ideal for our use case. With MQTT, data can be rapidly and effortlessly transmitted from the phone to the Raspberry PI, eliminating the need for intricate communication protocols.

Another factor that contributed to the selection of MQTT was the abundance of available learning resources. This proved invaluable for the project, as it allowed me to promptly grasp the protocol and integrate it into my application. The Eclipse Paho MQTT client, for instance, offers a wealth of resources such as documentation, tutorials, and sample code, which expedite the learning process for developers.

Furthermore, the decision to adopt MQTT was influenced by its compatibility with both the mobile app and Raspberry PI during the testing phase. By leveraging MQTT, I was able to develop a robust and effective data transfer system that facilitated seamless data transmission between the phone and Raspberry PI, ensuring that the vibration motor was activated at the appropriate time.

To configure the MQTT Android subscriber/publisher, I relied on a tutorial from wildanmsyah, which provided in-depth insights into the functioning of the broker. I meticulously followed the instructions, incorporating the necessary dependencies, repositories, and permissions, albeit with slight modifications due to Android Studio updates.

I also registered a new account with MQTT Cloud, selecting a Humble Hedgehog instance as my data broker. Subsequently, I integrated the MQTT template code supplied by wildanmsyah into my project, modifying the serverUri, username, and password with information from my CloudMQTT broker, which was accessible in the details section of the CloudMQTT website.

Upon running the app, I encountered errors arising from the incompatibility between the API level 33 utilized in Android Studio and the current MQTT version. To resolve this issue, I opted for API level 29, which enabled the app to display messages on the android simulation screen via the CloudMQTT broker. Additionally, I discovered that I could verify the proper connection of my device to the server by examining the MQTT Cloud Log and Connections sections. To further identify potential errors, I sent messages through the Websocket UI and monitored whether the value in my application changed accordingly.

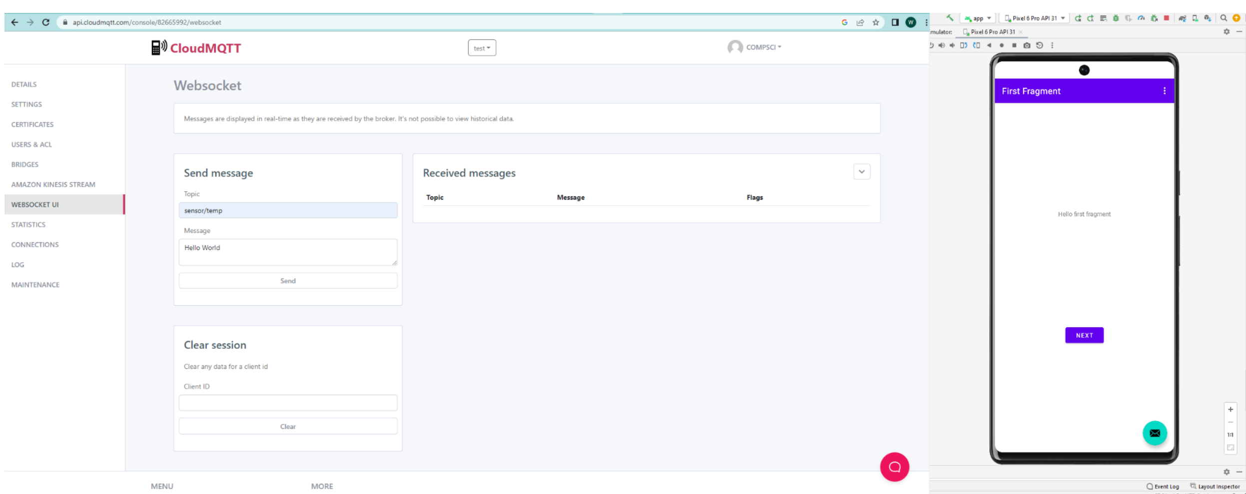

Figure 2. Before sending a broker message (Source: Wilson Neira, 2023).

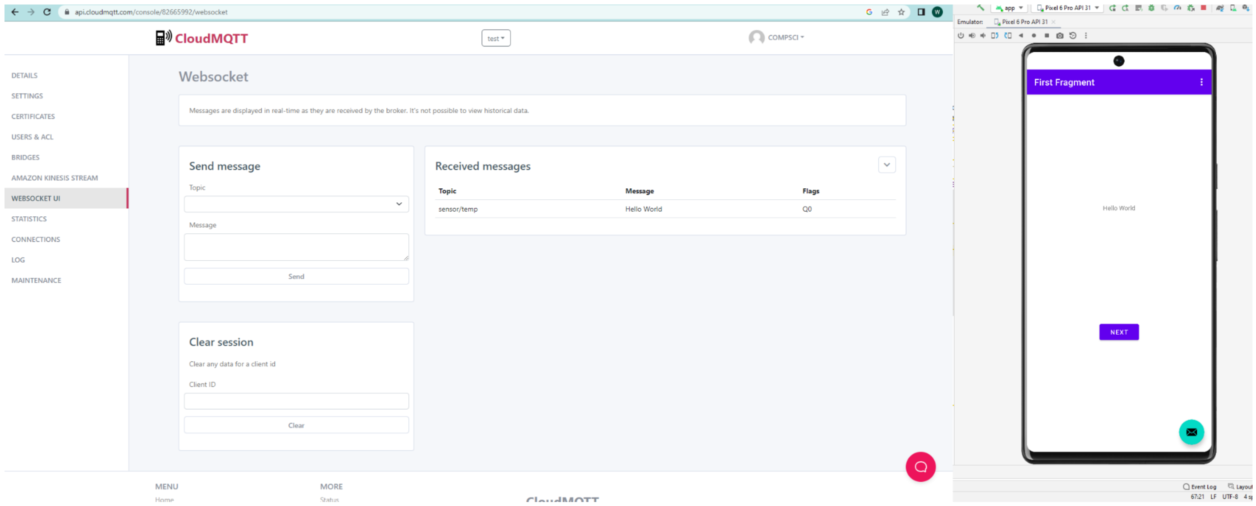

Figure 3. After sending a broker message (Source: Wilson Neira, 2023).

Upon successfully connecting the Android app to the MQTT broker, the next step was to establish a connection between the Raspberry Pi and the same broker. This connection was essential in order to receive data regarding a user's loss of concentration, which would subsequently trigger the vibration motor to alert them. To accomplish this, I followed a guide presented by YouTuber Rahul Jadhav, which detailed the process of linking the Raspberry Pi to the broker. Next, I modified the Python code to include my CloudMQTT broker server, port, username, and password. To control the sensor through the broker, I had to adapt the code, which compared the byte object msg.payload to the string "on" for activating the sensor. I achieved this by decoding the byte to a string using the ".decode('UTF-8')" method.

To address compatibility issues between MQTT and newer phone versions, I incorporated a library from "hannesa2" (available on GitHub) in addition to the "paho" library. The "hannesa2" library was designed to rectify compatibility issues with later API levels for MQTT 3. The original MQTT 3 library had not been updated to support newer API levels due to the development of MQTT 5. However, the newer version lacked the abundance of learning resources available for its predecessor. By implementing the "hannesa2" library, my device became compatible with Android phones using API level 33 and above, ensuring a broader range of functionality.

3.5. App Colors

For my mobile app design I decided on five best user interface colors for concentration and the reasons why they are effective based on past research:

- Blue is a calming color that has been shown to improve focus and productivity. It is associated with peace, tranquility, and serenity, making it an ideal color for creating a relaxing environment. According to a study published in the journal Color Research and

Application, blue can help reduce stress and improve cognitive performance (Lichtenfeld, Elliot, Maier, & Pekrun, 2012).

- Green is another calming color that is associated with nature, growth, and harmony. It has been shown to improve concentration and reduce eye strain. A study published in the journal Human Factors found that green backgrounds improved reading performance and reduced eye strain compared to other colors (Kumar & Srinivasan, 2013).

- Gray is a neutral color that can create a calming and soothing effect. It can be used to create contrast with other colors in the UI design, making important elements stand out. A study published in the journal Ergonomics found that gray backgrounds improved reading speed and accuracy compared to white backgrounds (Miyake & Friedman, 1998).

- White is a clean and simple color that can help reduce visual clutter and promote a sense of focus. It can also be used to create a sense of spaciousness in the UI design. A study published in the journal Ergonomics found that white backgrounds improved reading speed and accuracy compared to black backgrounds (Miyake & Friedman, 1998).

- Purple is a color that is associated with creativity, imagination, and inspiration. It has been shown to stimulate the brain and enhance problem-solving skills. According to a study published in the journal Color Research and Application, purple can promote innovation and creative thinking (Hemphill, 1996).

The chosen colors from this list I implemented for my device were a personal choice for what I believed looked best. I went for light blue for my buttons, light green for the status bar, and light gray for the background.

3.6. Java Mobile App

My next steps were to build the phone interface which I started by using Android Studio to implement a button that will block or unblock applications and notifications by implementing lock task mode. How I planned on using this feature is that a person will put a certain amount of time for which they want to concentrate on a task. Once the timer is running all applications and notifications are blocked and any attempt to open an application or exit the app will result in a vibration to the user reminding you that you should be concentrating.

For features such as blocking other apps I had to implement lock task mode where I first had to read some android documentation to gain a better understanding of the Android Studio Java code. I then proceeded to implement the practice code from the lock task mode documentation but the required function onActivityResult() had been recently deprecated and replaced by another. I attempted to implement the new function but there was little documentation about it, and when I tried running the program, I would get some device owner permission errors.

I then proceeded to look for a fix and possibly alternatives. That is where I noticed that I can override the back button, so that the user cannot exit the app while they are doing a task. Although that override could be useful for my project, it did not allow me to block the home button. Other overrides that I found about were to override the notifications and other features. I believe these customizable options could be useful for other mobile app developers, but for my app it was not what I was looking for at the moment.

Therefore, after reading over stackoverflow and some more documentation, I found a fix for the lock task mode function. One thing that I had noticed is that I had not implemented a controller class needed for the device administration receiver. The controller class targeting Android 8.1 (API level 27) or earlier, you will need device owner privileges for lock task mode. In that scenario, you might need a controller class that extends DeviceAdminReceiver to implement custom logic for handling device administration-related events. For Android 9 (API level 28) and later, you can use lock task mode without administrator privileges.

The controller class step was learned from the previous documentation in a different section than the lock task mode. This required me to add some code to the “AndroidManifest.xml” file which was related to the controller class and granting administrative permissions to the mobile application. This Java class named Controller is a part of an Android application and extends the DeviceAdminReceiver class. The DeviceAdminReceiver class is a BroadcastReceiver that serves as a base class for a device admin application, which enables enforcing policies on the device. The class has two overridden methods:

1. onEnabled: This method is called when the device administrator is enabled. In this implementation, it calls the superclass's onEnabled method, allowing the base class to handle the event.
2. onDisabled: This method is called when the device administrator is disabled. Similar to the onEnabled method, it calls the superclass's onDisabled method, allowing the base class to handle the event.

Other methods can also be used in the class. They could provide additional functionality, such as displaying Toast messages when the device admin is enabled or disabled, handling password changes, and handling a disable request.

To further implement the related administrator privilege code I worked on the class, MainActivity, which is the main activity of an Android application. To use the

DevicePolicyManager, ActivityManager, and ComponentName classes to handle the device owner privileges for the application.

To enable device owner privileges the DevicePolicyManager is instantiated with the getSystemService() method, which returns a handle to a system-level service. In this case, it returns the DevicePolicyManager for working with global device policy management. The ActivityManager is instantiated with the getSystemService() method to interact with the overall system. A ComponentName object is created with the current activity and the Controller class. This ComponentName is used to uniquely identify the device admin component.

In the onClick() method, I implemented the following actions of when the disable button is clicked, the code checks if the device admin privileges are active by calling devicePolicyManager.isAdminActive(componentName). If active, the application locks the device screen by calling startLockTask(). After a specified delay, the device screen is unlocked by calling stopLockTask().

This class does not directly enable the administrator privileges, but it does check whether the privileges are active and locks the device screen accordingly. To enable administrator privileges, the user needs to activate the device admin component in the Android settings, which will trigger the Controller class's onEnabled() method.

Although I now had a controller class, this still did not fix the problem. The final fix for using lock task mode when having technical difficulties with administrator privileges was to Override the onAttachedToWindow() function to use the startLockTask() function if it has not started already. I used a boolean “mIsLocked” to check if the app is supposed to be in lock task mode. I also had to implement the functions “stopLockTask()” and “startLockTask()” into my button code to either stop or start lock task mode.

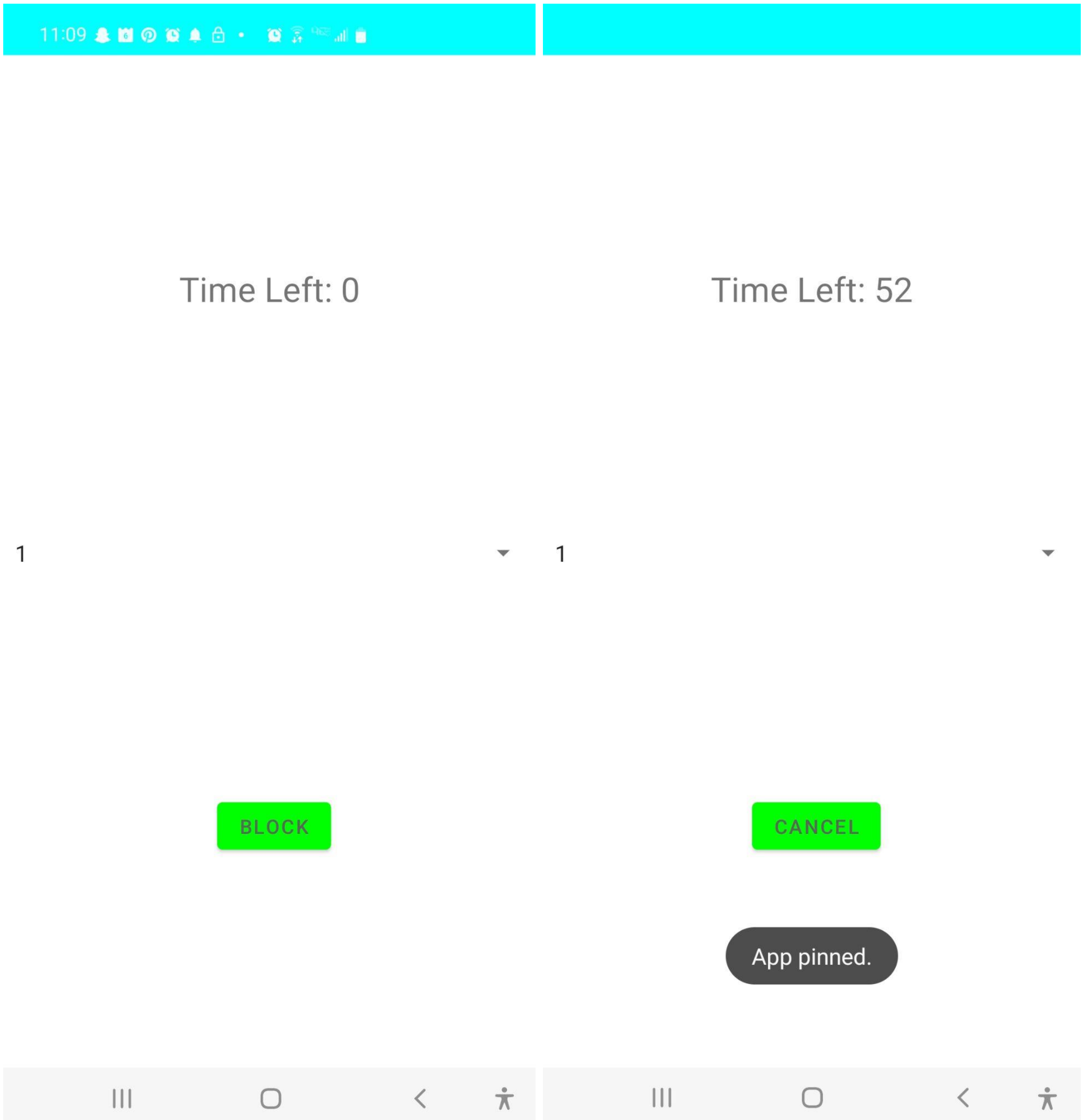

Figure 4. Mobile Android Application Lock Task Mode (Source: Wilson Neira, 2023).

Time units and a setting button were later added to the mobile application. The settings button logic is spread across the MainActivity.java and FirstFragment.java files. Here's how it is implemented:

In MainActivity.java:

The onCreateOptionsMenu(Menu menu) method inflates a menu resource file (R.menu.menu_main). This XML file should contain the definition of the settings button.

In the onOptionsItemSelected(MenuItem item) method, if the ID of the item selected is R.id.action_settings, the main activity content view is hidden, navigation to the FirstFragment is initiated, and true is returned. This is done with the following code:

```
if (id == R.id.action_settings) {
    View mainActivityContent =
findViewById(R.id.main_activity_content);
    mainActivityContent.setVisibility(View.GONE);
    Navigation.findNavController(this,
R.id.nav_host_fragment).navigate(R.id.FirstFragment);
    return true;
}
```

Figure 5. Hide main activity and go to FirstFragment code (Source: Wilson Neira, 2023).

The openSettings(View view) method essentially does the same thing: it hides the main content view and navigates to the FirstFragment. toggleNavHostFragment(boolean show) is a utility method that shows or hides the fragment containing the navigation host. showMainContent() shows the main activity content view and hides the NavHostFragment.

In FirstFragment.java:

This fragment is used to manage the settings view. In the onViewCreated(@NonNull View view, Bundle savedInstanceState) method, click listeners are set for buttons in this fragment. The 'Go Back' button has a listener that, when clicked, calls the showMainContent() method of MainActivity, showing the main content view and hiding the settings.

The 'Pomodoro' and 'Overdrive' buttons each have a listener that calls a specific method of MainActivity (startPomodoroTimer() and startOverdriveTimer(), respectively), indicating these buttons alter the settings related to changing to Pomodoro Mode or returning to the Overdrive default mode.

In summary, when the settings button is pressed, the main content of the MainActivity is hidden and the FirstFragment (which contains the settings) is shown. The FirstFragment includes buttons for changing settings and a button to go back to the main content.

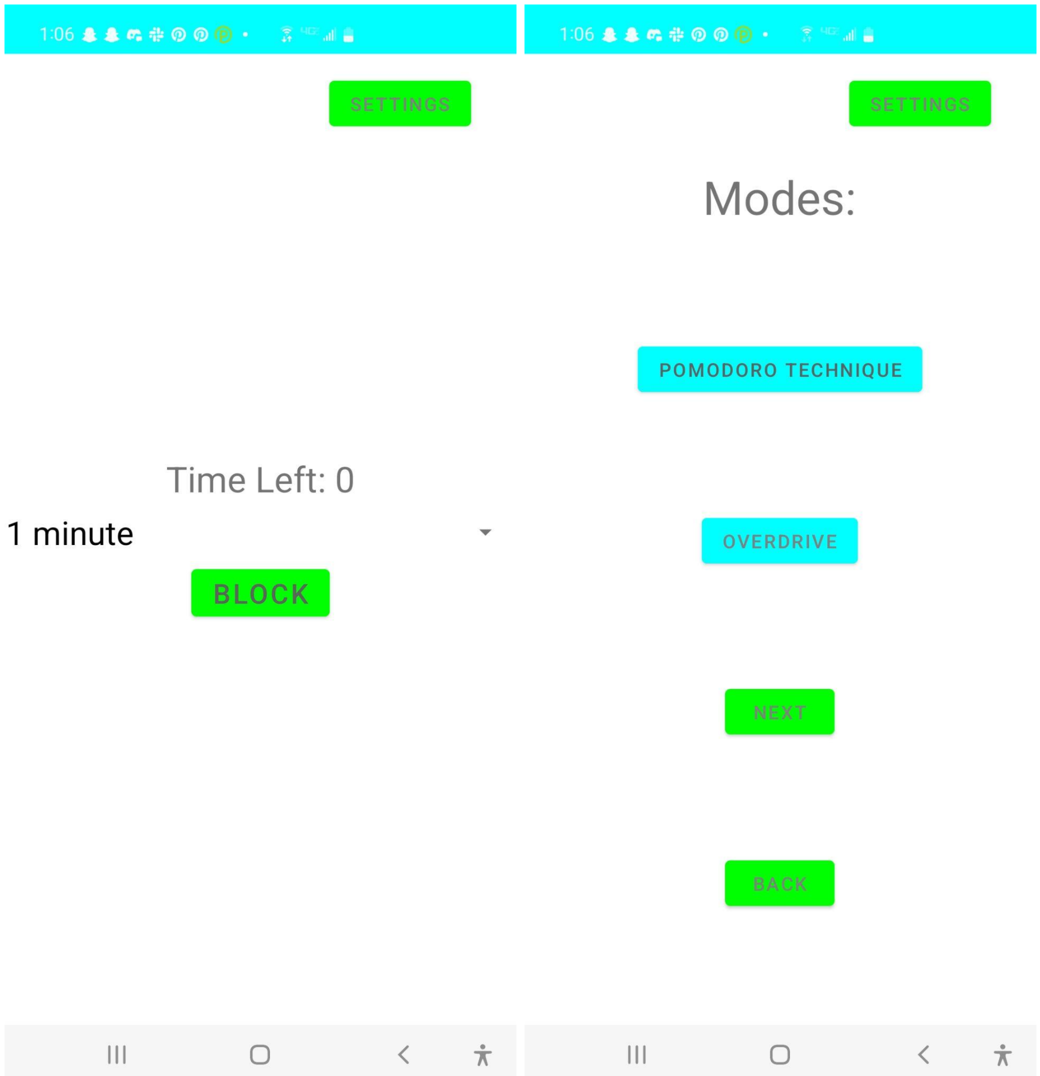

Figure 6. Mobile Android Application Mode Settings (Source: Wilson Neira, 2023).

The following code explanation defines a main activity for an Android application that controls a timer that can operate in two different modes: Pomodoro and Overdrive. Both techniques are used for time management and productivity enhancement. Let's understand these modes in detail.

Overdrive Mode:

In the overdriveImplementation() method, it starts a countdown timer when the "Disable" button is clicked. The length of the timer is set by the user's selection from a dropdown menu (durationSpinner). When the timer starts, it locks the app into a single task and starts a countdown timer. This is typically called "kiosk mode", which restricts user interaction with the device. This mode does not allow the user to leave the app until the timer has finished.

Once the timer finishes, the app is unlocked, the countdown timer is stopped, and a vibration motor is activated (by sending a message via MQTT) for 5 seconds as a signal to the user that the overdrive session has ended.

Pomodoro Mode:
In the pomodoroTechnique() method, the code creates two timers: one for the working period and one for the break period. The working period timer is set according to the user's selection from a dropdown menu, similar to the overdrive mode.

When the working period timer starts, it locks the app into a single task, similar to the overdrive mode. When the working period timer finishes, it unlocks the app and starts the break period timer. The break period timer is set to 5 seconds. This is a simplified implementation of the Pomodoro Technique for demonstration purposes, where typically the break period is 5 minutes, not 5 seconds.

Once the break period timer finishes, it re-locks the app and restarts the working period timer. Longer breaks are added after 4 pomodoros. This cycle continues until the user manually cancels the timer by clicking the "Cancel" button.

If the timer is canceled (either in overdrive mode or Pomodoro mode), it will unlock the app immediately, stop the timer, and activate the vibration motor for 5 seconds.

Also, the startPomodoroTimer() and startOverdriveTimer() methods set a boolean flag overdrive to decide which mode to use when the "Disable" button is clicked. If overdrive is true, it uses the overdrive mode, otherwise it uses the Pomodoro mode.

3.7. Why I Decided Not To Use ECG

My plans for detecting concentration aimed to go beyond just identifying when a person wants to use another device or application. I also wanted to recognize instances when a person stops working altogether or drifts into daydreaming. Initially, I considered implementing this feature using an affordable ECG module for the Raspberry Pi, called HealthyPi HAT, to obtain ECG data. Although there was some research on using ECG for detecting concentration, I soon realized that these studies were quite recent, and the authors did not provide any code or documentation on how to implement their findings.

As a result of time constraints, limited resources, and a lack of background knowledge in this area, I needed to shift my focus from obtaining electric signals to detect concentration through ECG to a more accessible method. Consequently, I decided to explore the use of EEG, given the extensive resources available for it, including comprehensive guides and working implementations. The transition to EEG provided a more feasible approach, allowing me to leverage existing knowledge and tools to achieve the goal of detecting concentration effectively and efficiently.

3.8. Raspberry Pi EEG Circuit

To create a functional Raspberry Pi EEG device, it is important to have the right guide and equipment. I found Ryan Lopez's (a now physics Ph.D. student at MIT) documentation on GitHub provides a comprehensive guide on how to build this device using a Raspberry Pi 4B and various components. The components used for this project include TDE-2143-C EEG Gold Cup Electrodes, Electrode gel, blue tape, Instrumental Amplifier AD622ANZ, Quad Operational Amplifier TL084CN, Potentiometer CT6EW102-ND, 1kOhm, Capacitors and Resistors, Two 9V batteries and battery cases, Breadboard and wires, ADC Chip ADS 1015, and a Multimeter (for testing the circuit). The documentation also suggested using something similar to Open Scope MZ to test the circuit. I did obtain this, but did not use it since it was unnecessary for my current goals.

To build the circuit I first had to make sure that I had the right resistors and capacitors. Which were 560, 27k, 3.9k, 100k, 22k, 120, 1.2k 5.6k, and 12k ohms, while the capacitors were 100 and 220 nanoFarads (nF). Then by guiding myself off Lopez's circuit diagram and picture I implemented it to its every detail. The picture on its own did not allow me to see the entire circuit so I had to self-study to have some understanding of the circuit diagram.

I did fail however a couple times to get the right circuit, like misplacing resistors or capacitors, wrongly connecting or disconnecting wires, and loosely connecting a battery wire. The last one I struggled the most with because it was the least expected, but to verify that the circuit is working you may want to double check if everything is actually connected. I also used the multimeter to check and see if the batteries had enough power.

To connect the circuit to the Raspberry Pi, it is essential to be cautious and follow the guide carefully. The green wire that connects to 3.3V should connect to a negative bus, which then connects to other wires on the breadboard and the positive and negative sides respectively of the two batteries. Care must be taken to avoid placing the ADS 1015 component in the wrong position, which can cause damage to the component or the Raspberry Pi.

It is recommended to complete the circuit first and test it before connecting it to the Raspberry Pi to avoid the risk of damaging either component. Once the circuit is complete, it is essential to connect it to the Raspberry Pi correctly. This involves connecting the ADS 1015 VDD wire to the Raspberry Pi 5V and the ADS 1015 GND wire to the Raspberry Pi GND. The ADS 1015 SDA should be connected to the Raspberry Pi GPIO 2 (SDA), and the ADS 1015 SCL should be connected to the Raspberry Pi GPIO 3 (SCL).

Building a Raspberry Pi EEG device requires following a comprehensive guide, having the right equipment, and being meticulous in implementing the circuit. It is essential to avoid making mistakes and to double-check connections to ensure that the circuit is functioning correctly. Care must be taken when connecting the circuit to the Raspberry Pi to avoid damaging either component. Following these steps can help create a functional Raspberry Pi EEG device for measuring brain activity. To complete the rest of the circuit you can guide yourself through the author's completed circuit diagram and my completed circuit from Figure 7 and 8 respectively.

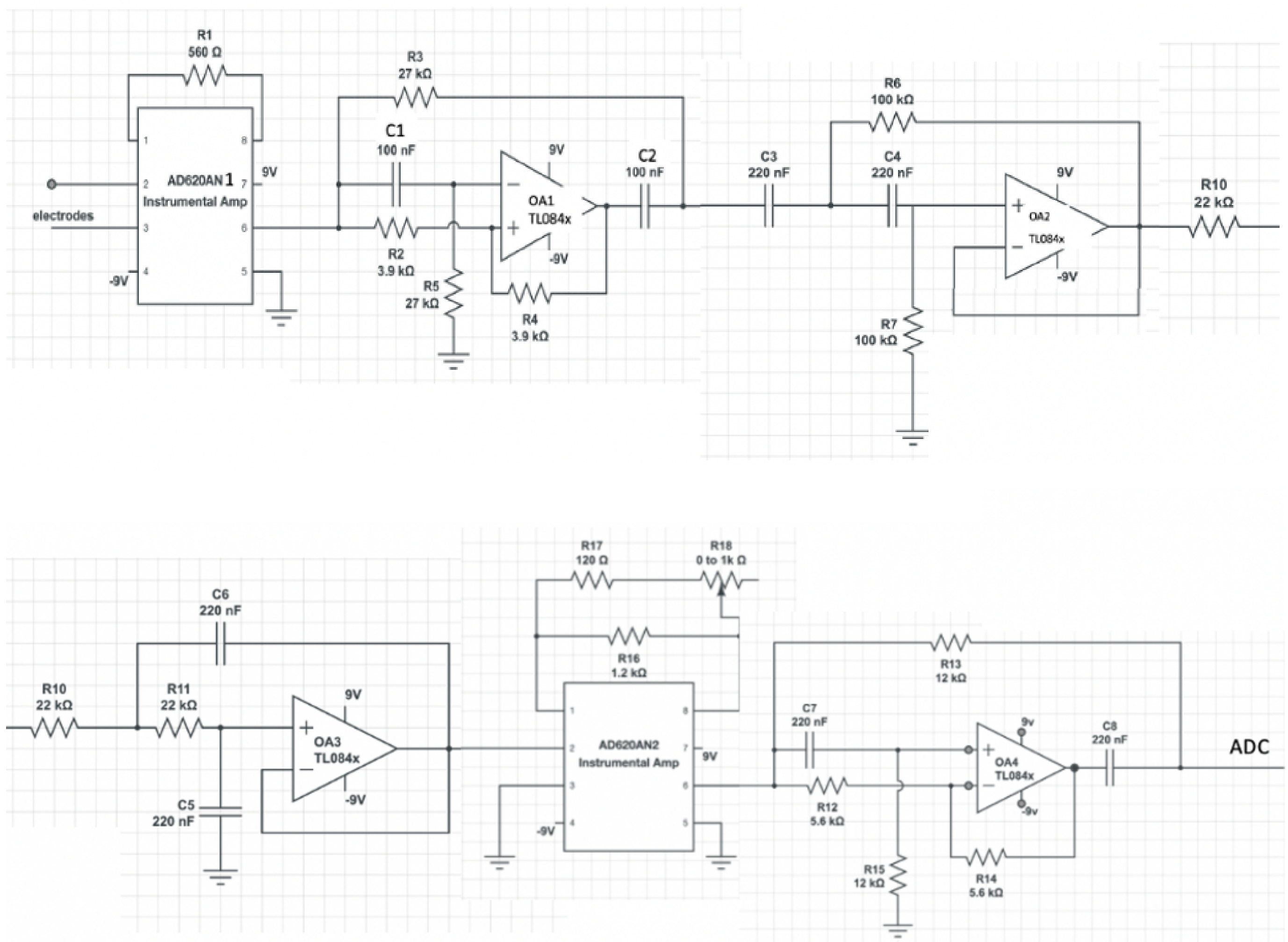

Figure 7. EEG Circuit Diagram (Source: Ryan Lopez, 2021).

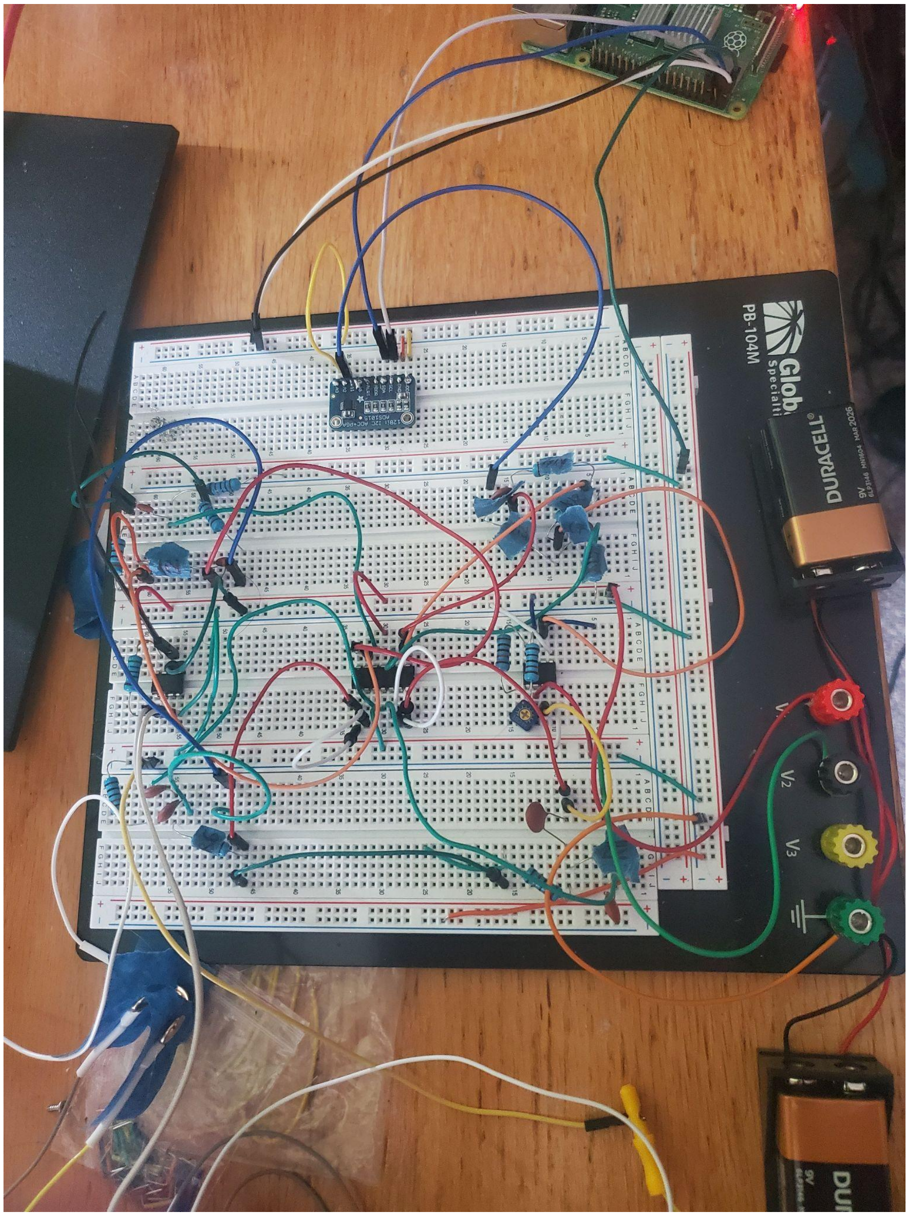

Figure 8. EEG Circuit (Source: Wilson Neira, 2023).

3.9. Raspberry Pi Python EEG Code

In order to develop the EEG code for the Raspberry Pi using Python, I opted to employ Ryan Lopez's implementation as a starting point. However, the ADC library that Ryan Lopez had utilized was no longer supported, rendering all functions associated with ADC inoperative. To resolve this issue, I first installed the updated ADC Circuit Python library as a replacement for the outdated version.

The process of adapting the original code to utilize the new library was more complex than anticipated, as there were significant changes to both function names and their operations. Consequently, I took the time to carefully study the updated library code and compared it to my existing implementation.

In an effort to streamline the process, I looked to identify the library that the student might have used, in order to gain insight into how the functions were designed to operate. This required extensive web searches, as the original library had been removed from Github when the repository was closed, leaving only the latest version accessible. Fortunately, I discovered a forum post from 2013 that contained the library with the appropriate function names. Notably, the code was written in Python 2, necessitating a conversion to Python 3.

Upon running the updated code, it did not function as expected. Nonetheless, it provided sufficient context for me to better understand the new Circuit Python library and adapt it accordingly.

The first step in updating the functions involved modifying the import line from the deprecated library to the new ADC Circuit Python library. Next, I needed to replace all instances of outdated function names and adjust the syntax to comply with Python 3 conventions. This included updating print statements, altering list comprehensions, and revising exception handling, among other changes.

Throughout the process, I maintained thorough documentation of the modifications made to the code, enabling me to track progress and troubleshoot any issues that arose. Ultimately, after considerable effort, the updated code successfully executed and interfaced with the new ADC Circuit Python library, providing a solid foundation for further development and optimization of the Raspberry Pi Python EEG code.

A further explanation of how the code works, the childattention.py script is used for monitoring a user's brain waves (specifically, alpha waves) and issuing an alert when the user's brain waves have been in a relaxed state for too long. The application of this script is to potentially help maintain a person's attention during learning sessions. This program is intended to run on a Raspberry Pi, and it reads data from an Analog Digital Converter (ADC) to analyze brainwaves.

The script utilizes several libraries, including numpy, matplotlib, and adafruit_ads1x15, among others. The program begins by importing necessary libraries and initializing the I2C bus and an ADC (Analog-to-Digital Converter) object to measure the voltage difference between two points in the circuit. The user is asked to input the session length in minutes, which is then converted to seconds. It then prompts the user for the maximum allowed rest time in seconds and the cutoff voltage, which can be manually entered or calibrated by the script.

The main part of the script runs in a loop that reads the voltage difference from the ADC, updates the time series data, computes the power spectrum of the time series data, and calculates the RMS (Root-Mean-Square) voltage for alpha waves. If the RMS voltage is greater than the cutoff value, it is assumed that the user is in a relaxed state; otherwise, the user is concentrating. If the user's last concentrate distance is more than the maximum allowed rest time, an alert is played to notify the user.

The script also features real-time plotting of the latest RMS voltage values over time, with a horizontal line indicating the relaxed cutoff. This allows the user to visually track their relaxation level throughout the session.

In addition to the main script, there is an analysis_tools.py module which provides several utility functions for working with the time series data and performing calibration. Some of these functions include:

- get_power_spectrum(): Applies a window function and Fourier transform to the time series data to obtain the power spectrum.
- get_rms_voltage(): Calculates the RMS voltage of brainwaves within a specific frequency range using Parseval's theorem.
- get_brain_wave(): Filters out the components of the time series data that are outside the specified frequency range.
- gaussian_eval(): Estimates the threshold voltage for separating relaxed and concentrated states by approximating the data sets as Gaussian distributions.
- calibration(): Collects and processes brainwave data during a calibration period.
- get_cutoff(): Prompts the user to record relaxed and concentrated states and returns the ideal cutoff RMS voltage between the two states.

The combination of these functions helps the script to analyze the user's brain waves and determine their level of relaxation or concentration, ultimately providing an alert when necessary to help maintain attention.

3.10. Raspberry Pi EEG Instructions For Usage

Using the Raspberry Pi EEG device for measuring brain activity involves some basic equipment and knowledge of electrode placement. Firstly, to get started with this device, it is essential to have electrodes, electrode gel, and tape to attach the electrodes to the scalp. It is important to note that there are various electrode placements possible, depending on what type of brain wave one intends to measure. For the purposes of the project, alpha waves were measured, which required three electrodes.

According to Ryan Lopez's documentation, the first electrode should be placed at the left mastoid, which is located at the back of the left ear. This electrode serves as the ground of the circuit and aids in noise cancellation. The second electrode should be placed one inch above and one inch to the right of the nasion, which is the midline bony depression between the eyes where the frontal and two nasal bones meet. The last electrode should be placed one inch above and one inch to the right of the inion, which is the projecting part of the occipital bone at the base of the skull. These 1st, 2nd, and 3rd electrode placements are approximately in the A1, O2, and Fp2 regions respectively as depicted in the Figure 9 diagram.

It is worth mentioning that the correct electrode placement is crucial for obtaining accurate and reliable measurements. Thus, it is advisable to follow the recommended electrode placements and ensure that they are securely attached to the scalp. Additionally, applying enough electrode gel to the electrodes helps improve conductivity, which in turn improves signal quality.

Using the Raspberry Pi EEG device requires a basic understanding of electrode placement, the right equipment, and knowledge of the type of brain waves to be measured. Following the recommended electrode placements, using enough electrode gel, and ensuring a secure attachment of electrodes to the scalp are crucial steps to obtaining accurate and reliable measurements.

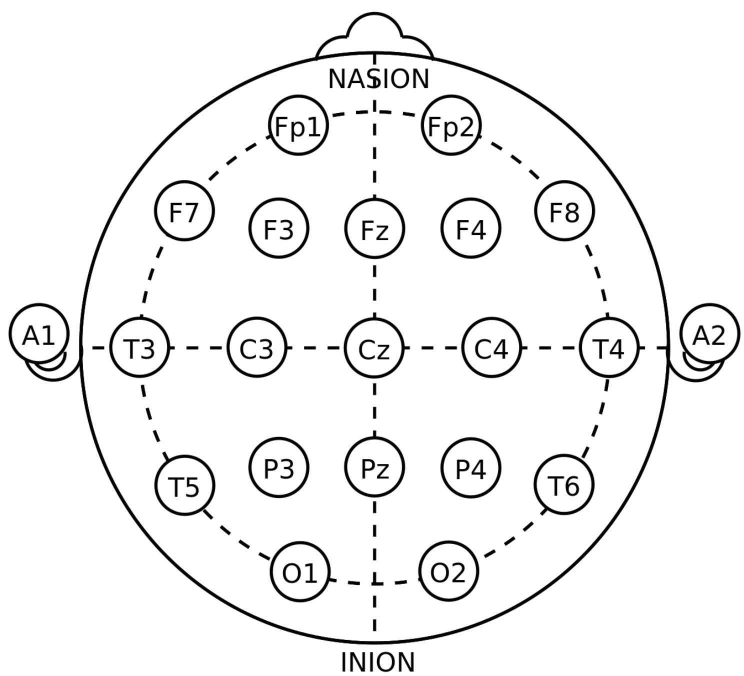

Figure 9. 21 Electrodes of International 10-20 system for EEG from Wikipedia

3.11. Alerting Sensor MQTT Mobile App Connection

After creating the base for my mobile application and its blocking feature, I wanted to connect the alerting sensor. The alerting sensor consists of a vibration motor which when turned on, vibrates somewhat similar to a phone vibration except stronger. For this to work I had to make sure that both my mobile application and raspberry pi vibration motor were connected to the MQTT cloud. For this part it was necessary to read and watch from Rahul Jadhav (a coding tutorial Youtuber) guide to implementing with python code a "MQTT Control LED Using Mobile Application with MQTT protocol On Raspberry Pi."

Rahul Jadhav's implementation of the Raspberry PI MQTT had a similar idea to mine when it came to connecting the Raspberry Pi to a mobile application. He had guided himself from several Raspberry Pi MQTT documentation from which he cited on his video. His implementation was meant to turn the LED on or off with a mobile application. With further tweaks to Rahuld Jadhav's code I made it work towards my specific needs of turning on the vibration motor when a user had stopped concentrating.

This code is a Python script for controlling a vibration motor connected to a Raspberry Pi using MQTT (Message Queuing Telemetry Transport) protocol. MQTT is a lightweight messaging protocol that provides a method for devices to communicate with each other over a network using a publish-subscribe pattern. It is often used in IoT (Internet of Things) applications to enable devices to send and receive data efficiently.

The code starts by importing necessary libraries, such as RPi.GPIO for controlling Raspberry Pi's GPIO pins, paho.mqtt.client for working with MQTT, and time for time-related functionalities. The GPIO pins are set to use the BCM numbering scheme, and warnings are disabled. The LED_PIN is assigned a value of 10, representing the GPIO pin number to which the LED is connected. The GPIO pin is then set up as an output pin.

Four callback functions are defined:

1. on_connect: This function is called when the MQTT client successfully connects to the MQTT broker. It subscribes to the "sensor/temp" topic with a QoS (Quality of Service) level of 0.

2. on_message: This function is called when a message is received from the MQTT broker. It checks the payload of the received message, and if it is '1', it turns the vibration motor on, and if it is '0', it turns the vibration motor off.

3. on_publish: This function is called when a message is successfully published by the MQTT client. It prints the message ID (mid) of the published message.

4. on_subscribe: This function is called when the MQTT client successfully subscribes to a topic. It prints the subscription message ID and the granted QoS level.

An instance of the paho.Client class is created, and the event callbacks are assigned to the MQTT client. The MQTT client is configured with the necessary username and password and connects to the MQTT broker at "driver.cloudmqtt.com" on port 18741 with a keepalive time of 60 seconds.

The script then enters a loop where it continuously calls the mqttc.loop() function, which processes the network events related to the MQTT connection. This includes receiving messages from the broker and maintaining the connection. If the connection is lost (rc == 7), the script attempts to reconnect and resubscribe to the "sensor/temp" topic.

The purpose of this code is to create an MQTT client on a Raspberry Pi that can receive messages from an MQTT broker and control a vibration motor based on the received message payloads. This can be used in IoT applications, such as remotely controlling the vibration motor based on mobile application data or user input from an EEG device.

3.12. Alerting Sensor MQTT Raspberry Pi EEG Connection

This code consists of a modification of the EEG attention monitor code to now be able to connect to the MQTT cloud by recycling my MQTT code implemented for the vibration motor. This step essentially implements some of the vibration motor MQTT code but instead of depending on a mobile application to tell it when to turn on or off, it now relies on the rest of the EEG monitor code.

Where the attention monitor will keep track of the brain band alpha from the brain and if the signal reaches above a preset threshold for an input period of time, the vibration motor turns on. The turning on of the vibration motor is done by implementing the MQTT publish code. This is placed inside the if statement concerned with checking if the alpha band has reached the threshold. As a brief reminder the alpha band is a frequency between 8 and 12 hertz, and corresponds to measuring its power when it is large it means the user lost concentration. When the alpha band has low power, or below the threshold, it means the user is concentrated on the task. So, if the alpha power stays below the threshold again, the vibration motor turns off.

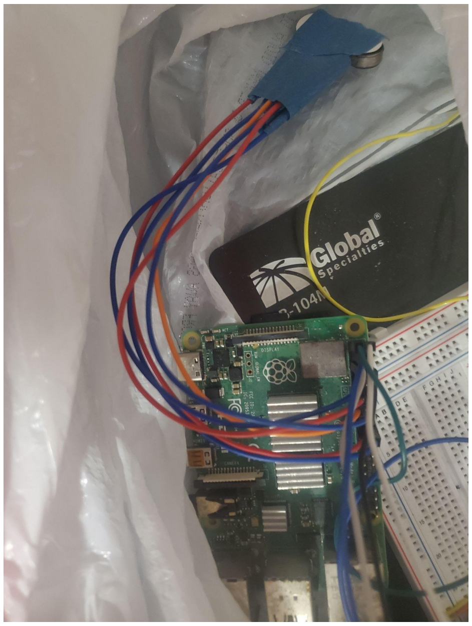

Figure 10. Raspberry Pi Vibration Motor Pad (Source: Wilson Neira, 2023).

3.13. Complete Device Prototype Instructions For Usage

After completing building the device, it is now time to put it to the test and be able to use it. To start using the device you would need to firstly have installed its mobile application. After the installation of the mobile application, you should carefully put on the homemade EEG cap. Then you should place the electrode not connected to the EEG cap on your left mastoid right behind your left ear. After the electrodes are carefully placed you should place the electrode gel inside each of the electrodes to strengthen the connection between the electric signals, your scalp, and the electrodes.

After the electrode placement you should turn on your Raspberry Pi to run the required python scripts. Once this is completed, you can now launch your mobile application. In the app you have the option to select a time in minutes and then proceed to block your access to applications and notifications by going in the phone's lock task mode. If the user attempts to leave lock task mode before the user's session has ended, the vibration motor will turn on for a few seconds.

The mobile application also has a settings button to select how you want your timer to work. By tapping in the settings button you can tap on overdrive (default) or the pomodoro technique. The pomodoro technique is known for improving work performance, and can help in reducing work fatigue. You will now return to the home screen and by selecting the time and starting the lock task mode, lock task mode will be divided by the amount required for pomodoro technique. So it will go into lock task mode and after some time, exit lock task mode. Then proceed to go back into lock task mode, and so on, until it completes the technique.

3.14. Creative Ways To Use This Device

The device is meant to be used for doing tasks while sitting down. Due to its prototype stage it is not yet that portable. So a user is restricted to a certain sedentary task, but there can still be many uses related to concentration. Some examples can be, when attempting to use the device to improve the maximum amount of time required to do an assignment, study, or read a book. The time to do these tasks can worsen if the person is vulnerable to procrastination and does not realize they have started to procrastinate.

Although I have shown one case in which this device can be used, such as in certain tasks without being distracted. There are potentially many other creative ways for which a device like this can be used to alert a person when they have stopped concentrating. One example I believe is when driving and one for some reason becomes distracted, they may benefit from a device that alerts them back to concentrating in driving. Or even in a more dangerous scenario when a soldier is at war and has not been sleeping, and still needs to remain alert in order to not perish in battle.

4. Future Research

The existing prototype has shown promising results, but there's still room for improvement. Future research should focus on refining and optimizing the hardware and software components of the device for better accuracy and usability. This might include improving the EEG cap design for better comfort and signal quality or enhancing the mobile application's user interface for a more intuitive user experience. Furthermore, the current device uses the alpha band frequency and vibration motor alerts as the basis for its operation. Future research could explore alternative or additional cognitive measures and alert mechanisms. This might involve looking at other brainwave frequencies or leveraging haptic feedback devices that could provide more nuanced alerts. The current prototype is suitable for stationary use. Future iterations could focus on making the device more portable, thus increasing its utility in a variety of settings and making it more accessible for users.

Future research should also aim to study the long-term effects of using this device on users' cognitive performance, concentration levels, and mental health. This will provide crucial insights into whether the device is beneficial for prolonged use. The device's efficacy in various real-world settings such as the workplace, classroom, or home should be investigated. This will offer valuable data about its versatility and potential for widespread adoption. It will also reveal any practical issues that might be encountered in different usage scenarios. While this device currently focuses on enhancing concentration, future research could explore its utility in other areas, such as alertness monitoring during driving or soldier watch duties, as mentioned in the text.

By incorporating machine learning algorithms, the system could potentially learn to adapt to the individual user's brain patterns, thereby providing a personalized experience. This approach could help in improving the accuracy of concentration detection and the efficacy of the alerts provided by the system. The system, as it stands, cannot differentiate between concentration spent on productive tasks versus concentration spent on potential distractions, such as YouTube or social media. This does present an inherent challenge when the purpose of the system is to facilitate productive concentration and reduce procrastination. Another potential avenue for future research could be the integration of application usage monitoring with the EEG system. By tracking which applications or websites are active when the EEG system detects a state of concentration, the system could potentially distinguish between productive and unproductive concentration states.

This could be achieved by having a list of "productive" applications or websites (such as word processors, coding software, educational platforms) and "unproductive" applications or websites (such as YouTube, social media platforms). If the EEG system detects a concentrated state and the user is using a program from the "unproductive" list, the system could then trigger an alert. To make this system more personalized, users could be allowed to customize their lists of "productive" and "unproductive" applications, accounting for the fact that what might be considered a distraction for one user could be a crucial work tool for another.

It's worth noting, however, that implementing such a feature could raise privacy concerns, as it would involve monitoring a user's application or website usage. As such, proper safeguards would need to be put in place to ensure user data is protected and used responsibly. Overall, by combining brainwave monitoring with application usage data, future iterations of the system could potentially offer a more nuanced and effective approach to promoting productive concentration and reducing procrastination. Overall, these future research directions can pave the way for substantial improvements in the Concentro Shook device and can help further its potential as a tool for cognitive enhancement.

5. Conclusions

In conclusion, this research project aimed to develop a comprehensive concentration-enhancing solution, which involved creating a smartphone application, an EEG cap, and a Raspberry Pi-powered device. The application was built using Android Studio and implemented lock task mode to block app access and notifications during focus periods. The Pomodoro technique was also integrated, offering a customizable approach to concentration training. By leveraging technology, this solution aims to assist users in maintaining focus and avoiding distractions, ultimately enhancing productivity and cognitive abilities.

The project faced challenges in implementing lock task mode, including deprecated functions and device owner permission errors. However, through research and problem-solving, the solution effectively locks the device screen and provides a responsive system to keep users on track. This research contributes to the growing field of human-computer interfaces (HCI) that focus on improving user experience and receptiveness to feedback.

Moreover, this project showcases an interdisciplinary approach, combining elements of neuroscience, electrical engineering, and software engineering research. By overcoming obstacles in hardware development, software implementation, and integrating both components, the project demonstrates the value of interdisciplinary collaboration in solving complex problems. The resulting device and mobile application have the potential to benefit individuals seeking to improve their cognitive abilities in various aspects of life, paving the way for future innovations in this rapidly evolving field.

Future research can build upon these findings by refining the prototype such as utilizing machine learning to personalize the user's experience and improve its accuracy in detecting distractions, exploring alternative approaches, and assessing the long-term effects of using such devices on cognitive performance and mental health. Studying the device's efficacy in various settings, such as the workplace, classroom, or home, will provide valuable insights into its versatility and potential for widespread adoption. Overall, the Concentro Shook prototype signifies an important step towards harnessing technology to improve concentration and enhance our cognitive capacities.

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