Worcester Polytechnic Institute
Digital WPI

Major Qualifying Projects (All Years)

Major Qualifying Projects

April 2018

Using Personality Traits and Chronotype for Personalized Feedback in a Sleep Web App

Holly Alexandra Nguyen
Worcester Polytechnic Institute

Follow this and additional works at: https://digitalcommons.wpi.edu/mqp-all

Using Personality Traits and Chronotype for Personalized Feedback in a Sleep Web App

A Major Qualifying Project
Submitted to the Faculty of
Worcester Polytechnic Institute
in partial fulfillment of the requirements for the
Degree in Bachelor of Science in
Computer Science
By

_____

Holly Nguyen

Date: April 26, 2018
Project Advisor:

_____

Professor Carolina Ruiz, Advisor

Abstract

This project addresses the issue of sleep deprivation among college students by proposing and implementing an innovative approach to personalizing the web application, *SleepHealth*. Sleep deprivation can have serious health repercussions and can be detrimental to academic success. To mitigate this issue, *SleepHealth* uses individual personality and chronotype characteristics to support personalized feedback to users about their sleep patterns. Users' personality and chronotype are assessed using questionnaires in the app, the results of which are used in personalizing the content, timing, and frequency of the app's notifications. These notifications are targeted at encouraging healthier sleep behaviors. This project accomplished full implementation of the questionnaires as well as the personalized feedback in *SleepHealth*.

Acknowledgements

This project would not have been possible without support from certain individuals and organizations. Their encouragement and feedback were instrumental in completing this project.

First, I would like to thank Worcester Polytechnic Institute and the Computer Science Department for the educational background and opportunity to complete a Major Qualifying Project (MQP). The unique project-based learning has provided hands-on experience and added valuable expertise to my skill set.

This MQP is a project that I desired to work on in part due to my experience as a Luce Scholar. I would like to thank the Luce Foundation for the opportunity to experience and work on a research project for the summer of 2016.

I would also like to acknowledge all those who are part of the Knowledge Discovery and Data Mining in Research Group. The feedback provided during our meetings to improve my presentations and implementation ideas was invaluable.

Most of all, I would like to thank Professor Ruiz for supporting my work on this project through many iterations. The mentorship through research and encouragement to further my own ideas is an experience I would not have had otherwise. I have been able to take advantage of many opportunities through Professor Ruiz's guidance, which has aided in furthering my own work to places I never knew were possible.

Table of Contents

List of Figures

List of Tables

1 Introduction

This project addresses the issue of sleep deprivation among college students by proposing and implementing an innovative approach to personalizing a sleep web application called *SleepHealth*. College students are notorious for their lack of sleep and irregular sleep patterns [1]. Although sleep may seem like a trivial and habitual activity, it actually fulfills a wide expanse of functions and is necessary for a successful, healthy life. Sleep deprivation can have serious health repercussions and can be detrimental to academic success [2]. This issue is difficult to solve in a short time period because it requires substantive shifts in behavior. However, self-awareness and creation of goals to change unhealthy sleep patterns are good steps to begin this process.

The *SleepHealth* app was initially developed by other students at WPI with basic functionality allowing users to track their wake and bed times, as well as log their activity (i.e., physical exercise) and caffeine consumption each day. To aid in encouraging the above awareness of and behavioral change in sleep patterns, our project describes a framework which extends the functionality of the existing *SleepHealth* app. This proposed structure is implemented in the enhanced app and uses personality and chronotype characteristics to support personalized feedback for users about their sleep patterns. Users' personality and chronotype are assessed using questionnaires, the results of which are used to personalize the content, timing and frequency of the app's feedback. These notifications are designed to encourage healthier sleep behaviors.

This enhancement, on the whole, aims to engage users in reviewing feedback of their own sleep patterns to promote consistent use of the app, leading to a cycle of ongoing positive behavioral change. The proposed feedback is delivered via email. These emails use individuals' personality and chronotype characteristics that are associated with specific sleep patterns as identified in previous research. For example, recent personality research has linked sleep behavior to the Five-Factor Model (FFM) of personality, which encompasses five personality traits: conscientiousness, neuroticism, extraversion, agreeableness, and openness [2]. As explained later in this paper, individuals' FFM characteristics can be used to predict the types of unhealthy sleep behavior that they are most at risk for and the types of feedback that they are most likely receptive to. Another characteristic to consider is chronotype. This describes individuals' natural inclinations toward the times when they are most alert or drowsy as well as their preferences for morning or evening activity [2]. Even a slight preference for morning or evening activity can significantly impact sleep schedules. Thus, our hypothesis is that chronotype will be an important factor to consider in developing personalized feedback to motivate healthier sleep patterns.

An app accessible via technology that students already use daily is an effective tool for behavioral change [3]. Using current, existing technology reduces the need for new learning to occur, which makes the overall process of adopting new behaviors easier. Additionally, this high level of engagement with technology will help the enhanced *SleepHealth* app to regularly encourage users to adhere to their sleep goals and promote self-awareness of their sleep patterns. A web app, as well as emails, are particularly useful because both are accessible on all types of devices and do not rely on the underlying operating system.

This project posits that personalization increases the likelihood of consistent engagement, and that college students are frequently attached to smartphones and other electronic devices. Based on this hypothesis, a framework for personalized feedback was implemented in the enhanced *Sleephealth* app to promote self-awareness and positive behavioral change. This project contributes to existing research by

being an example demonstrating a personalization approach which had the potential to expand and be applied to other areas of behavioral health.

2 Background

In this chapter, sleep health and its effects on other aspects of a person's life are discussed. How personality and chronotype are linked to sleep behavior is discussed in detail in light of previous research. Furthermore, sleep deprivation is explored as an issue that requires substantive shifts in behavior that the *SleepHealth* app can support. Competitor research about other existing sleep apps is described at the end of the chapter.

2.1 Sleep Health and Sleep Deprivation

Sleep health can be characterized by many different attributes according to current research. The first, most obvious attribute of positive sleep is total sleep time (TST) [2]. The National Sleep Foundation recommends 8-10 hours of TST per night for young adults. In a study conducted by the same organization, it was found that the recommended amount is much higher than the amount of time students actually sleep per night, which was about 6.1-7.4 hours per night [4]. Consider a college-aged student who gets 7 hours of sleep per night, which is still higher than the minimum TST found in the study. This student requires 1 extra hour of sleep per night. Therefore, in one week, the student has missed a combined amount of 7 hours of sleep. This is significant, especially when one considers the total amount of missed sleep over a time period of several weeks.

Another important characteristic that contributes to sleep health is sleep quality. This attribute is harder to quantify but is just as significant in determining whether sleep patterns of an individual are healthy or not [2]. Sleep onset latency (SOL) is the term used to describe how long it takes a person to fall asleep and is an additional indicator of sleep health [5]. Rapid Eye Movement (REM) sleep latency is similar but refers to the time it takes a person to transition from sleep onset to the REM cycle of sleep [5]. The last attribute that is imperative to sleep health is called weekend/weekday misalignment. This refers to how well an individual is able to maintain the same sleep schedule throughout the week when comparing weeknights to Friday and Saturday nights (i.e., weekend nights). For example, when an individual stays up late on weekends but goes to bed early during the week this is referred to as high weekend/weekday misalignment, which should be mitigated [3].

2.2 Consequences of Sleep Deprivation

Sleep deprivation can have serious health consequences, including higher risk for diseases, reduced cognitive function, and poor academic performance. Lack of sleep can negatively affect an individual's immune system, metabolism, inflammatory process, and cholesterol [6]. Additionally, new research has shown that sleep health is linked to a greater likelihood of developing Alzheimer's Disease (AD) and dementia as a person ages. In a study from the journal *Neurology*, a group of adults at risk for AD reported their sleep habits. Those with poorer sleep habits had a greater "AD-related pathology" [7]. Clearly, these health conditions have both short and long term effects, which highlights the significant

role that sleep plays in an individual's well-being. It also demonstrates how necessary this field of research is in mitigating negative far-reaching consequences for young adults.

Sleep deprivation can also impair memory formation, critical thinking skills [6] and sustained attention, all of which are necessary for academic success [8]. When students are unable to focus in class, much of the knowledge that is presented is not retained. Similarly, students who have trouble creating new memories or remembering curriculum are less likely to perform well on tests, quizzes, and homeworks. Finally, academic success requires critical thinking due to the demanding course curriculum in college. Without this skill, students are at a significant disadvantage because of their poor sleep schedules. All of the reasons outlined previously could contribute to a lack of academic success in one's college career. Moreover, erratic sleep patterns have been linked to reduced activation in cortical and subcortical reward-related brain regions [9]. This lack of neural activation means that risky behavior does not produce the same effect and reaction in the brain. This can lead individuals to engage in reward-seeking behavior, which can result in poor decision-making and excessive risk taking [9]. For example, some of these risks could include drowsy driving or increased alcohol use [3], [9]. Both examples have extensive consequences that involve long-term health as well as the safety of others.

2.3 Causes of Sleep Deprivation

Clearly, sleep deprivation is an issue that must be addressed. However, identifying the root cause can be difficult because there are a variety of factors which can contribute to lack of sleep. One such factor is usage of electronic devices, such as video and gaming systems, before bedtime. These devices can reduce sleep quality (e.g., contribute to difficulties falling asleep, less restful sleep, and repeated awakenings) due to light from the device suppressing melatonin levels [3]. Melatonin is the hormone that makes a person feel sleepy and drowsy, which is a signal to go to sleep at night. Suppressing melatonin means that this cycle is disrupted and falling asleep becomes more difficult [3].

Another factor is lack of exercise. The results of a three-week study of 51 adolescents demonstrated that 30 minutes of regular exercise each weekday could provide longer total sleep time (TST), shorter sleep onset latency (SOL) and higher Rapid Eye Movement (REM) sleep latency [5]. SOL and REM sleep latency indicate improved sleep quality. This study shows the relationship between sleep and exercise, as well as how it can benefit sleep health overall.

Additionally, caffeine consumption can harm the length and quality of sleep. According to a study done by Nature and Science of Sleep, 34% of 18-24 year olds consume energy drinks regularly [3] and the effects of caffeine consumption can last up to 7.5 hours after consumption [3]. Caffeine can be used to artificially reduce daytime sleepiness in order to remain awake. This may temporarily alleviate drowsiness when individuals are sleep-deprived [10], however, it does not resolve the underlying problem of needing to increase total amount of sleep in general. Results of a survey of 844 undergraduate college students found that higher consumption of energy drinks is linked to lower GPAs (Grade Point Averages) as well as lower TST [11]. Not only is caffeine detrimental to sleep health but the combination of caffeine with poor sleep habits may lead to poor academic performance.

Reducing the use of electronics, increasing the amount of exercise, stopping caffeine consumption by 5pm, and maintaining a regular sleep schedule are some effective methods to improve sleep health. However, there is often a dismissal of the need for better sleep health in the college culture, which makes it difficult to raise awareness of this issue.

2.4 Personality, Chronotype and Sleep

Individual characteristics relating to personality and chronotype are important contributors to sleep patterns. Many studies have linked sleep behavior to personality traits that are components of the Five Factor Model (FFM) [12]. These five traits are defined in the following way [13]:

- *Conscientiousness* is characterized by a tendency to be reliable, well-organized, and hardworking.
- *Neuroticism* reflects self-consciousness, insecurity, and tendency to worry.
- *Extraversion* describes behavior that is sociable, affectionate, cheerful, and assertive.
- *Agreeableness* is characterized by a tendency to be soft-hearted, sympathetic, and trusting.
- *Openness* is marked by originality, open-mindedness, and creativity.

A study published by Behavioral Sleep Medicine found that lower scores for conscientiousness are linked to irregular sleep patterns due to lower levels of self-control [1]. This finding is corroborated by a survey of 77 college freshmen that suggests a positive correlation between sleep quality and conscientiousness and a negative correlation between sleep quality and neuroticism [12]. The combination of high neuroticism and low conscientiousness is a key predictor of poor sleep [12]. These correlations between the FFM and sleep patterns is discussed further in Section 3.2.

One of the controversies behind using personality as the basis for design and implementation is that personality traits among younger adults (i.e., the college population that is being discussed in this paper) are unstable. However, a study published by PsycNet in 2012 demonstrates an opposite trend to this assumption. In this study, the authors found that four of the Big Five traits, namely openness, conscientiousness, agreeableness, and extraversion, are less stable among older populations [14].

A second type of individual characteristic that is important to sleep is chronotype, describing an individual's morning or evening preference. A morning preference means that an individual, given the choice, would rather wake up early than go to bed late. Another description of this preference is that a morningness individual has more energy in the morning. A propensity for *morningness* is associated with higher levels of conscientiousness and openness, and with lower levels of neuroticism [2]. This finding suggests that chronotype may also be an effective predictor of preference for various sleep patterns and, potentially, a useful factor in developing feedback to promote sleep health. This is discussed in more detail in Section 3.2.

2.5 Available Sleep Apps

Many mobile applications already exist to track an individual's sleep and allow the user to set a sleep duration goal. In this section multiple sleep apps are compared to *SleepHealth* to determine benefits and drawbacks of competitors.

Both Android and Apple smartphones provide built-in health apps that incorporate sleep tracking. For example, the Apple Health app allows a user to review sleep history in a graphical display organized by each day of the week. It also distinguishes the amount of time in bed compared to the amount of time asleep. This is valuable information that *SleepHealth* on its own does not capture without user input.

The *SleepBot* app tracks total sleep time and sleep debt and provides a graphical display of sleep history as well. Additionally, this app uses movement tracking and sound recordings to evaluate sleep. One of the unique aspects of this app is its ability to "hashtag sleep entries". This provides an outlet for users to discuss sleep habits and categorize them based on concepts that they may already be familiar with. *SleepBot* does not provide extensions for sleep tips that are not related to the sleep goal or the alarm

that wakes a user up. This is something that *SleepHealth* focuses on and is much more competent in accomplishing.

Another sleep-tracking app, called *Pillow*, lets users set a wake time (which contributes to their overall sleep goal) and view daily statistics, audio recordings of a user's sleep, and other factors such as eating late, on vacation, or reading a book. This app has many additional features that *SleepHealth* does not, such as mic sensitivity and methods for a user to make notes about their sleep. However, the app is not as intuitive for a user to use. The setting of a sleep goal or how to use the app is not immediately apparent. In this way, *SleepHealth* aims to separate itself from competitors by providing a simpler interface that is easier for a user to navigate. In addition, *Pillow* provides personalized feedback based on inputs to the phone (if a user enables them), but does not accomplish personalization beyond this. There are many features which *SleepHealth* could emulate, such as more intricate summaries of sleep history and a built-in alarm.

Many of the sleep apps available in the market offer sleep-tracking functions and can even record a user's restlessness during sleep, as described in some of the apps above. These functionalities are possible because the mobile apps have access to physical sensors from the smartphone, such as a microphone. This is one of the benefits that *SleepHealth* does not currently offer. However, the drawback to all of these apps is that there is very limited personalization for a user. The modifications to the *SleepHealth* app seek to assess how personality and chronotype affect sleep and how these factors can be used to make the user experience more engaging and to encourage healthier sleep behaviors.

3 Methodology and Design

The methodology for this project centered around completing the objectives listed below. These objectives mainly centered around the design and implementation of the personalized feedback, as well as the choices regarding the full stack of the web application and the back end relational database.

1. Determine how to assess a user's personality and chronotype.
2. Identify associations between personality and chronotype characteristics in relation to sleep behavior to determine a framework for the content, timing, and frequency of the personalized feedback.
3. Choose a method for delivery of the personalized feedback (i.e., desktop notifications, emails).
4. Determine how to implement delivering the personalized feedback on a continuous schedule.
5. Design the user interface to appeal to a broad demographic.
6. Set up a server to host the web application.
7. Design a relational database schema to support data persistence needs.

The objectives specified above were built upon an initial implementation of *SleepHealth* that was aimed at accomplishing some of the functional requirements below [15]. This prior version of *SleepHealth* provides functionality to:

- Record when user wakes up (i.e., user is able to self-report their wake time via a button or other app component)
- Record when user goes to sleep
- Record caffeine intake
- Record exercise per day

Our extended version of SleepHealth provides additional functionality to:

- Obtain and record personality type (according to FFM)

- Obtain and record chronotype
- Allow the user to set a sleep goal
- Track hours of sleep per night relative to the sleep goal

This chapter focuses on the approach followed to achieve each of the seven objectives and the extended functionality, as well as overall design decisions made throughout the course of the project.

3.1 Measuring Personality and Chronotype

The first objective was to determine how to assess a user's personality and chronotype and how to display this to the user. This was imperative to design in the final version of the web app because the results of measuring personality and chronotype are the foundation for the personalized feedback.

The personality assessment, called the Big Five Personality Test was conducted through an external site that provides results (i.e., scores for each factor in the FFM) free of charge and linked to the web app for user accessibility [16]. It provides a rating of low, medium or high for each of the five personality factors. Research has been conducted about the accuracy and validity of Big Five Inventories and whether they can be reliably used in research projects. Not only have many studies relied on the Big Five framework but research shows that these factors are enduring personality traits and "are found in different age, sex, race, and language groups" [17]. One such study demonstrates that even a 15-question Big Five Inventory, known as the BFI-S, is still a reliable instrument for measuring personality [16]. Therefore, the 50 question Big Five Personality Test that this research uses is a reliable and valid method to collect personality data.

The chronotype quiz was implemented directly in the web app because there was no online quiz available. The measurement used for this was the Composite Scale of Morningness (CSM) [17]. The CSM is scored on a number range with a score below 22 indicating an evening type and a score above 44 indicating a morning type. Any person who receives a score between 22 and 44 is not definitively a morning or evening type. However, any score above 22 and lower than 33 indicates a tendency towards being an evening type whereas a score above 33 but lower than 44 indicates a tendency towards being a morning type. These scores are indicated in the visual below. The CSM was tested in another study for validity based on correlating actual sleep patterns and performance with scores to determine if the CSM provided a valid measurement [18].
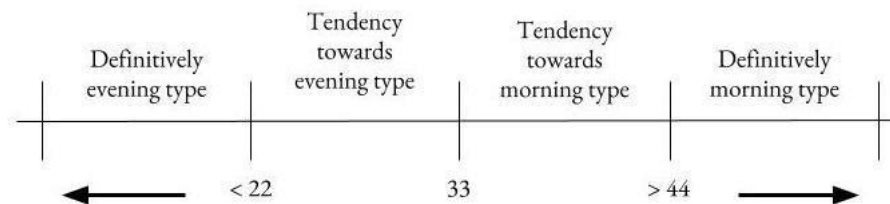
Figure 1: Depiction of chronotype scale

Different levels of these individual characteristics or specific combinations are likely to predict different potential problems in sleep patterns. Furthermore, different feedback is likely to work better for users with different characteristics in encouraging them to change their behaviors to healthier ones. In the following section, the analysis and predictions of how individual personality and chronotype

characteristics are likely to affect sleep patterns is presented. Where problems in personality or chronotype characteristics are predicted, a framework is proposed that outlines the type of notification a user should receive (i.e., the content, timing, and frequency of a potential notification).

3.2 Design of Personalized Feedback

The second objective focuses on designing a framework for the personalized feedback that includes how the content, timing, and frequency of the feedback changes based on personality and chronotype characteristics. Each personality factor and chronotype was considered to determine how it is associated with sleep based on previous research. These findings were then taken and extrapolated to create ideas for the content, timing, and frequency of potential feedback for users of that personality type or chronotype. Each of these notifications (or, in other words, personalized feedback) was deemed a "Reminder of the Day", or a "feedback message".

The target for the majority of the feedback message notifications were the extremes for each of the personality and chronotype characteristics because they represent the target demographic with a higher likelihood of poor sleep behavior. Thus, the scores of low and high (but not medium) were used from the FFM because they represent the extremes in each of those personality factors. In other words, medium scores are less likely to exhibit extreme behavior (either positive or negative), and thus was not a focus for the feedback messages. Additionally, both morning and evening types were considered as well. Each of the personality and chronotype characteristics are described below with the extrapolated feedback messages. Moreover, a basic feedback message is first introduced as the foundation for those users who do not belong to the extremes in any characteristics.

The feedback messages were designed based on initial concepts about each personality and chronotype type. These concepts are described in the following paragraphs. Each personality type and its associated scores have the message content, the frequency and the timing of the feedback. A similar process was used for the morningness and eveningness chronotypes. Each feedback message can be placed in one of the following categories based on its content: sleep goal, sleep patterns or quality, caffeine or electronics, or additional feedback outside the realm of sleep but directly related. It was important to consider categorization of the feedback because it demonstrated the relation of the characteristic to the area of sleep behavior that was being targeted.

3.2.1 Basic Feedback Message

The first step was to create a basic feedback message for those users with a "medium" score in any of the personality characteristics. This message, shown in Table 1, revolves around the sleep goal that users create for themselves and compares how well the user accomplished this goal. All users in this category will receive this notification each week. The timing of this feedback is on Monday in order to promote user awareness about their sleep goal throughout the rest of the week.

Table 1: Basic feedback message

BASIC FEEDBACK MESSAGE			
Content	**Frequency**	**Timing (day of week)**	**Timing (hour)**
Reminder comparing a user's average total sleep time from the past week to their sleep goal	Once per week	Monday	morning

3.2.1 Conscientiousness

One of the most important personality factors to assess is conscientiousness, due to its association with better and longer sleep [1]. Individuals with low levels of conscientiousness are more susceptible to poor sleep behavior due to lack of self-control, which may play a role in weekend/weekday misalignment as well as a late bedtime. Due to these tendencies, the implementation of personalized feedback will vary depending on whether individuals score low or high for conscientiousness. In Table 2, an overview is provided in terms of the type of feedback, the behavior to target, as well as the frequency.

Table 2: Feedback message framework for conscientiousness personality types

CONSCIENTIOUSNESS				
Score	**Content**	**Frequency**	**Timing (day of week)**	**Timing (hour)**
Low	Reminder suggesting going to bed at a reasonable time	Twice per week	Monday, Thursday	evening
	Reminder to encourage maintaining the same sleep schedule on weekends because misalignment can be detrimental to sleep health	Once per week	Friday	evening
High	Reminder of user's sleep goal for the week	Once per week	Monday	afternoon
	Message to encourage avoidance of all-nighters and caffeine consumption after 5pm	Once per week	Tuesday	morning

For those low in conscientiousness, their lack of self-control could result in their forgetting their sleep goal, which is why feedback for those users will occur twice per week. Additionally, an absence of willpower increases the likelihood of weekday/weekend misalignment, a situation where sleep patterns change erratically. Thus the second feedback message will be transmitted on Fridays.

Those who score high in conscientiousness are more goal-driven, which is why their feedback will be sent on Mondays and will focus on their goal for the week. Also, those scoring high in conscientiousness tend to be organized, prepared and detail-oriented [19]. These characteristics make it more likely that a conscientious person will succeed academically. Therefore, their feedback messages will be targeted towards avoiding behavior that may increase short-term academic success, but can negatively impact long-term health and academics, such as carrying out all-night study sessions and excessive use of caffeine to do so. Not receiving any sleep for one night is extremely detrimental to the regularity of one's sleep schedule. Additionally, excessive consumption of caffeine can negatively impact quality of sleep, as stated in Section 2.3.

3.2.2 Neuroticism

Another factor that is strongly associated with sleep behavior is neuroticism. Highly neurotic individuals have less emotional stability, are more prone to impulses and, therefore, are more likely to be affected by stress [19]. High neuroticism has been associated with poor sleep habits and poor sleep

quality [2]. An individual with a high score in neuroticism is significantly more likely to already exhibit unhealthy sleep behavior. However, any harmful sleep patterns may manifest in different ways, including short sleep duration and long sleep duration, both of which have been associated with high neuroticism [13]. Highly neurotic individuals may respond to stress in different manners. Some may lean towards insomnia in the case where stress prevents sufficient sleep. Others may be on the other end of the scale where the extreme stress necessitates an exorbitant amount of sleep in order to cope. Due to these considerations, the feedback message in Table 3 have been identified as areas of need in terms of neuroticism.

Table 3: Feedback message framework for neuroticism personality types

NEUROTICISM				
Score	**Content**	**Frequency**	**Timing (day of week)**	**Timing (hour)**
Low	No need for particular feedback or reminders based exclusively on personality type	N/A	N/A	N/A
High	Reminder with suggestions and references about how to control stress and improve mood	Twice per week	Monday, Thursday	morning

Therefore, those scoring high in neuroticism will receive feedback focused on the underlying problem: controlling stress. Thus, feedback messages may include tips and references about mindfulness, resisting impulses, prioritization techniques, coping skills, and encouragement to exercise in order to reduce stress [2]. These feedback messages will occur twice per week to provide continual reinforcement about incorporating positive behaviors into daily life, which would then positively affect sleep behavior. On the other hand, individuals with low neuroticism may not require any particular feedback based merely on their personality type.

3.2.3 Extraversion

A high score for extraversion indicates that the individual tends towards an outgoing personality and, therefore, is more likely to seek out social situations [19]. While higher extraversion is typically characterized by lower stress levels and shorter sleep latency, there is still the possibility for social situations to impact a highly extraverted individual's sleep patterns [13]. The feedback message in response to this pattern can be found in Table 4.

Table 4: Feedback message framework for extraversion personality types

EXTRAVERSION				
Score	**Content**	**Frequency**	**Timing (day of week)**	**Timing (hour)**
Low	Message to encourage avoidance of electronics before bed and caffeine consumption after 5pm	Once per week	Wednesday	morning

High	Reminder to encourage maintaining the same sleep schedule on weekends because misalignment can be detrimental to sleep health	Once per week	Friday	evening

For example, highly extraverted individuals may be more likely to support their social needs by staying up late, especially on weekends. Hence, feedback encouraging regular sleep hours during weekends is likely to help this group of people. For a low score in extraversion, the opposite must be considered. Higher stress levels and longer sleep latency indicates that the individual may have difficulty falling asleep. Feedback messages that are targeted towards reducing the use of electronics and avoiding caffeine consumption after 5pm could be useful.

3.2.4 Agreeableness

Individuals who score high in agreeableness are associated with a longer sleep duration and may be more open to recommendations about how to further improve their sleep habits [13]. While those scoring low in agreeableness have not been linked to specific sleep behavior, these individuals are less cooperative and more competitive than those who score high for this characteristic [19]. These ideas for notifications are described in Table 5.

Table 5: Feedback message framework for agreeableness personality types

AGREEABLENESS				
Score	**Content**	**Frequency**	**Timing (day of week)**	**Timing (hour)**
Low	Message comparing user's average sleep data that week to recommended amount according to National Sleep Foundation	Once per week	Wednesday	evening
High	No need for particular feedback or reminders based exclusively on personality type	N/A	N/A	N/A

As described before, a person with a lower score in agreeableness could benefit from feedback that fuels their competitive nature. This idea could be leveraged through development of a gamification and community aspect in *SleepHealth*. Creating an online community within the app is one way for users to find motivation if they are less likely to respond purely to the individualized feedback. Ultimately, the gamification aspect would fuel an individual's competitive drive and promote positive sleep goals.

3.2.5 Openness

A high openness rating has been associated with longer sleep in one study, but there is still feedback that could improve users' sleep health [12]. A high score for openness indicates that the individual may be willing to try new suggestions that are outside of their current behavior patterns relating to sleep [19]. This would include suggestions about additional healthy behaviors, such as reducing caffeine intake and increasing exercise, in order to further improve sleep health. Additionally,

individuals with a high score for openness may be receptive to suggestions about changing or improving their sleep goal if their sleep could be further optimized.

On the other hand, those scoring low in openness are much less likely to be willing to adopt any new ideas that *SleepHealth* suggests. Therefore, it is important to continue to reiterate true, factual ideas supported by research that are directly related to sleep behavior. For example, this may include reminding the user about the stipulated number of hours of sleep that the National Sleep Foundation recommends in order to encourage the individual to reach that goal. These ideas about openness are summarized in Table 6.

Table 6: Feedback message framework for openness personality types

OPENNESS				
Score	Content	Frequency	Timing (day of week)	Timing (hour)
Low	Message providing factual statements to improve sleep patterns, such as the National Sleep Foundation's recommendation about number of sleep hours per night	Once per week	Sunday	evening
High	Reminder suggesting going to bed at a reasonable time	Twice per week	Monday, Thursday	evening
	Reminder to encourage maintaining the same sleep schedule on weekends because misalignment can be detrimental to sleep health	Once per week	Friday	evening

Other studies suggest that openness may not have as much of a direct association with sleep quality and quantity, but that it greatly affects social behavior [13]. This suggests that the aforementioned idea about gamification and community in *SleepHealth* could be very effective for those who are motivated by the social aspect of an app.

3.2.6 Chronotype

The last portion of feedback was designed based on chronotype. An intuitive approach was used for these characteristics. An individual identifying as a morning person may choose to wake up early due to their inherent productivity and energy earlier in the day. This choice may be made to increase productivity early in the day despite the onset of daytime sleepiness later in the day. This daytime sleepiness would occur no matter what time they plan on going to bed if the user woke up early. Therefore, the feedback messages for morningness are targeted to remind a user not to consume caffeine after 5pm. Additionally, morningness is associated with high conscientiousness which also indicates that a person may be responsible, reliable, and organized. These characteristics lead to the assumption that this person may be getting a sufficient amount of total sleep time, as indicated by the self-control that highly conscientious people often exhibit. However, perhaps sleep quality is an issue for this chronotype. Due to this, electronics and caffeine are the main focus to mitigate poor sleep behavior, which are often associated with causing poor sleep quality as stated previously. For eveningness there is a natural issue of

staying up later while also being required to wake up at a certain time in the morning, potentially resulting in an inadequate amount of sleep per night. Due to this reasoning, it is proposed that those who are evening people should be reminded of a reasonable bedtime consistently. This will reinforce the habit of setting a bedtime and adhering to it in order to accomplish the goal of total sleep per night that they set for themselves (or that the National Sleep Foundation recommends). Feedback messages based on chronotype are summarized in Table 7.

Table 7: Feedback message framework for chronotype

CHRONOTYPE				
Score	**Content**	**Frequency**	**Timing (day of week)**	**Timing (hour)**
Morning	Message to encourage avoidance of electronics before bed and caffeine consumption after 5pm	Once per week	Wednesday	morning
Evening	Reminder suggesting going to bed at a reasonable time because this person is more likely to be staying up late	Once per week	Tuesday	evening

These concepts about personality factors and chronotype described above then had to be turned into the actual content for the feedback message. These fully described notifications can be found in Appendix A. The notifications that had overlap in content were combined so that personality types or chronotypes that had similar feedback would receive the same notification. This consolidated some of the feedback messages and is displayed in the weeklong schedule in Table 8 below. The notation for the table uses the capitalized first letter of the personality types and the score associated with the feedback message to be sent. Chronotype is denoted by "morning" or "evening". If feedback messages are combined on one day (i.e., a user will receive a message if they fit any of the personality or chronotype characteristics listed), the notations are separated by the disjunction "or".

Table 8: Weeklong overview including each feedback message

	Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
Morning		Basic or N (high)	C (high)	E (low) or Morning	N (high)		
Afternoon		C (high)					
Evening	O (low)	C (low) or O (high)	Evening	A (low)	C (low) or O (high)	C (low) or O (high) or E (high)	

Based on this information, the database table called "notifications" was created. The entries were modeled largely after the information in Table 8, which displays the schedule, as well as the message content, timing and frequency already described in previous sections. The full list of entries in this table can be found in Appendix A. The appendix includes a fixed number of notifications due to space and time constraints. However, it has been noted that these notifications would need to be expanded and revised in future iterations of the app when users have been continuously using it. This is due to the fact that users

would likely not need to receive the same notifications for an extended period of time. Additional notifications could be added to vary the content, but users may also change their sleep behavior to become more positive and thus would no longer require the same feedback messages.

3.3 Personalized Feedback Delivery

The third and fourth objectives prioritized choosing a method to deliver each feedback message and selecting a scheduling system that would be most appropriate for delivering messages from a webapp. These decisions differed from original versions of the *SleepHealth* app since it was originally an Android app using the built-in smartphone notification system. Desktop notifications were deemed to be ineffective because users most likely do not have their laptops open at all times of day. Additionally, notifications via the desktop are hard to accomplish since a web application does not have access to any built-in notification systems. Therefore, the first design decision about delivery of feedback messages was to migrate to an email notification system, which could reach users at anytime regardless of whether users are using the web app on their desktops, laptops or mobile devices.

While initial reactions to email notifications may include hesitancy due to any concerns about spam email, the frequency of the feedback messages was considered in the design of the feedback. In order to mitigate this negative reaction, one of the design steps already described was to review a weeklong schedule with all possible feedback messages listed. This is shown in Table 8 in the section above. With this overview it was determined that users could not receive more than three emails per day and this is only produced by one combination of personality and chronotype characteristics. This combination occurs on Monday and represents the extreme or maximum reminder case. While this may seem excessive at first, it is important to promote awareness at the beginning of the week so that behaviors can be modified throughout the rest of the week. The hypothesis is that the frequency of emails, which would usually be zero or one reminder each day, would be sufficient to promote behavioral change. However, this aspect of the design would have to be studied further to confirm this result.

The framework for each feedback message was described in Section 3.2. The goal for sending emails with these messages was to make it fully automated, only using the back end database as the source of content (since this would have already been populated). This automation was accomplished through a cron job. A cron job is a Linux-based program that aids in implementing scheduled tasks [20].

For the purpose of this web app, the cron job would need to execute a script every day in the morning, afternoon, and evening. This was done through the cron entry shown below. This specifies that the cron job should be executed at the hours of 8:00am, 14:00 (i.e., 2pm), and 19:00 (i.e., 7pm). The asterisks indicate that the cron job should execute every day (1-31), every month (1-12), and every day of the week (Sunday through Saturday). The first "0" simply indicates the minutes associated with the hour (i.e., in this case, it executes at the top of the hour). The last portion indicates the command line to be executed which simply uses php to execute the sendEmail.php file.

0 8,14,19 * * * /usr/bin/php /var/www/html/BCSS-Sleep/resources/php/sendEmail.php >/dev/null

The sendEmail script checks the database to see if any notifications match the time of day, day of the week, and week of the month (i.e., first week in the month, second, etc.). If notifications were found, the script finds all users that match the corresponding personality type or chronotype. For each user found, if any, an email is sent using the user's email, the subject in the notification table, as well as the

message content specified. Also included in every email is the user's sleep goal as well as their average hours of sleep in the past 7 days. At the bottom of the email are four feedback buttons. Users are able to indicate whether they found the reminder "very useful", "somewhat useful", "I already knew this" and "not useful". These are stored in the database for future use in analysis of determining which reminders had a positive effect for real users in changing behavioral sleep patterns.

3.4 User Interface of Web Application

The fifth objective was modifying the user interface. The basic user interface for the *SleepHealth* app had specifications for what information a user could record and what information the user could then access. This list of functional requirements was implemented in the app as shown in Chapter 4, the Results. In addition to these specifications listed above, the overall look and feel of the app had to appeal to a broad set of users. This was true in terms of the colors used and the images not being gender or age specific. These goals were applied generally to all aspects of the web app, which is further discussed in Chapter 4. Additionally, the *SleepHealth* app was initially designed as an Android app so it was important with the switch to the web app to ensure that responsive design for the UI was incorporated. This is further discussed in Section 3.5.

3.5 Full Stack with Relational Back End Database

The last two objectives revolved around the full stack for the web application and the design of the relational back end database. The presentation layer of the app utilizes HTML, CSS and JavaScript to render UI design and components and be responsive to any user actions. Additionally, to organize layout and make components uniform, Foundation was used as a front end framework tool for UI components. For the business logic and data access layers, PHP was used for server side code and data persists through a relational model in Postgres.

Foundation was chosen because it is simple to add to an app with CSS and JavaScript styling, as well as offers a variety of components that are easily customizable. All buttons, dropdown menus and navigation bars were created using the base Foundation components. Foundation also provides a grid-based layout that is responsive for different size screens. This makes it an ideal tool for this app because of the demands for responsive design.

PHP is primarily a server-side scripting language, specifically designed for web applications to work in harmony with JavaScript and HTML, both of which handle the client-side details [21]. PHP also allows communication with a database as well. It is a popular choice with a large developer community and is used for web applications such as WordPress, Drupal, and Facebook [22]. One of the benefits to PHP is the ability to create dynamic content easily [22]. Given that the *SleepHealth* web application has time-sensitive content and pulls in data from the database on many of the web pages, the functionalities of PHP are suited to the necessities of this application.

Another benefit to using PHP is the ease with which resources for sending emails is provided. One of the benefits built specifically for this use is the mail() function. The mail function handles all internal capabilities and only needs to be provided with the appropriate information about the sender, who the email is going to, the subject and the message. This functionality allowed email notifications to be sent using a PHP script.

One of the major reasons why Postgres was chosen was due to its reliability with data integrity and its scalability to arbitrarily large numbers of users. Due to the fact that most of the operations that are performed are write operations based on user data, speed is not a necessity for this web application. Additionally, the read operations that are performed are quite minor.

The framework for data persistence involved a PostgreSQL database (also referred to simply as Postgres). Postgres is a free, open-source database management system [23]. Below, in Figure 2, is a picture of the data that is stored in the database. The three sections specify which tables make up subcomponent schemas. The purple section is focused on the activities that users can log. These include sleep, wake, activity, and caffeine consumption, which have been included since the previous version of the app [15]. The green section was added to using the "personality" table, which supports records of each user's personality and chronotype. Additionally, the orange section specifies the notifications schema where notifications are listed with the personality type they correspond to as well as the timing and frequency for each. The personality type was encoded by using the following format, for example, of "score_c=high" to indicate that the feedback message should be sent to all users who have a score of high for conscientiousness. If multiple personality types and chronotypes were associated with a feedback message, the format would combine the above format using "or" in between each type. The content of the notification is split into a subject and a message due to later usage in the PHP mail script. The other table in the notifications schema keeps a record of the buttons that a user clicks in response to the feedback message they were just sent. This records the code for the notification and whether the user thought the feedback was useful, somewhat useful, not useful, or if they already knew the information in the feedback message.
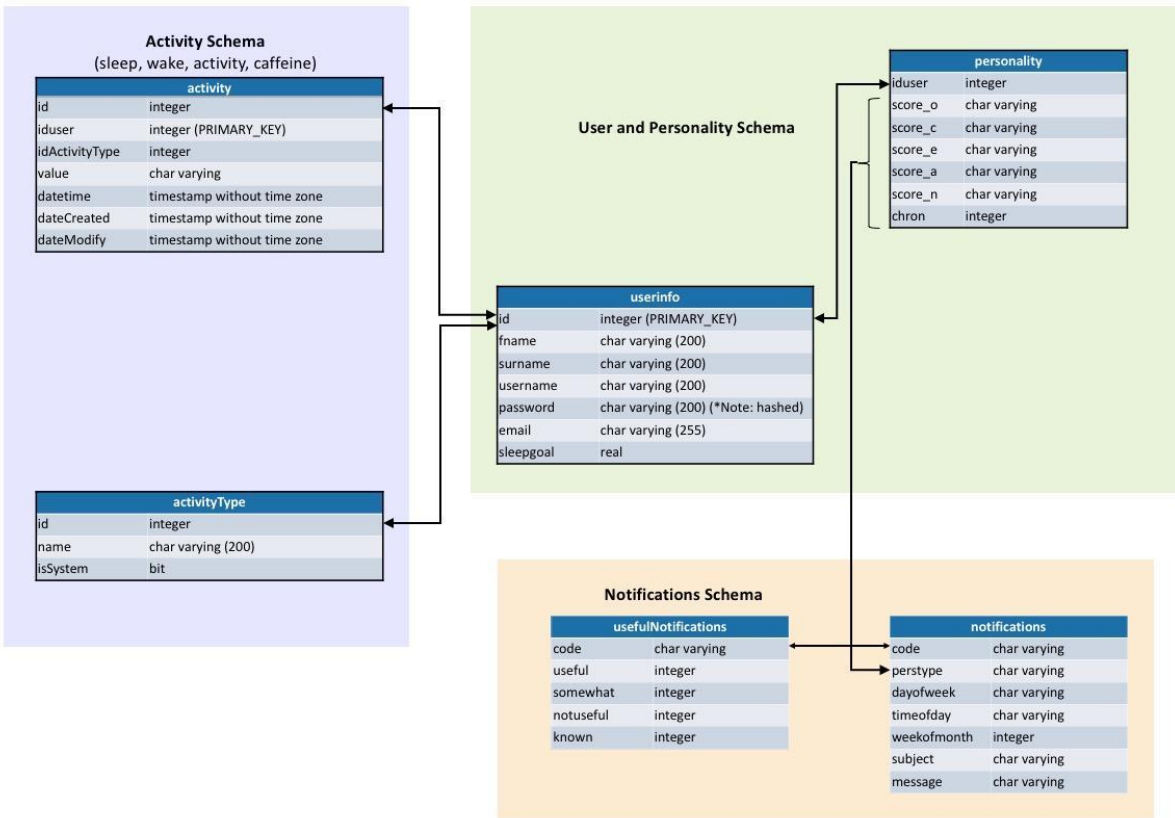
Figure 2: Database schema for SleepHealth app

3.6 Authentication for Security

The final objective of this project was to ensure security of the app through user authentication. This is important due to the fact that the data stored for this app is related to a user's personal sleep goals, sleep times, exercise/caffeine intake information, and also includes personal information such as name, email, and personality information. To prevent any abuse of personal information, a user's password is hashed using the PHP function. This ensures that any system admins do not know any user's actual password. The hashed version is stored in the database only to allow a user to log in.

Logging in can only occur once an account has been created. A separate "Create Account" page allows users to make their own account. There are requirements that no two users can have the same email address. Additionally, users must enter their password twice to ensure there are no mistakes in what the user wanted to enter.

The server used to host the *SleepHealth* app is password protected. Only those working on this project as well as the system admin have access to this data. This protects any entries in the database as well as the actual web app code.

4 Results

This chapter of results focuses on the implementation and modifications that were made to the app. Different pieces of functionality are separated into sections such as login, implementation of questionnaires, mobile design, and "Reminder of the Day" or feedback message emails.

4.1 Login and Home Page User Interface

When users go to the *SleepHealth* site for the first time, they can log in or create a new account. Logging in requires a username and password, as shown in Figure 3 below. Creating an account requires additional information to ensure that users with the same personal information do not create multiple accounts as depicted in Figure 4.
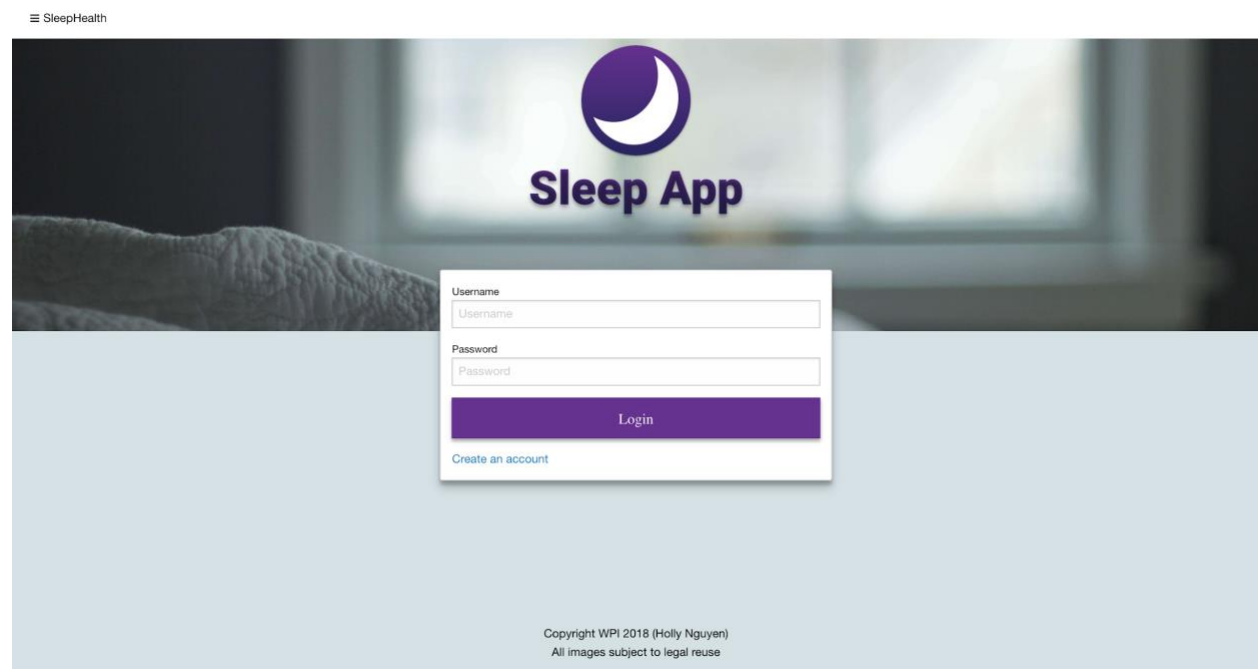

Figure 3: Login page for the SleepHealth app requires a username and password

Figure 4: Form to create a new account, which differs from the login information

The home page, shown in Figure 5, is simple to appeal to many users. The color scheme is slightly contrasting to provide a more interesting visual appeal. At the top is the navigation bar with a simple but effective dropdown menu, leading to all of the other pages. This is a simple, white color so as not to distract the user's eye away from the page content.

The greeting overlaid with the sunrise picture adds a personalized touch to the app, using an appropriate greeting based on the time of day and also including the user's first name. If a user has not completed their "personalization settings" (i.e., taking the personality and chronotype quizzes), a short sentence will display below the greeting that reminds a user to take the quizzes.

Modifications were made to the home page based on the previous version of *SleepHealth* [15]. Each of the buttons was originally designed with a background image providing visual confirmation of what page the button leads to. For example, the "Log Activity" button has dumbbells in the background image to symbolize and denote exercise. These buttons were modified to use a darker blue overlay to match the newly chosen soft blue color for the background.
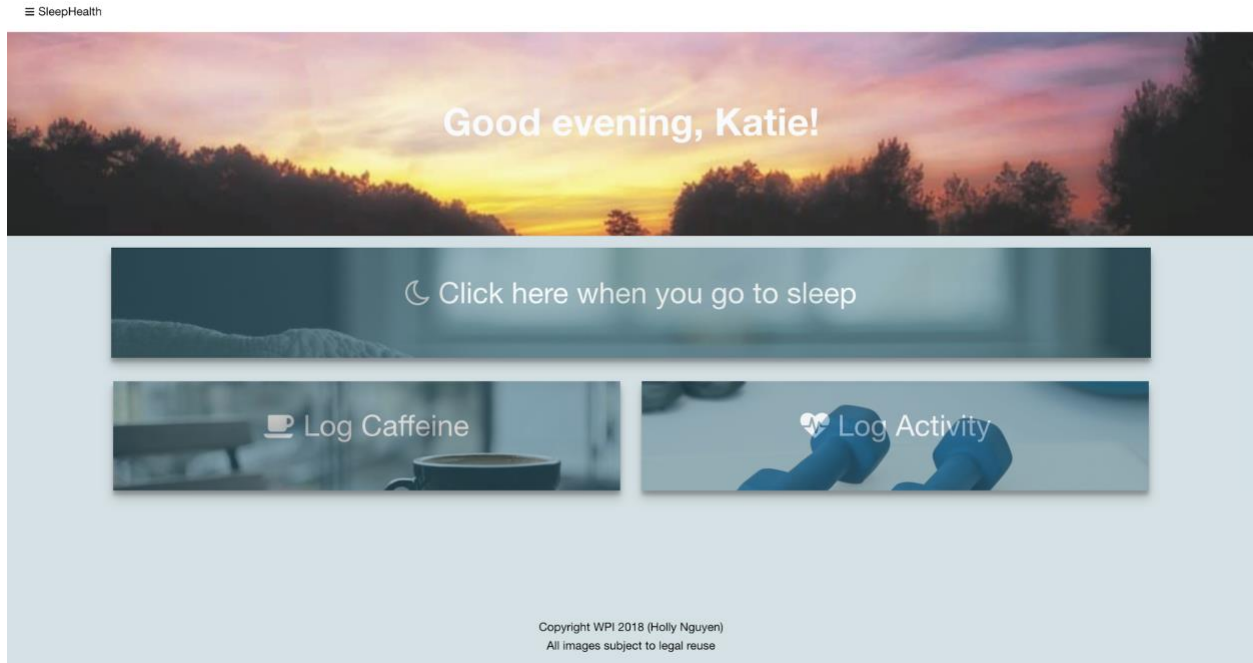
Figure 5: Home page of the SleepHealth app, modified from [15]

Navigation is accomplished by using the "hamburger" menu located at the top left of the screen as shown in Figure 6. This allows a user to be directed to see their sleep history, a logging page for either activity or caffeine, the personalization page, a settings page and a "Log Out" button. This ensures that users are able to sign out of their account for security reasons and then would have to provide the correct authentication to log in again.
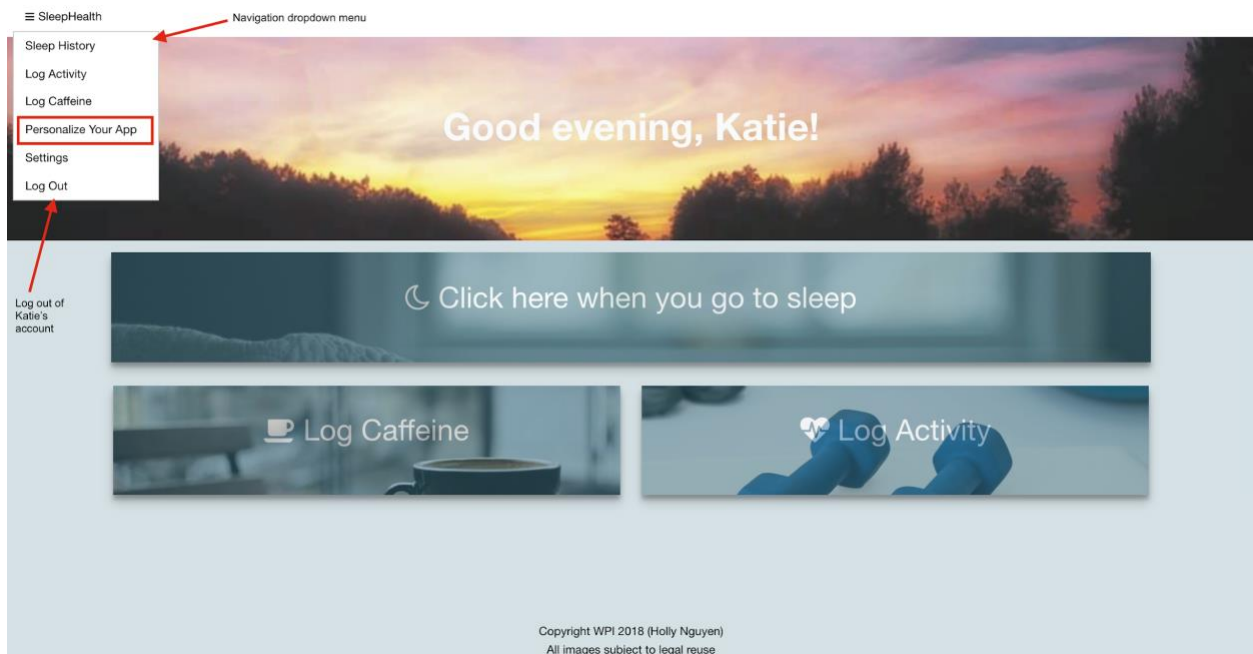

Figure 6: Main dashboard with navigation dropdown menu displayed

As can be seen in Figure 6, the final web app has a simple navigation scheme, which is also described below:

SleepHealth Home
- Sleep History
- Log Activity
- Log Caffeine
- Personalize Your App
- Settings
- Log Out

4.2 Implementation of Personalization Questionnaires

The questionnaires that were discussed in Section 3.1 were added to the web app via one dashboard display, or web page depicted in Figure 7. This allows easy access to all personalization tools in one location on the site (e.g., setting a sleep goal, taking the personality quiz, and taking the chronotype quiz).

To access this web page, the user can click on the dropdown menu in the top left corner and select "Personalize Your App", which is highlighted in a box in Figure 6. The user can set their sleep goal (if they have not done so before, or reset it by clicking on the reset button) as well as take the personality and chronotype quizzes, which is at the crux of designing the notifications for each user.
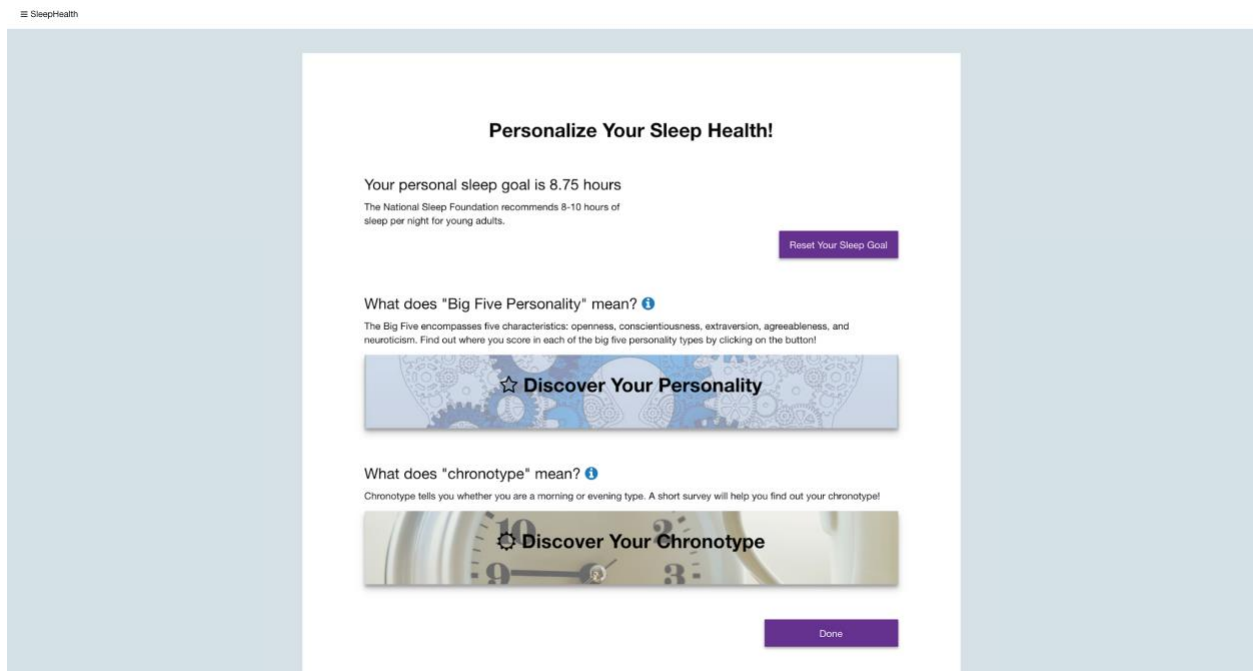

Figure 7: Main dashboard to begin personalizing the SleepHealth app

The following steps describe how a user would navigate the site to discover their personality and their chronotype (i.e., take the questionnaires). This is an important process because the results can then be used to tailor the email feedback.

Step 1: Click on "Discover Your Personality".

Step 2: Click on "Take the Big 5 Personality Test" which directs users to an external website that provides the FFM questionnaire to take and the scores of low, medium, or high for each FFM factor. When users navigate back to the *SleepHealth* site, user clicks on "Report Your Personality Scores" to provide their scores. See Figure 8 for details.
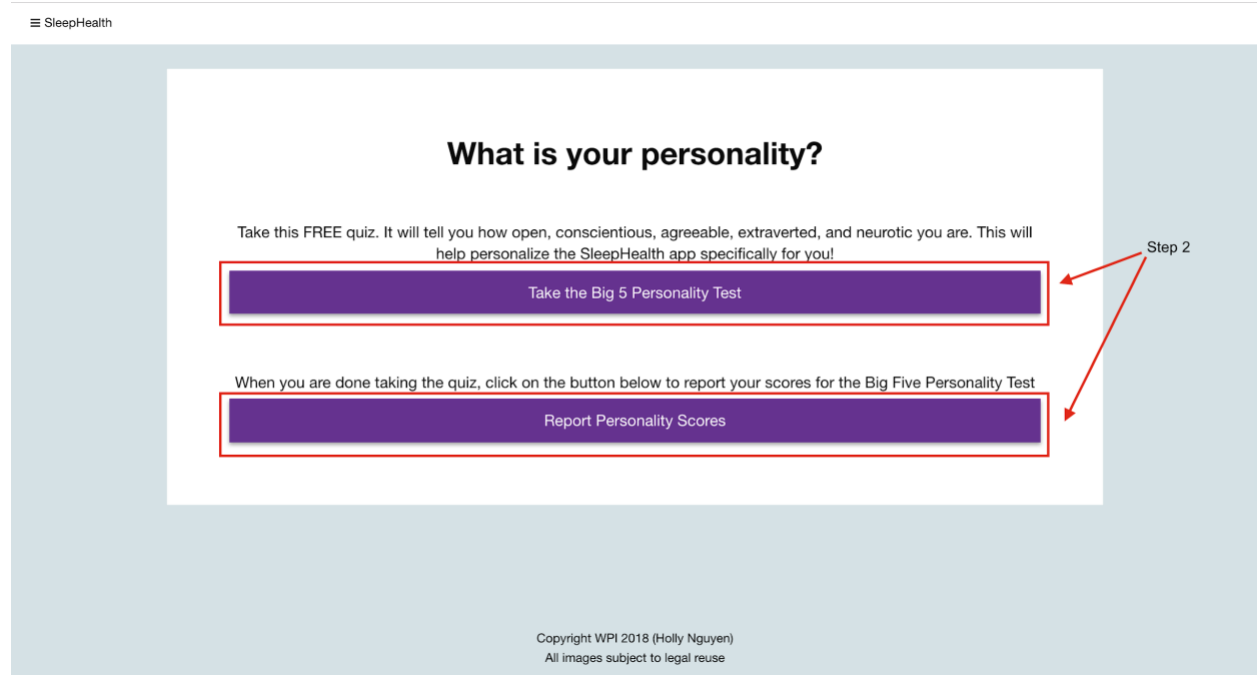

Figure 8: Personality introduction page with link to questionnaire

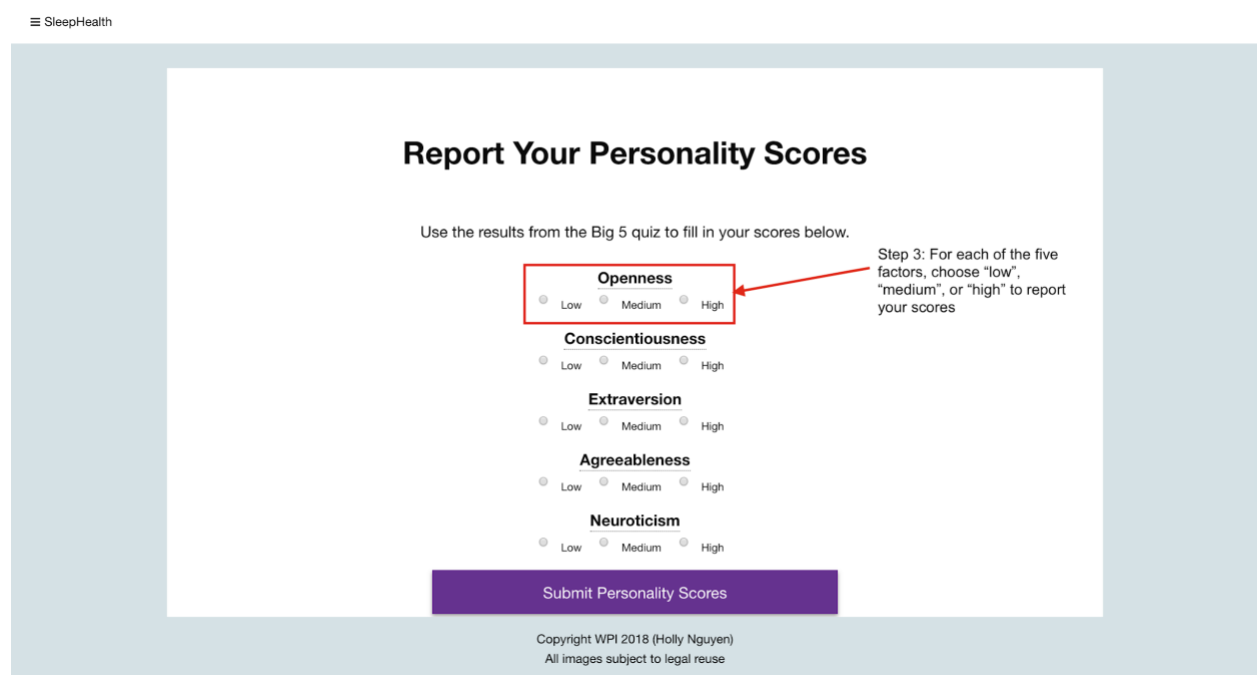**Step 3:** User reports scores as "low", "medium", or "high" on the page shown in Figure 9.

Figure 9: Reporting personality scores page

Step 4: User's scores are shown on personality results page. User has the option to click "Done" to return to the main personalization page or retake the personality quiz if they accidentally misentered information. Both options are highlighted in Figure 10 below.
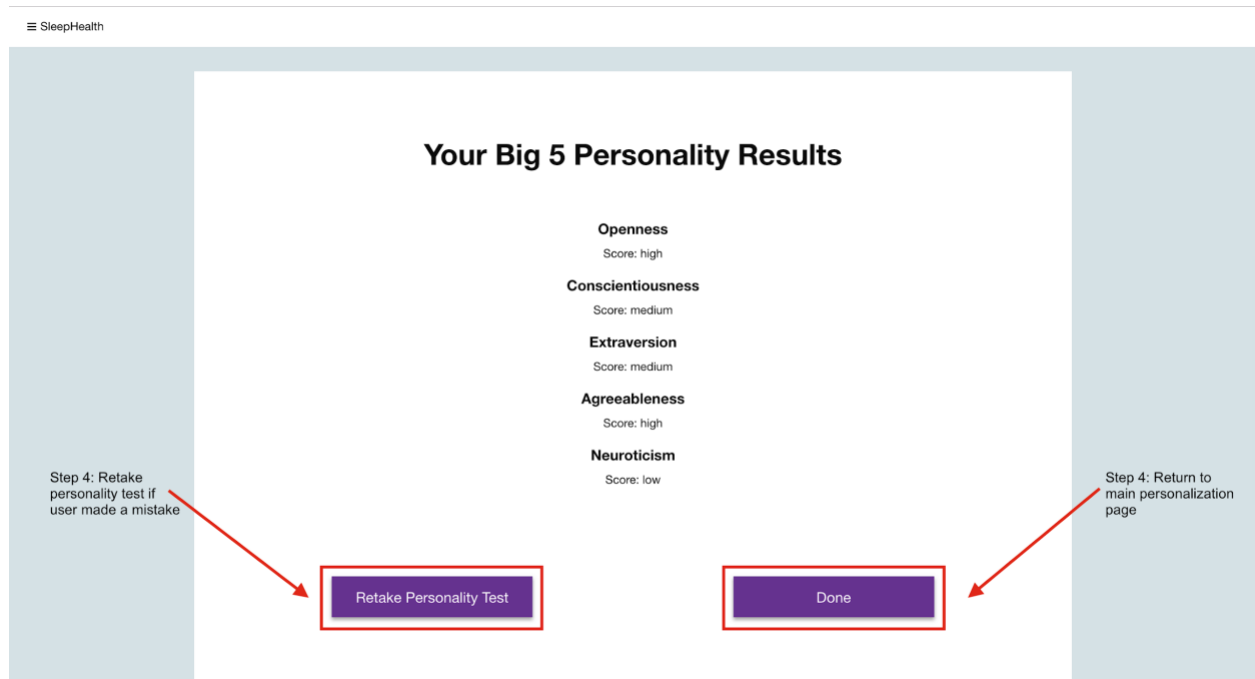
Figure 10: Personality results page

Step 5: When the personality quiz is complete, users can access the chronotype quiz back on the main personalization page. The user must click on "Discover Your Chronotype" and will be directed to a survey built in the app (though the questions are based on the Composite Scale of Morningness). The first question of the survey is displayed in Figure 11. Once the user selects one of the answers the "Next" button will be enabled. Below the question is a blue progress bar that will show the user's advancement through the questions as they move from question 1 to 13.

Figure 11: First question in chronotype survey

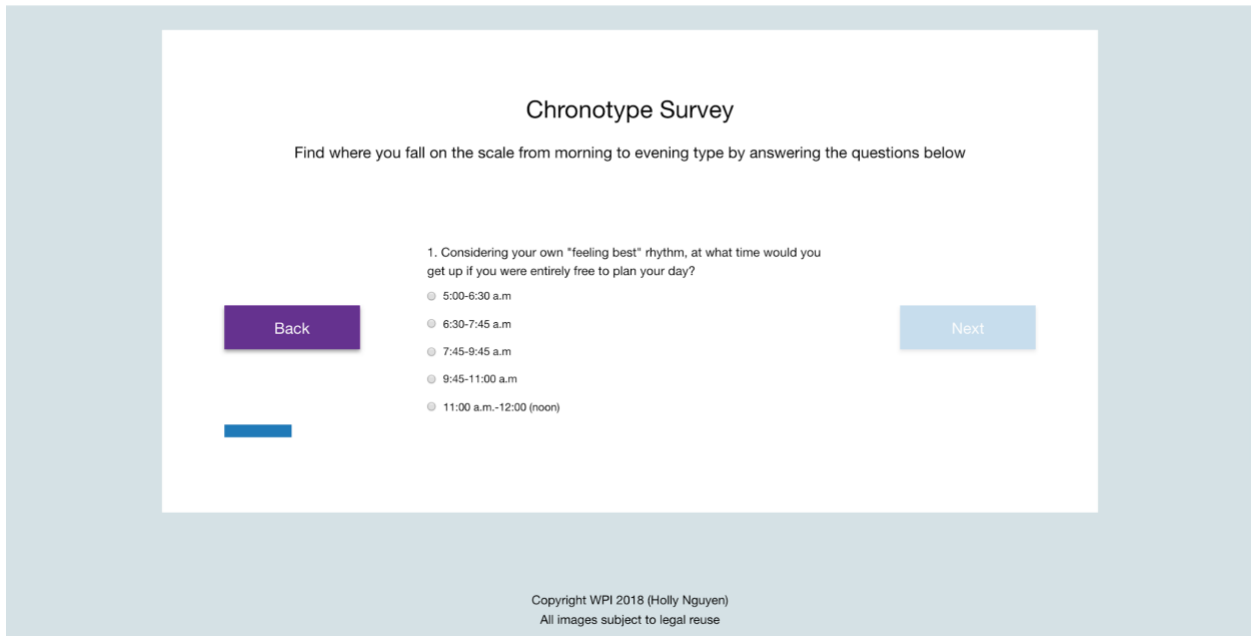**Step 6:** The end of the chronotype survey shows the user their chronotype score and where they fall on the scale of being a morning or evening person. Similar to the personality quiz, the user can retake the quiz at any time. This is shown in Figure 12.
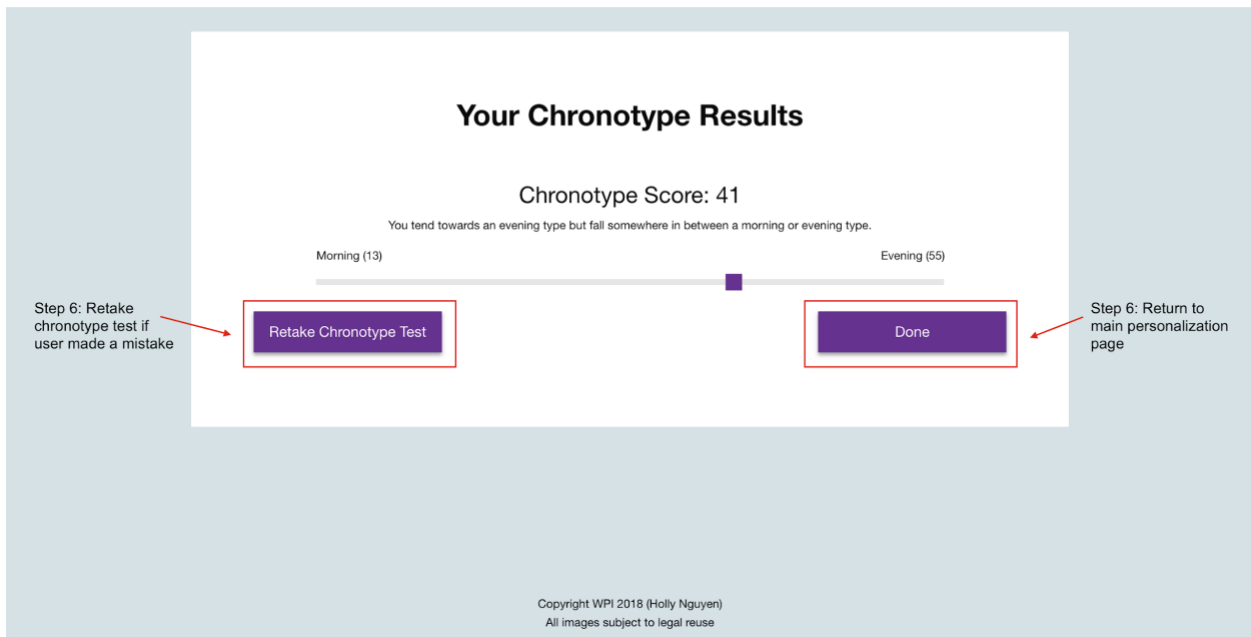
Figure 12: Chronotype results page

4.3 Mobile Design

One of the necessary results in this project was to ensure that the web app design was portable and responsive across multiple devices. In order to demonstrate this, screenshots from a smartphone are shown in Figures 13-17.
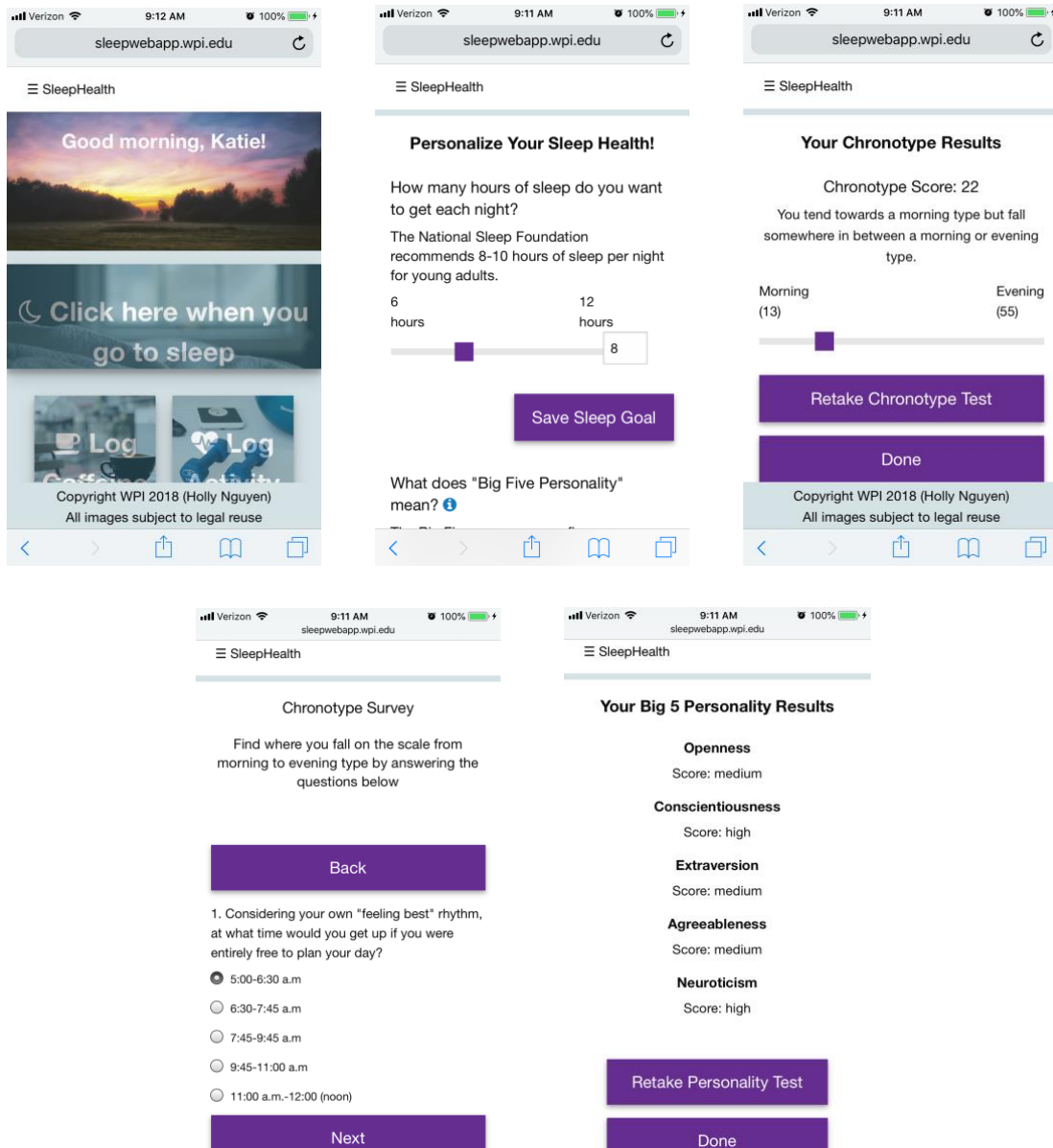
Figures 13-17: Mobile screenshots to demonstrate responsive design

4.4 Feedback Message Emails

After both quizzes have been taken and a sleep goal has been set, the user will begin to receive personalized emails. An example of this is shown in Figure 18. The final email notification implements a

sleek, simple design with three main colors: white, black, and teal. The main message (which is stored in the database to allow for easy access and future modifications if needed) is in the top teal rectangle and is called the "Reminder of the Day". This highlights the importance of the reminder the user receives and also focuses the user's attention on that specific feedback message. The following two sections highlight the sleep goal and also soliciting user feedback, as described in Section 3.4.

Figure 18: Example email notification

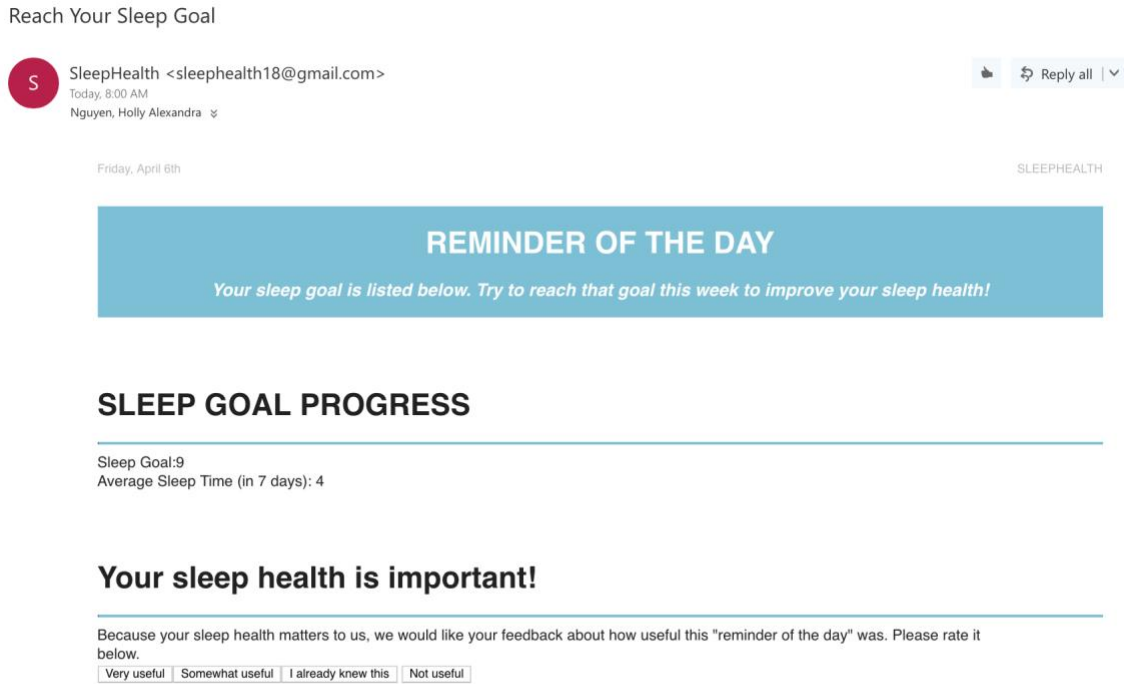Another example of an email containing a feedback message can be found in Figure 19 below. This feedback message targets the issue of weekend/weekday misalignment for those who are highly extraverted, low in conscientiousness or high in openness.

REMINDER OF THE DAY

Having a different weekend sleep schedule can be detrimental to your sleep health. This weekend, try to wake up and go to bed at approximately the same time as you would during the week.

SLEEP GOAL PROGRESS

Sleep Goal:8.75
Average Sleep Time (in 7 days): 4

Your sleep health is important!

Because your sleep health matters to us, we would like your feedback about how useful this "reminder of the day" was. Please rate it below.

| Very useful | Somewhat useful | I already knew this | Not useful |

Figure 19: Example email notification to address weekend/weekday misalignment

The third example email is one that targets those who have a morning chronotype or are high in conscientiousness. This feedback message focuses on relating the importance of caffeine consumption to sleep and academic success.

REMINDER OF THE DAY

All-nighters and caffeine consumption can throw off your sleep schedule and can result in lower GPAs.

SLEEP GOAL PROGRESS

Sleep Goal:9
Average Sleep Time (in 7 days): 4

Your sleep health is important!

Because your sleep health matters to us, we would like your feedback about how useful this "reminder of the day" was. Please rate it below.

| Very useful | Somewhat useful | I already knew this | Not useful |

Figure 20: Example email notification to address caffeine consumption

5 Conclusion and Future Work

This research posits that personalization increases the likelihood of consistent engagement. Moreover, personalization provided through technology that is already familiar to users has a greater chance for success and behavioral change as compared to technology without this personalization. This essential idea can be applied to other areas of behavior (e.g., poor health behavior), which can be improved through the use of technology.

In designing a web app interface, there were many considerations to make in terms of placement, sizing, and visual appeal of elements. One of the main verdicts was that information, whenever possible, should be provided for users instead of requiring them to seek it out. For example, reminding users to take the personality and chronotype questionnaires on the main home page was an important addition to increase the likelihood for a user to personalize their app. This same principle was evident in the amount of energy and thought that a user invested when using the app. For example, when designing the chronotype quiz, it was important to consider how far a user had to move their mouse to advance to the next question. Additional effort for users was mitigated in the design using these methods.

The framework for the personalized feedback that was designed and implemented in this project has many benefits. It targeted the extreme personality and chronotype characteristics, which were more likely to lead to unhealthy sleep behavior. This very basic idea of targeting extreme behavior represents one way to attack the issue of sleep deprivation. However, another method could be considering how to maintain positive behavior once a user has achieved that. The final implementation of this generally focuses on changing negative behavior and begins to incorporate maintenance of positive behavior. For example, the app sends at least one reminder each week, even to users with personality characteristics associated with healthy sleep habits, and allowing personalization through the sleep goal. This means that users with moderate or positive behavior still receive some feedback. The proposed framework could easily be expanded further as new research findings relating personality and sleep behavior continue to emerge.

Using a database as the central location for storage of user data as well as of the reminders and their message, timing, and frequency is an efficient method for persistence. This also ensures the ability to update the content easily for future expansion or modification. For example, if many users did not like receiving a notification on a specific day, it could easily be changed in the database and the modification would take place immediately with no delay. Additionally, the cron job ensures that emails are sent on schedule with no maintenance required by a person. Both of these additions make the job of the developer less complicated.

The delivery of notifications via email did not use a novel technology, but rather technology that most individuals already have access to and are familiar with. This was an important consideration because accessibility is more likely to increase engagement. As a user receives emails from *SleepHealth* the notification will be found at the top of their inbox. This is important because it could remind a user that this is a priority. While emails are not a new technology, they allow an emphasis on prioritization of sleep because of the way a user interacts with them. Future work could include further evaluating different platforms to connect the app to in order to determine if methods of delivery affect a user's reaction.

There is significant potential for additional future work. The main next step would be conducting a user study to evaluate how well the personalization works to promote healthier sleep behavior. Additionally, data analysis of the types of notifications that users find useful could inform the future

design of the notification framework. On a similar note, more research about common personalities and chronotypes among college students may indicate more prevalent types to focus on.

There are also many other areas of personalization that can be explored. Analytics for how a user is navigating around a site and which pages they visit can be informative in determining their locus of control. This is another evaluation technique for learning more about a user and is more automated (i.e., less work for a user). These and other approaches could be explored further to continue refining the implementation of *SleepHealth* and enhancing its effectiveness as an enabler of healthier sleep behavior.

References

1. Taylor, D. J., Vatthauer, K. E., Bramoweth, A. D., Ruggero, C., & Roane, B. (2013). The role of sleep in predicting college academic performance: Is it a unique predictor? *Behavioral Sleep Medicine, 11*(3), 159.

2. Duggan, K. A., Friedman, H. S., McDevitt, E. A., & Mednick, S. C. (2014). Personality and healthy sleep: The importance of conscientiousness and neuroticism. *PloS One, 9*(3), e90628.

3. Hershner, S D and R D Chervin. (2014). Causes and consequences of sleepiness among college students. *Nature and Science of Sleep, 6*, 73-84.

4. *Teens and sleep.* (2016). Retrieved June, 2017, from https://sleepfoundation.org/sleep-topics/teens-and-sleep

5. Chennaoui, M., Arnal, P. J., Sauvet, F., & Léger, D. (2015). Sleep and exercise: A reciprocal issue? *Sleep Medicine Reviews, 20*, 72.

6. Herman, R. (2016). *How lack of sleep affects cholesterol.* Retrieved June, 2017, from https://www.sleepassociation.org/2016/04/24/lack-sleep-affects-cholesterol/

7. Sprecher, K. E., Koscik, R. L., Carlsson, C. M., Zetterberg, H., Blennow, K., Okonkwo, O. C., et al. (2017). Poor sleep is associated with CSF biomarkers of amyloid pathology in cognitively normal adults. *Neurology, 89*(5), 445-453.

8. Onyper, S. V., Thacher, P. V., Gilbert, J. W., & Gradess, S. G. (2012). Class start times, sleep, and academic performance in college: A path analysis. *Chronobiology International, 29*(3), 318-335.

9. DeMartini, K. S., & L.M. Fucito. (2014). Variations in sleep characteristics and sleep-related impairment in at-risk college drinkers: A latent profile analysis. *Healthy Psychology, 33*(10), 1164-1173.

10. Taylor, D. J., & A.D. Bramoweth. (2010). Patterns and consequences of inadequate sleep in college students: Substance use and motor vehicle accidents. *J Adolesc Health, 46*(6), 583-596.

11. Champlin, S. E., Pasch, K. E., & Perry, C. L. (2016). Is the consumption of energy drinks associated with academic achievement among college students? *Journal of Primary Prevention, 37*(4), 345-359.

12. Williams, P. G., & Moroz, T. L. (2009). Personality vulnerability to stress-related sleep disruption: Pathways to adverse mental and physical health outcomes. *Personality and Individual Differences, 46*(5-6), 598-603.

13. Hintsanen, M., Puttonen, S., Smith, K., Törnroos, M., Jokela, M., Pulkki-Råback, L., et al. (2014). Five-factor personality traits and sleep: Evidence from two population-based cohort studies. *Health Psychology, 33*(10), 1214.

14. Sneed, J. R., & Pimontel, M. A. (2012). Stability and change of personality across the life course: The impact of age and major life events on mean-level and rank-order stability of the big five. *Journal of the American Psychoanalytic Association, 60*(5), 1057-1059. Retrieved from http://dx.doi.org/10.1177/0003065112459954

15. Chris Chagnon. (2017). *SleepHealth web application.* Worcester Polytechnic Institute:

16. Hahn, E., Gottschling, J., & Spinath, F. M. (2014). Short measurements of personality – validity and reliability of the GSOEP big five inventory (BFI-S). *Journal of Research in Personality, 46*(3), 355-359.

17. Smith, C. S., Reilly, C., & Midkiff, K. (1989). Evaluation of three circadian rhythm questionnaires with suggestions for an improved measure of morningness. *Journal of Applied Psychology, 74*(5), 728–738.

18. Randler, C. (2008). Validation of the full and reduced composite scale of morningness. *Biological Rhythm Research, 40*(5), 413-423.

19. Cherry, K. (2017). *What are the big 5 personality traits?* Retrieved June, 2017, from https://www.verywell.com/the-big-five-personality-dimensions-2795422

20. Heng, C. (2017). *How to create a cron job (scheduled task) for your website or blog.* https://www.thesitewizard.com/general/set-cron-job.shtml

21. *Role of PHP in web applications.* (2018). http://www.phpknowhow.com/basics/role-of-php-in-web-applications/

22. Wayner, P. (2017). *PHP vs. node.js: An epic battle for developer mind share.* https://www.infoworld.com/article/3166109/application-development/php-vs-nodejs-an-epic-battle-for-developer-mind-share.html

23. *SQLite vs MySQL vs PostgreSQL: A comparison of relational database management systems.* (2014). https://www.digitalocean.com/community/tutorials/sqlite-vs-mysql-vs-postgresql-a-comparison-of-relational-database-management-systems

Appendix A

This Appendix contains the full database entries in the notifications table for all personality types and chronotypes.

ID/code	Personality type	dayofweek	timeofday	Week of month	Subject
code1_1	score_n=high	Monday	morning	1	Manage Your Stress
Message:	*When you feel stressed try taking a walk to give your mind a break and get light exercise.*				
code1_2	score_n=high	Thursday	morning	1	Manage Your Stress
Message:	*Avoiding alcohol, nicotine, and caffeine can help reduce stress. Alcohol is generally a depressant but can act as a stimulant in smaller quantities, which is not helpful for your sleep health.*				
code1_3	score_n=high	Monday	morning	2	Manage Your Stress
Message:	*Yoga is a great way to relax and decrease your stress levels.*				
code1_4	score_n=high	Thursday	morning	2	Manage Your Stress
Message:	*Exercise for 30 minutes at least 3 to 5 times per week has been proven to reduce stress and allow for better sleep.*				
code1_5	score_n=high	Monday	morning	3	Manage Your Stress
Message:	*Stress can be caused by being overwhelmed. To help with this, keep a running to-do list that you can prioritize.*				
code1_6	score_n=high	Thursday	morning	3	Manage Your Stress
Message:	*Mindfulness is a skill that can reduce stress. Try taking soothing, deep breaths whenever you are tense.*				
code1_7	score_n=high	Monday	morning	4	Manage Your Stress
Message:	*Eating a healthy, well-balanced diet can reduce stress. Try to fill your plate evenly with fruits, vegetables, protein and whole grains!*				
code1_8	score_n=high	Thursday	morning	4	Manage Your Stress
Message:	*When you need a break, try listening to your favorite music.*				
code1_9	score_n=high	Monday	morning	5	Manage Your Stress
Message:	*Taking time for self-care is important to lead a lower stress life. Make time for your hobbies each day!*				
code1_10	score_n=high	Thursday	morning	5	Manage Your Stress
Message:	*One of the best ways to reduce stress is to talk about your problems and what is causing the stress with the people in your life.*				
code2_1	score_c=high	Monday	afternoon	9	Remember Your Sleep Goal
Message:	*Remember that your sleep goal is _____ hours and you should try to reach that every night! Make sure you plan ahead!*				

code2_2	score_c=high	Wednesday	morning	9	Sleep and Academics
Message:	*All-nighters and caffeine consumption can throw off your sleep schedule and are correlated with lower GPAs.*				
code3_1	score_o=low	Sunday	evening	9	What Does the National Sleep Foundation Say?
Message:	*The National Sleep Foundation recommends 8-10 hours per night of sleep.*				
code4_1	score_a=low	Wednesday	evening	9	Compare Your Sleep
Message:	*Your average sleep per night this week is listed below. Compare that to the recommended average which is at least 8 hours per night.*				
code5_1	score_e=low OR score_c=high OR chron<22	Tuesday	morning	9	Protect Your Sleep Quality
Message:	*Using electronics in the hour before bed as well as daytime caffeine consumption after 5pm can negatively affect your sleep quality.*				
code6_1	score_c=low OR score_o=high	Monday	evening	9	Set a Bedtime
Message:	*It is important to go to bed at a reasonable time each night! Do not forget your sleep goal!*				
code6_2	score_c=low OR score_o=high	Thursday	evening	9	Set a Bedtime
Message:	*Try to reach that sleep goal tonight by setting a reasonable bed time for yourself based on when you have to wake up the next morning.*				
code6_3	score_c=low OR score_o=high	Friday	evening	9	Maintain That Sleep
Message:	*Having a different weekend sleep schedule can be detrimental to your sleep health. This weekend, try to wake up and go to bed at approximately the same time as you would during the week.*				
code7_1	score_e=high	Friday	evening	9	Maintain That Sleep
Message:	*Having a different weekend sleep schedule can be detrimental to your sleep health. This weekend, try to wake up and go to bed at approximately the same time as you would during the week.*				
code8_1	chron > 44	Tuesday	evening	9	Watch Your Sleep Schedule
Message:	*You are a night owl, so make sure to watch your sleep schedule and go to bed at a reasonable time for the rest of this week.*				