**Sleep Score Explanation: Improving Sleep Quality via Interpretable ML**

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**Benjamin Orndorff**

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Technical Project Team Members

Benjamin Orndorff

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Briana Morrison, Department of Computer Science

# Sleep Score Explanation: Improving Sleep Quality via Interpretable ML

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Benjamin Orndorff
Computer Science
The University of Virginia
School of Engineering and Applied Science
Charlottesville, Virginia USA
bto5fs@virginia.edu

## ABSTRACT

Lack of sleep has become a major health issue, with 35.2% of adults in the US getting less than the recommended 7 hours of sleep every night. Although many apps have been developed to track sleep, they only provide sleep scores, which are not easily interpretable by users. In an effort to improve sleep quality, this report proposes the development of a new app that takes in sleep data and sleep scores from other apps and applies an explainable regression model to provide users with an explanation for their sleep score based on their habits. The app will then recommend tailored steps for users to take to improve their sleep score. This solution aims to provide users with more information about their sleep habits and offer more personalized advice for improving sleep quality. The future work for this app includes the development and testing of the application to ensure functionality and accessibility of the application.

## 1. INTRODUCTION

Sleep is a crucial component of a healthy lifestyle, yet a staggering 35.2% of adults in the US fail to get the recommended 7 hours of sleep per night (CDC, 2017). Insufficient sleep in the short term can lead to mood swings and impaired judgment, while long-term sleep deficiency can cause chronic health problems such as heart disease, obesity, and depression (National Heart, Lung, and Blood Institute 2021). However, adopting proper sleep hygiene, which includes healthy habits, behaviors, and environmental factors that contribute to adequate sleep, can effectively mitigate these issues and is easily teachable. Creating habits such as consistent wake-up times, reducing blue light exposure before bedtime, and cooling the bedroom before sleeping can significantly improve sleep hygiene (Sleep Foundation 2023).

In the interest of improving sleep quality, many applications have been developed to analyze users' sleep to determine patterns within them and assign sleep scores. However, these generated sleep scores are not easily interpretable by humans as these apps do not explain why a score was assigned or what factors were most important in determining it. Consequently, it becomes hard for users to take action to fix their sleep based on the sleep score alone. To address this limitation, I propose developing an application that uses explainable regression models to analyze users' sleep scores and provide customized plans for improving sleep hygiene. This will enable users to take specific actions to enhance their sleep quality and overall health.

## 2. RELATED WORKS

Raymann (2022) conducted an analysis of the sleep data from two sleep-tracking applications, SleepScore Max (SleepScore Labs) and S+ (ResMed), to determine how well users of these devices

are sleeping. The study analyzed data from 40,892 users and 5,513,369 nights and found that less than 30% of users slept on average for the recommended amount, while slightly over half of the users showed the recommended sleep efficiency. Additionally, at least 79.7% of users fell asleep on average within 30 minutes. The conclusion drawn from this analysis is that sleep improvement campaigns need to focus on extending sleep duration and improving sleep hygiene to enhance the sleep quality of users. This research partly inspired my proposal, as it highlights how current sleep trackers are still inadequate at improving sleep.

In a discussion on the importance of consumer sleep technologies (CST), Watson (2019) noted the lack of widespread help from board-certified sleep physicians, with only one for every 46,000 American citizens. Moreover, people are often unwilling to seek professional help when dealing with sleep issues. Watson's argument underscores the potential of CSTs as a powerful tool to help many people with sleep issues. My proposal is similarly inspired by this perspective, as I believe that proper use of CSTs can play a significant role in improving the sleep quality of individuals.

## 3. PROPOSED DESIGN

The Sleep Score Explanation System aims to provide users with personalized insights and recommendations to improve their sleep quality. By analyzing users' daily habits and sleep scores, the system generates an interpretable explanation of their sleep quality and provides tailored recommendations to enhance it. In the following subsections, we will describe the system architecture, key components, and requirements for achieving this objective.

### 3.1 Architecture Overview

The Sleep Score Explanation System will be an independent application designed to provide users with personalized insights into their sleep quality. The system will consist of both front-end and back-end components.

On the front end, users will be able to view their sleep scores, along with a detailed breakdown of the factors influencing their scores. This information will be presented in an easily interpretable manner, allowing users to understand the impact of their daily habits on their sleep quality. Additionally, users will be able to view their sleep history and data visualizations of their sleep habits and scores.

The back end of the system will interface with popular sleep apps to retrieve users' daily sleep scores. The system will use an explainable regression model to analyze this data, as well as users' daily habits, to predict their sleep score given their recent habits. The LIME explanation technique (Ribeiro 2016) will be used to identify the key habits that are driving the predicted sleep score.

### 3.2 Requirements

To effectively provide personalized insights and recommendations to users for improving their sleep quality, the Sleep Score Explanation System will require the following components: a habit-tracking system, a sleep analysis and recommendation system, and an analytics system.

The habit tracking system will allow users to input their daily habits, including scientifically proven factors that affect sleep quality such as caffeine intake, alcohol intake, blue light exposure, exercise, and other habits they wish to track. This input will provide the data required for the sleep analysis and recommendation system to

generate personalized sleep quality predictions and recommendations.

The sleep analysis and recommendation system will use the sleep scores retrieved from popular sleep-tracking apps in combination with users' daily habits to generate sleep quality predictions. An explainable regression model will be employed to provide an interpretable analysis of users' sleep scores, which will highlight the key habits that are driving the predicted score. Based on this analysis, the system will generate personalized recommendations to improve users' sleep quality, which will be displayed in an easily interpretable manner.

Finally, the analytics system will provide users with historical data on their sleep quality, including data on which habits are the most disruptive or beneficial, and specific correlations between sleep quality and habits. This information will be presented in an easily interpretable manner to provide users with a better understanding of their sleep patterns.

**3.3 Key Components**

The Sleep Score Explanation System will consist of a user interface (UI) and a backend, each of which will be designed with specific components to support its functionality.

The UI will be developed using the Expo CLI, a React Native framework that will enable us to develop a dynamic mobile application for both Android and iOS devices. The UI will be designed to be simple and easy to use, with a focus on allowing users to easily view and interact with their sleep data.

The backend will consist of a MongoDB database, APIs to integrate with existing sleep analysis apps, and an explainable regression model.

The database will be used to maintain users' unique information, especially for ingestion during training. The NoSQL aspect of MongoDB will allow for a more flexible schema for users who will have different habits they track.

The backend will include APIs to other sleep analysis applications to retrieve user data. For example, users of Fitbit will need to connect their account to our application to retrieve their sleep score daily using the Fitbit API.

The explainable regression model is a critical component of the proposed sleep quality application, as it provides a means to predict a user's sleep score based on their sleep habits data from other sleep analysis applications. This regression model will be trained on a dataset of sleep habits data and corresponding sleep scores, which will allow it to make predictions based on a user's inputted sleep habits. Furthermore, as users input their own data, the regression model will be retrained using a pre-existing model as a starting point, ensuring that the model's accuracy improves over time.

Once the regression model has been created, we will modify it to include interpretability using post-hoc explanations from LIME. Specifically, LIME uses perturbation, whereby it modifies the input to a prediction model and uses the resulting changes in the output to assess the importance of each aspect of the input. In the case of sleep score prediction, this could entail removing certain input features, such as caffeine intake or bedtime, and observing how the removal affects the predicted sleep score. Through this process, LIME assigns importance values to each input feature for the sleep score prediction. By integrating LIME's explanation method into the regression model, the output will provide both the predicted sleep score and the importance values for each input feature.

**3.5 Challenges**

One potential challenge is the lack of APIs from some sleep analysis apps, which may require alternative methods such as web scraping. However, this could lead to legal issues.

Another challenge is managing high traffic at similar times of day, which could slow down the ingestion of data and analysis of sleep scores. It will be important to address these challenges to ensure the usability of the application for a large number of users.

## 4. ANTICIPATED OUTCOMES

The Sleep Score Explanation System is expected to have the following outcomes:

### 4.1 Improved Sleep Quality

By providing personalized insights and recommendations, the Sleep Score Explanation System aims to help users improve their sleep quality. With a better understanding of the factors affecting their sleep quality, users will be able to adjust their habits and behaviors to optimize their sleep. The anticipated outcome is a higher proportion of users achieving the recommended 7 hours of sleep per night and experiencing the benefits of proper sleep hygiene, such as improved mood, cognitive function, and overall health.

### 4.2 Validation of Explainable Regression Models

The use of explainable regression models in the Sleep Score Explanation System presents an opportunity to validate their effectiveness in real-world scenarios. By testing the accuracy and usefulness of the model in predicting sleep quality and providing tailored recommendations, this study can provide insights into the feasibility of using these models in other health applications.

## 5. Conclusion

The sleep score explanation system is a proposed application with the goal of providing actionable recommendations to users based on the uninterpretable sleep scores of other sleep analysis applications. The application will incorporate an explainable regression model where when given a user's sleep score and sleep hygiene habits it will provide the importance of each of the habits towards the sleep score. This allows for custom recommendations for users to generate so that they can take steps to improve their sleep quality.

## 6. Future Work

As this is a proposed design, the next step would be the actual implementation of the application and models in the form of a minimal viable product. It is vital that the application is tested thoroughly and the model is accurate so that the goals of this system can be reached.

Once the base functionality of this application has been established, the focus would shift towards enhancing the accessibility of the system. This could entail improving the speed of the system, especially for the explainable regression model, enhancing the accuracy and explainability of the model, and integrating more sleep analysis applications. The ultimate goal of these enhancements is to ensure that the application can provide widespread easy-to-use help to its users.

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