Do we dream or do we have a nightmare?

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Abstract

Sleep is fundamental to the overall health and well being of humans. There are five stages of sleep: 1, 2, 3, 4, and REM (rapid eye movement) sleep. We cycle through the stages from 1 to REM, and then repeat. Stages 1 and 2 are classified as light sleep, stages 3 and 4 are referred to as deep sleep, and stage 5 is REM sleep. Sleep is so crucial to our ability to function on a day-to-day basis and is largely dependent on our daily routine and environment factors, such as temperature, darkness, quietness, emotions, and eating patterns. By studying daily environmental and behavioral patterns along with the sleep/wake patterns of users, I will analyze how these factors impact a user's overall sleep.

Introduction

Sleep is fundamental to the overall health and well being of humans and is therefore a widely studied phenomenon. As mentioned above, when we fall asleep and how we sleep is largely affected by our behavior leading up to falling asleep. The more consistent our routine, the better we sleep. In addition, environmental factors, such as temperature, darkness, and quietness affect how we sleep.

Therefore, by studying daily environmental and behavioral patterns along with the sleep/wake patterns of users, I will analyze the relationships between the various factors. As a result, I seek to discover the key factors that are impacting users sleep patterns, both negatively and positively, in an effort to improve the overall sleep of the users.

First, I will collect user-inputted data related to their daily behavior, including overall nutrition, exercise information, usage of technology prior to sleep, current emotional state, and environmental conditions at time of sleep such as quietness, temperature, and darkness. The second consists of collecting user-generated data during the actual period of sleep. Using this user-generated information, I can build a network which categorizes how all of the factors mentioned above impact sleep. By analyzing the network, I will determine which factors strongly affect the sleep/wake patterns of a user and which factors do not play as strong of a role.

Previous work

I will briefly describe a few approaches to the problem of analyzing the sleep/wake pattern. In relation to my work, these fall into two categories: applications that monitor the sleep behavior of a user and algorithms/studies that analyze movement events and the different phases of sleep using accelerometer or other sensor data.

Most of the current sleep apps focus on waking the user up at the optimal time. Sleep Bot and Sleep Cycle are two popular sleep tracking phone applications. They use accelerometer and other movement related data to estimate the sleep phases of the user. The user can set a target time to wake up, and then the app will wake the user when they are in the light sleep phase and near the target time. They can also see a time based graph which displays the different sleep phases. This is closely related to my approach, but I am also focusing on collecting and analyzing data related to user behavior before and after sleep.

There are numerous algorithms and studies related to using movement data collected during sleep to estimate the sleep/wake pattern. I will briefly discuss one that relates closely to my approach. During this study, three professors at the University of Virginia collected movement data using the WISP platform: active RFID-based sensors equipped with accelerometers. They compared the results using these WISP sensors to both pressure sensors embedded in a mattress and to a simple iPhone application, which is similar to my method. Their method was 100% accurate in detecting discrete movement events during sleep and is 90% accurate at determining body position on a bed. This study is one of many in the field of using sensor data to analyze the sleep/wake patterns.

Approach

I built an Android application that collects user-generated data related to their sleep/wake patterns and their daily behavior. Before going to sleep, the application collects data corresponding to the exercise/general activity of the user, the number of caffeinated drinks consumed throughout the day, their current emotional state and stress level, the current temperature, the amount of time they spent using bright-screened, electronic devices prior to going to sleep, how quiet the environment is, and the lighting situation (dark/light). It collects this data through a short question and answer format for the user to fill out. The user then leaves the phone on their bed while they sleep and it records the movement related data to their sleep/wake pattern. It uses the accelerometer in compatible phones to collect and measure data related to the movements of the body during sleep, which can be related to the different stages of sleep, as mentioned prior. The accelerometer sensor records five measurements per second and records the x, y, and z acceleration measurements in m/s^2. Every 40 measurements, the application sends the data to a server running in Google App Engine, which stores it for processing at a later time. Finally, once they wake up, the app will display information to the user regarding their sleep/wake pattern via a time-based graph of movement events. They will then fill out another quick survey answering their current emotional state and to rate their previous night of sleep.

I am using the accelerometer built into a user's phone in order to measure movement data while they sleep. These accelerometers are not the most accurate method to measure movement patterns, especially since the phone is placed on the bed next to the user. A more accurate method would be to place sensors on the user or cover the mattress with an array of sensors, but by using the accelerometer within the phone I can create an inexpensive and unobtrusive method to collect reasonably accurate movement data.

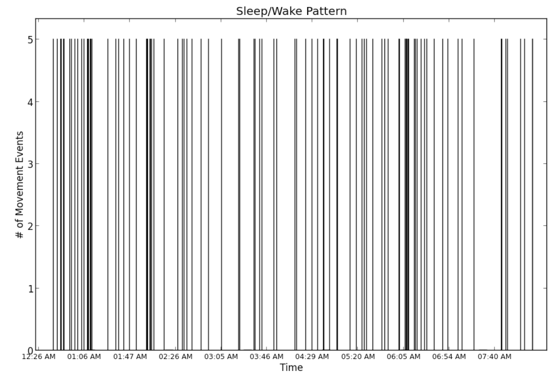
Estimating the phases of a user's sleep using solely measurement data is very difficult. The stages of sleep are characterized by noticeable changes in brain waves, body temperature, and heart rate. However, recording measurements related to these different factors would require external sensors and hardware, while I assume that I can reasonably estimate the phases of a user's sleep through the patterns of movement events throughout a night of sleep, as previous studies have shown.

Once I have gather user data, I will begin to create the initial networks representing the data and analyze/visualize the network using the tools mentioned in class. From this, the relationships between the various factors that impact sleep and how the user is sleeping can be analyzed, in order to improve the user's sleep.

Experimental setup and results

So far, I have collected data using the application myself over the course of three nights. I was most interested in trying to determine movement events from the accelerometer data. The algorithm I used consisted of calculating the mean and standard deviation of the x, y, and z accelerations. Any acceleration measurements that were outside of the mean plus/minus three times the standard deviation were classified as movement events. If multiple of these events were clustered together within five second, I considered these to be legitimate movement events.

The graph below illustrates these movement events over one night of sleep. At the start, there is a cluster of movements when I am first falling asleep, and then two clusters of movement events in the middle of the night that correspond to points in the night when I woke up. The results do indeed correspond to actual movement events, but I need to gather more data in order to verify these results. I plan on collecting data in a more controlled setting, a control setup, where I can simulate movement events and non-movement events.



Conclusion and short-term plans

By studying daily environmental and behavioral patterns along with the sleep/wake patterns of users, I will analyze the relationships between the various factors. As a result, I seek to discover the key factors that are impacting users sleep patterns, both negatively and positively, in an effort to improve the overall sleep of the users.

For milestone 2, I have two main goals. First, I will switch to using the algorithm discussed prior, since it is accurate and relies only on x, y, and z accelerometer data. It is based on looking at the derivative of the accelerometer data with respect to time. The key part of the algorithm is establishing a threshold value for the movement events, so I plan to gather user data through control situations in order to distinguish between movement and no movement.

Secondly, I will make small changes to the application and the Google App Engine server in order to allow multiple users to use the application. The changes are mainly need to keep track of user information, as well as tagging accelerometer data collected over one sleep period together. From this, I will collect data from 5-10 users over a 1-2 week period in order to have enough data to begin to analyze the relationship between the factors mentioned throughout this paper and the user's sleep/wake pattern.

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