

Problem:

Sleep is an understated need in our society. Many people don't recognize the importance of sleep in our day to day lives especially college students. An article by the University of Cincinnati states, "college students could be undermining their own education, simply because they're not practicing proper sleep habits". The study found that out of 200 undergraduate students, only 24 percent of the students reported getting enough sleep. Students were obviously sacrificing sleep due to academic and financial concerns. This sleep deprivation comes with a plethora of cons including but not limited to caffeine dependence, alcohol dependence, obesity, poor memory, poor creativity, increased impulsiveness, overall poor judgement, increased stress, suppressed immunity, and an increased risk of cardiovascular disease as a result of rising blood pressure.. Not only does it matter how much we sleep but also when we wake up. The National Institute of Neurological Disorders and Stroke (NINDS) states "People awakened during deep sleep do not adjust immediately and often feel groggy and disoriented for several minutes after they wake up. Waking up groggy gives us that urge to press the snooze button and fish for those extra sweet minutes of sleep often making us late to our engagements.

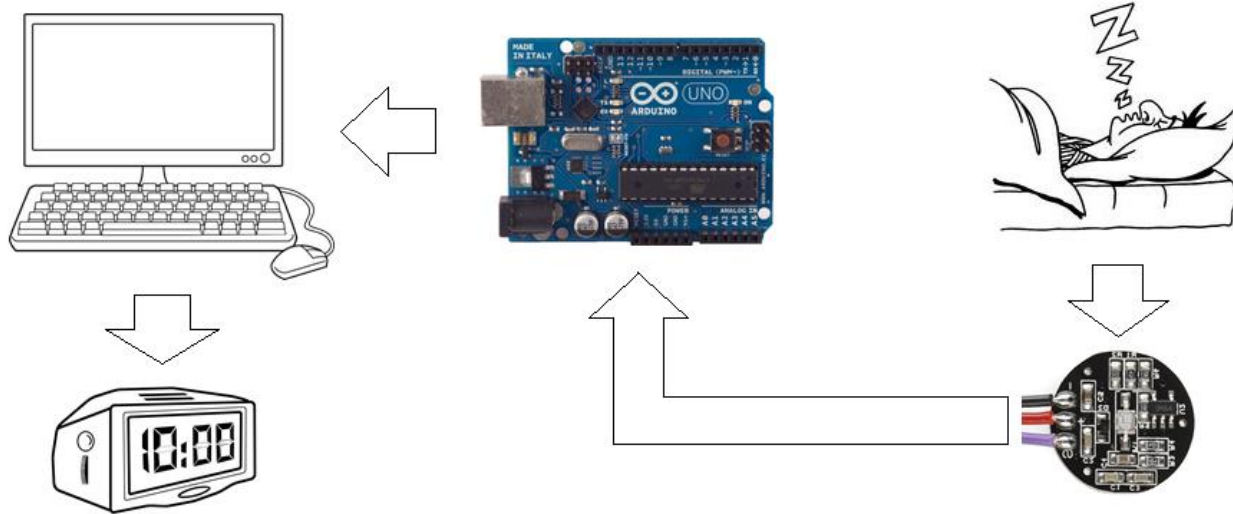
Personal Interest:

My interest with sleep came from a link between sleep and mental illness. In a talk given by Russell Foster, a British professor of circadian neuroscience at Brasenose College at the University of Oxford, it is stated "The neural networks that predispose you to normal sleep, give you normal sleep, and those that give you normal mental health, are overlapping. He further mentions that mental disorders such as schizophrenia smash our sleep system and that sleep disruption actually precedes certain types of mental illness such as bipolar disorder. He also mentions that certain data shows that sleep disruption may actually exacerbate or make the mental illness state worse. This resonated with me because I suffer from adjustment disorder caused by repeated childhood traumatic occurrences. Desperately seeking a way to cope with my mental illness I overlooked sleep completely. This made me search for devices that monitor sleep. By monitoring my sleep I believed that by regulating my sleep I could attain some relief from my mental illness. This project gave me the opportunity to create my own sleep monitoring system.

Device Proposal:

I propose a simple device that uses a heart rate sensor in order to detect the distinct sleep stages that we go through every night. Tracking the stages of sleep is important because we need a certain percentage of each stage in order to gain full restorative sleep. Once the data is collected a computer will process it and based on heart rate separate the stages and calculate the time spent in each. Then using research standards compare it to the normal or necessary percentages of each stage giving the user a report of how well they slept. Also the device will have an alarm component. By gathering and processing data in real time the device will be able to find the best time to wake you up based on when you want to wake up and when you are in the first stage of sleep which is the stage when we can be woken up easily without the side effect of grogginess. This device would encourage sleep by monitoring the amount and quality of sleep and giving the user a description of their sleep process allowing them to get help if needed be attempting to solve both problems of sleep deprivation and waking up groggy.

System Diagram



Related Systems:

Listed below are some sleep tracking systems chosen to show the variety of sleep tracking gadgets all falling under the quantified-self technology sphere. The quantified-self devices are devices that keep track of our day to day personal data such as how much we weigh, how much we sleep, how often we exercise, our peak heart rates when we exercise, our resting heart rates, our temperature. These devices collect our data and attempt to analyze it or just present it for our knowledge so that we may improve ourselves in some way.

Zeo Sleep System

Zeo Inc. actually went out of business but their device idea for sleep tracking was unique to the rest of the market so I thought I'd mention it. The Zeo sleep system uses a headband that measures the electrical current of the brain and allows for a more accurate detection of each individual sleep cycle. The head band syncs information to an alarm clock looking device which then uploads the information to the internet. The data is represented in a graph that shows when an individual is awake, in light sleep, deep sleep and REM sleep. It shows the amount of minutes in each stage and compares these results to the average readings. Also the data provides its own sleep scoring by adding the "good sleep" numbers and subtracting the awakenings so that one may compare each night's sleep quality and to an average person in your age group. The device also comes with an alarm feature that wakes you up to half an hour earlier so as to wake you up during your lighter sleep stage in order to prevent a groggy wake up call. This device does everything that I hope my device does except it uses an EEG sensor and mine will use a heart rate sensor which is a much simpler approach.

Luna Sleep System

The Luna system is a bed cover that senses motion and regulates temperature. The system utilizes ballistocardiography in order to track sleep measuring heart rate breathing rate. With this data it can isolate the individual sleep stages. The system also includes a smart alarm system which wakes the user at the appropriate time for a groggy free morning. The temperature regulator allows the user to adjust the bed temperature to his or her liking, each side of the bed having its own temperature setting. The device gathers information on when the user normally goes to sleep and automatically adjusts to the users schedule altering the temperature of the bed when the user is about to go to sleep. My device will measure heart rate just like this device in order to ascertain the individual sleep stages however my device will take the shape of a finger cuff while luna system consists of a bed spread. My proposal also does not include the addition of a temperature regulation device but includes the smart alarm. My device will not monitor respiration as well.

Beddit

This system also utilizes a motion sensor and uses ballistocardiography in order to monitor the users sleep. This device uses a much smaller motion sensor in order to detect heart rate and respiration and syncs the data to the user's IOS device or android device. The device also keeps track of snoring, the time it takes to fall asleep, total sleep time and bed exits. It takes this information and gives the user a sleep quality reading. My device again will only track heart rate but will still give the user sleep stage information and a quality of sleep report. The Beddit device does not include a smart alarm feature that wakes the user based on sleep cycle. My device however will.

Goals:

Short Term

My short term goal is to construct a heart rate sensor that can be used with the Arduino board and write a program that measures my heart rate throughout a night's sleep. A goal inside of this will be learning how to program the Arduino board itself. Another short term goal is to find a programmable alarm either on the computer or a simple speaker attached to the Arduino board.

Long Term

My long term goal is to figure out a way to use the sleep research and the heart rate data in order to isolate individual sleep stages within a program. This program would also calculate the percentage of time within each stage and compare the results to studied averages to give the user an idea of how his or her data compares to the average person. The data acquisition and analysis would be done in real time. Another long term goal will be to figure out how to trigger the alarm at the correct time as to wake the user at the best possible time.

Final

My final goal is to combine everything done before and finishing the alarm calibration and finding a way to represent the data. This may mean finding a simple graphing library that could represent the data in a bar or line graph. Also this phase would include working out any final bugs.

Benefits / Expected Outcomes:

The educational benefits alone will be great. I will have learned how to program an Arduino board in C. I will learn how to use a sensor to measure heart rate and also how to use a sensor within a real time system. Another benefit may come from the device as well. It may result in me understanding my sleep patterns better and getting more sleep because well the device will need to be tested thoroughly. I expect a lot of errors as well. For example the heart rate sensor may not work as well as necessary in order to gain the required data. I fear the sensor may fall off during sleep and that wearing the sensor on my finger will result in disturbed sleep. I may jerk during my sleep and dislodge the sensor as well as harm the device. I think all in all that I will collect sufficient data and create at least a semi workable device that will accomplish the goals of this project.

Assumptions:

One assumption which should be obvious is that the user is human. The interface will require that the user turn on a program on the computer. Another assumption would be that the user have fingers. The sensor comes in the form of a small finger strap. The next assumption is very hopeful and that is that the user stays semi still so as not to pull the sensor out of the Arduino or slip the sensor off of his or her finger. The user would also have to have a heartbeat. The pulse sensor won't work without a pulse. The last assumption that I can think of is that the user have a computer with a linux system because the program is not cross platform.

Methodology:Studying Sleep

From the National Institute of Neurological Disorders and Stroke website we learn that sleep is not dormant state as previously thought. Our brains are quite active during sleep and the mechanism that transpire during sleep affect our daily function and our physical and mental health. When we sleep we go through five phases of sleep. The first four are numbered one through four and the final stage is called REM short for rapid eye movement. The phases cycle throughout our sleep going from one to REM and then back to one again. A paper in Neuropsychopharmacology titled *Dynamics of Heart Rate and Sleep Stages in Normals and Patients with Sleep Apnea* states that we spend 50 – 60% of our sleep in light sleep (stages 1 – 2), 15 – 20% in deep sleep (stages 3 – 4), 20 – 25% in REM, and 5% or less is spent in wakefulness. This sequence called the sleep cycle has a typical duration of 90 – 110 mins. A normal sleeping period consists of six sleep cycles.

Stages one and two are considered light sleep. In this phase we drift in and out of sleep and can be easily awakened. This is the best time to be awoken. Our eyes move very slowly and our muscle activity slows as well in this phase. When people awake in this stage, they remember fragmented images and many may experience sudden muscle contractions followed by the sensation of falling. When we begin stage 2 of sleep, our eye movements stop and our brain waves slow with occasional sudden bursts of rapid waves called sleep spindles.

Stages three and four are considered deep sleep. In stage three, the extremely slow brain waves called delta waves occur with sleep spindles interweaved. Following this the brain produces delta waves exclusively in stage 4. It is more difficult to wake someone from these two stages. These are the stages during which if we are woken we wake up groggy.

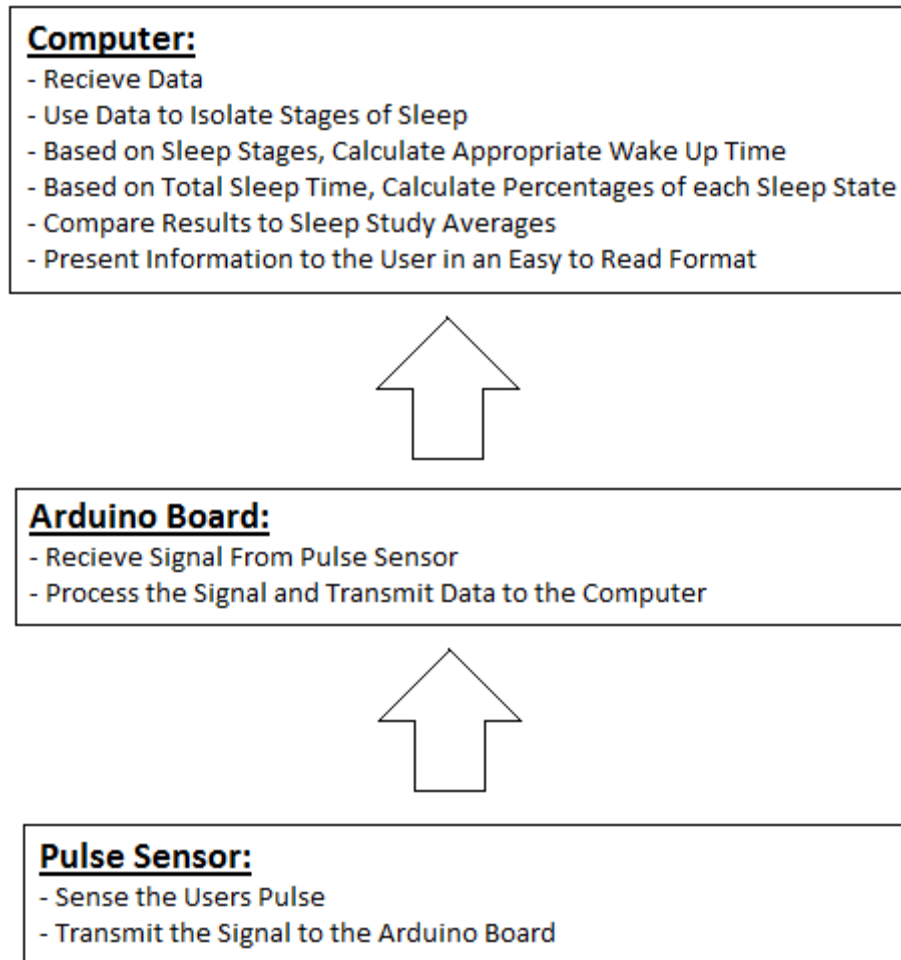
After deep sleep we enter REM sleep. During this phase our breathing rate increases, becomes irregular, and shallow. Also our eyes jerk quickly in random directions, our muscles become temporarily paralyzed, our blood pressure rises, our heart rate rises, and males develop penile erections. If we are awoken during this time, we can describe bizarre and illogical tales. The first REM phase usually occurs around 70 to 90 minutes after we fall asleep. The first sleep cycles contain long deep sleep periods and shorter REM phases but as the cycles progress the REM phases becomes longer and the deep sleep periods become shorter.

Heart Rate Study

In the paper mentioned above it states that your average heart-rate values drop from wakefulness to light sleep and further to deep sleep. It further mentions that during REM sleep your heart rate increases again showing a high variability, which may exceed the variability observed during quiet wakefulness. Further an article by Walt Pickut called *What Is a Normal Heart Rate While Sleeping?* it states that predicting your normal sleeping heart rate depends on your normal heart rate. In addition it states, "Dr. K. Krauchi, in a study reported in "Neuropsychopharmacology" (2001), detected an average drop from 64 to 52 beats per minute, about 8 percent, by the end of his subjects' gradual sleep onset.". With this information one can approximate his or her sleep onset heart rate by subtracting 8 percent from their awake-resting heart rate.

Assembling the System

With this information a sleep pattern detection system can be created. First we know that heart rate dips about eight percent as we descend into our light sleep phase. Using this information when the system detects a slowdown in heart rate it can safely assume that the user is entering his or her light sleep phase so it can begin timing the light sleep phase. Once the system detects another heart rate decrease it will know to stop the timer for the light sleep phase and to start the timer for the deep sleep phase. After that the system will wait for an increase in heart rate and cease timing the deep sleep phase and begin timing the REM sleep phase. The next phase will be triggered by a decrease in heart rate being the light sleep phase again. The system after analyzing the first cycle will be able to categorize the separate stages of sleep. The system will also have to keep track of instances during which the user awakens during his or her sleep. These occurrences will be marked with sudden increases in heart rate. The start and finish times of the sleep term will be the user running the program and terminating it or putting the sensor on and taking it off. With all of this timing information, percentages can be calculated for each sleep phase. Then the calculations can be compared to averages stated above and the user can see how he or she is doing compared to expected results.

System Flowchart**Timeline/schedule:**

Task	Approximate Completion Date
Learn How to Program the Arduino	4/15/15
Learn How to Use the Heart Rate Sensor with the Arduino Board	4/17/15
Write a Program to Read in the Heart Rate Signal	4/18/15
Write a Program to Collect the Heart Rate Data Over a Long Period of Time	4/19/15
Write Code to Segregate Different Heart Rate Zones	4/22/15
Alter the Code to Ignore Short Term Abnormalities with the Sensor	4/17/15
Add the Alarm Component	4/18/15
Write Code to Have the Alarm be triggered by Changes in Heart Rate	4/18/15
Debug the System All Together Collecting Multiple Sets of Data	4/19/15
Change the Code to Display the Results in a User Friendly Format	4/20/15
Final Runs and Error Checks	4/22/15

Strengths of the System:

The data acquisition may not always be accurate or consistent but using a large computer, there will be a lot more capability to error check and improve the results so since the system has additional computing resources makes it more stable. The sensor being attached to the user's finger makes it more stable than other systems using a motion sensor pad that can be easily moved away from during sleep. By only measuring heart rate, the system is more simple and understandable by the user. The user is able to understand the data better because they aren't bombarded with multiple variables or additional features.

Limitations:

Some limitations that the system has is that first of all is that you have to wear it. A finger cuff sensor may result in it being unplugged during sleep. It may also disturb the users sleep because he or she will have to be worried about accidentally unplugging it. Another downside is since I'm using a computer to process the data, the system consumes a lot of power. Plus the computer is a major resource that would be immensely underutilized. Another limitation is that the system probably won't be that accurate. Using heart rate to discern sleep phases isn't that accurate and the sensor may shift and or fall off altering the results. The program processing the data will be susceptible to a lot of accuracy error and all of the errors may not be able to be accounted for.