

### **Abstract:**

Sleep deprivation is a major problem in the United States especially amongst 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. In order to tackle this problem companies have invented simple sleep monitoring systems in order to track sleep cycles. My system works to track sleep by using a heart rate sensor.

### **Introduction:**

The system consists of a processor, Arduino board and Pulse sensor. The Pulse sensor came preassembled and the processor I used is an Intel i5 quad core processor. The goal of the project was to see if I could use the sensor to isolate different sleep stages and use that information to produce a sleep progress report which would inform the user on how much time he or she spends in each stage. Then using medical averages I hoped to tell the user on how well he or she was sleeping. Also I wanted to figure out a way to activate an alarm at the opportune time for someone to wake up.

### **Background:**

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.

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.

### **System Description:**

The system consists of the following: an Arduino board, an Intel i5 quad core processor, and a pulse sensor. The pulse sensor came with two programs. The first of which is uploaded to the Arduino and performs the analog to digital conversion of the pulse signal and outputs the signal to the computer. The second program is a processing program that processes the data and outputs a graph of the heartrate. I managed to tweak the second program to output the data into a text file. I wanted to initially write a program to process static data and then tweak the program to perform the calculations as the data is being collected so that when the user wakes up the data is already processed and ready to be viewed. I however never made it to this stage and was only able to collect the raw data. I didn't manage to write a processing program. When I acquired a new sensor I made the wire longer as can be seen in the image below. Please ignore the green board.



### Experiments and Results:

The project wasn't completed so the only experiment I performed was a preliminary test of the given programs provided by the Pulse Sensor site. I ran the tweaked processing program and managed to collect a small amount of data from two short sleep periods. I ran into complications because the sensor fell off for the first run and for the second run the sensor broke when yanked from the Arduino probably due to a head jerk occurring mid sleep. I decided to attach the sensor to my ear the second time around hoping that it would stay on better then on my finger attached by a Velcro strap. The following images show the data collected. As you can see heart rate does in fact change mid sleep. This proves that the project is viable.

#### Heart Rate Data Collected:

Transistion Point 1:	Transition Point 2:	Transition Point 3:
81	55	95
83	55	99
85	55	104
87	55	79
88	54	67
90	55	62
91	55	61
91	55	61
91	55	61
91	57	60
90	58	60
89	60	58
87	61	56
84	61	68
82	62	79
79	61	87
76	60	92
73	58	81
72	56	79
70	54	81
69	52	84
68	50	89
68	49	94
68	48	94
67	47	95
65	48	96
66	48	96
65	48	120
64	49	127
65	49	131
64	50	135
63	49	124
62	50	116
62	50	116

#### Discussion and Conclusions:

The raw data I managed to collect coincided with the sleep research. What caught me sort of off guard was the variability of heartrate in general. Our hear rates are very volatile so trying to isolate averages and changes happened to be a lot more of a daunting task than expected. I regret not giving myself more time for this project. I had a lot of things to process internally and that I was able to accomplish anything is a feat within itself. Nothing left but to look towards the future.

#### Sources:

<http://www.uc.edu/news/NR.aspx?id=14097>

<http://circ.ahajournals.org/content/91/7/1918.full>

[http://www.ninds.nih.gov/disorders/brain\\_basics/understanding\\_sleep.htm](http://www.ninds.nih.gov/disorders/brain_basics/understanding_sleep.htm)

<http://www.nature.com/npp/journal/v28/n1s/full/1300146a.html#bib3>