Monitoring Relaxation Levels and Abnormalities During Sleep

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The main objective of this report is to put forth our techniques for sleep monitoring which show the person's relaxation levels and abnormalities during their sleep. A good sleep quality has many benefits, of which some of them are, it boosts our immune system, increases levels of productivity, improves memory, contributes in preventing weight gain, lowers stress levels, reduces risk for health issues, like diabetes and heart diseases, and enhances mood. Sleep quality and sleep quantity are two different attributes. Sleep quality refers to the sleep experience rather than the duration, which is quantity. A good sleep quality is preferred over a longer sleep quantity (duration). We conducted an experiment using an OpenBCI kit and a Fitbit device to measure heart rate variability.

1. Importance of Sleep

Sleep plays a crucial role in maintaining our health and allows our body to regenerate cells and heal. Sleep is very closely connected to the body's metabolic and hormonal processes. Lack of sleep lowers the white blood cell count which negatively impacts our body's disease fighting antibodies. It also reduces the production of cytokines and melatonin. Cytokines are chemical messengers which play an important role in reducing infections and inflammations. Melatonin is a hormone that promotes sleep and combats stress, and low levels of melatonin can lead to higher risk for cancer. Sleep deprivation increases the amount of C-reactive protein (CPR) in the body. High levels of CPR increase risks for heart disease.

1.1 Motivation for good Sleep Quality

Sleep tracking helps people suffering with narcolepsy and other problems related to sleep. People who are deprived of sleep have a greater risk for chronic renal disease and diabetes when compared to

those who have adequate sleep. The statistics below shows the difference between individuals with enough sleep and those who are deprived of sleep. Keeping a regular track of sleep quantity and quality can reduce risk for heart diseases, obesity, and diabetes.

	Short sleep (<7 hours)		Sufficient sleep (≥7 hours)	
Chronic condition	%	95% CI	%	95% CI
Heart attack	4.8	(4.6–5.0)	3.4	(3.3–3.5)
Coronary heart disease	4.7	(4.5–4.9)	3.4	(3.3–3.5)
Stroke	3.6	(3.4–3.8)	2.4	(2.3–2.5)
Asthma	16.5	(16.1–16.9)	11.8	(11.5–12.0)
COPD (chronic obstructive pulmonary disease)	8.6	(8.3–8.9)	4.7	(4.6–4.8)
Cancer	10.2	(10.0–10.5)	9.8	(9.7–10.0)
Arthritis	28.8	(28.4–29.2)	20.5	(20.2–20.7)
Depression	22.9	(22.5–23.3)	14.6	(14.3–14.8)
Chronic kidney disease	3.3	(3.1–3.5)	2.2	(2.1–2.3)
Diabetes	11.1	(10.8–11.4)	8.6	(8.4–8.8)

Sleep Quality statistics

1.2 Challenges faced

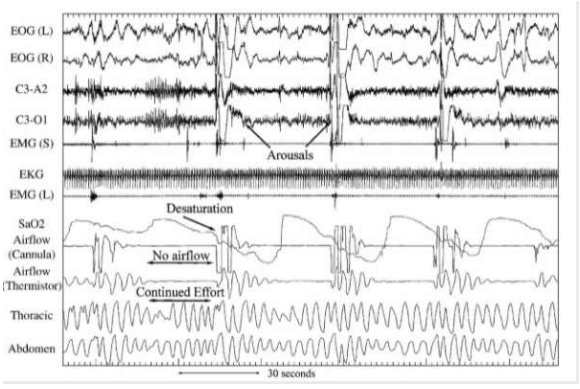
Challenges faced in the project using the OpenBCI Kit:

- The solid electrodes of the OpenBCI kit makes it difficult to sleep, hence affecting the quality of sleep.
- The electrodes should be in contact with the skin (at the back) of the head to acquire EOG, EMG, and EEG signals.
- EEG, EOG, and EMG signals will be affected by the motion artifacts if the pressure on each electrode is not appropriate.
- EOG, EEG, and EMG signals can be affected by the surrounding environment if the experiment is conducted in a less electromagnetic wave environment.

2. Electrophysical Signals

2.1 About electrophysiological signals

Electrophysiology is a branch of neuroscience that is based on the molecular and cellular mechanisms that control the signaling of neurons and their electrical activity. Neurons use these signals to communicate. Change in electrical potential produced in the tissues, muscles, and organs are known as electrical bio-signals.



2.2 Electrooculography (EOG)

It is a method used for measuring the corneal-retinal standing potential that exists between the front and the back of the human eye. The resulting signal is

called the electrooculogram. Its primarily used in ophthalmological diagnosis and in recording eye movements. It does not measure response to individual visual stimuli unlike the electroretinogram.

2.3 Electroencephalography (EEG)

It is a diagnostic imaging test which records the brain's bio-electrical activity by using metal electrodes that are glued to the scalp. Sometimes, these electrodes are also placed in the brain matter or on the surface of the cortex. Brain cells generate electrical impulses through which they communicate. These are converted into waves by the electrodes on the electroencephalogram, which are then recorded by the polyphonic machine and then transmitted to a computer screen.

2.4 Electromyography (EMG)

It used to evaluate function of nerves and muscle functions by keeping a record of the electrical activity generated by the skeletal muscles. It plays a crucial role in diagnosing neuromuscular disorders and to evaluate disorders of peripheral nervous system.

2.5 Choosing an EEG for the experiment

The main aim of the experiment is to determine the quality of sleep. EEG is a biological signal that can reflect physiological changes of the human correctly and smoothly. It also has a resolution in milliseconds which is better than other imaging techniques like PET, SPECT, fMRI, etc. It has crucial reference data and can accurately represent the brain's activity. Hence, it is important to have accurate representation as it determines accuracy of sleep quality.

3. Sleep Cycle, Sleep Stages, and Bio-Signals in every Stage

3.1 Sleep cycle

There are multiple stages in human sleep cycle. An individual goes through three to six sleep cycles each night. All cycles are not of the same duration and each cycle lasts from about 70 to 110 minutes.

3.2 Sleep Stages

There are about three phases in ach sleep cycle, which are, wakefulness (W), non-rapid eye movement (NREM), and rapid eye movement (REM). The NREM is split into three phases, N1, N2, and N3. Hence, the four main sleep stages are N1, N2, N3, and REM.

- N1

  This stage lasts for about one to five minutes and is referred to as the powering off stage. The body and brain start to decelerate their function through brief movements. There are minute changes in brain activity and its very easy to wake someone in this stage of sleep, but if undisturbed they will transit into N2.

- N2

  This cycle lasts for about ten to twenty-five minutes. The human body relaxes by reducing the temperature, relaxing its muscles, and decreasing the heart and breathing rate. This is followed by the change in brain waves and eye movement finally stops. With the decrease in brain activity, the brain resists the brief bursts of activity.

- N3

  This cycle lasts for about twenty to forty minutes and its difficult to wake someone at this stage. This causes a drop in muscle tone, respiratory rate, and pulse causing the body to relax more. A noticeable pattern of brain activity occurs in this stage, which is known as delta sleep. This cycle is plays a critical role in physical growth and regeneration, along with providing aid wo creativity, perceptive thinking, and memory.

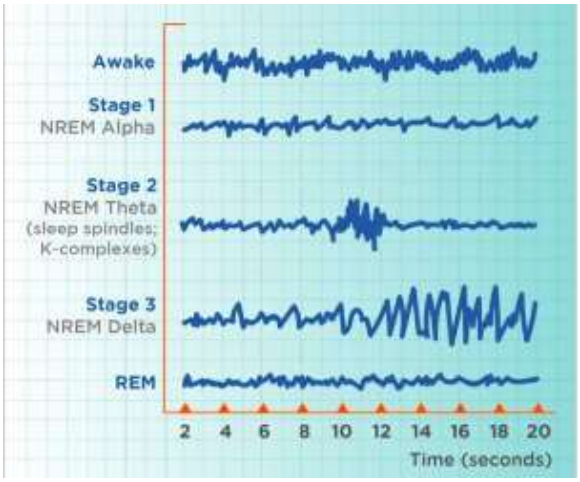
- REM

  This lasts for about ten to sixty minutes. Brain activity increases to the levels that are experienced when awake. This increase in brain activity is responsible for vivid dreams.

3.3 Brain waves in Each stage

EEG recording during each stage of sleep:

- Brain produces alpha waves during the N1 stage
- Brain produces theta waves the body transitions itself from N1 to N2 stage.
- Brain generates delta waves in the N3 stage. The N3 stage is often referred to as the delta sleep.
- During the REM stage the brain produces waves similar to those generated when the brain is active.

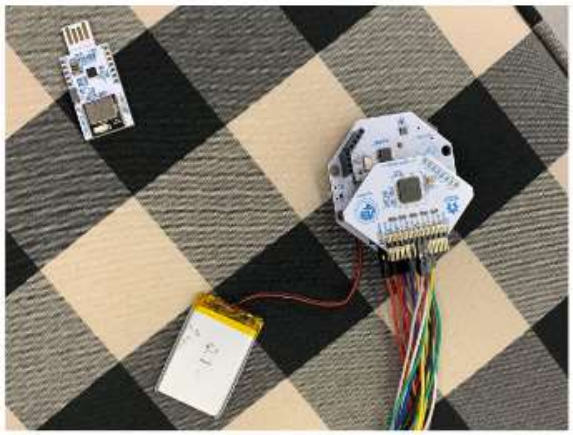


EEG waves in each stage

4. Equipment Required

4.1 OpenBCI Kit

The OpenBCI Kit used in our experiment contains a Cyton Board with 8 channels, 5V battery, Daisy Board optical extension with 8 channels, a Dongle that is plugged to the laptop or PC, and a jumper that is attached to the electrodes from the Cyton pins.



Engineering Principle: It is an open-source brain-computer interface that enables us to collect and visualize the waves produced by the brain on the computer. The user must attach the electrodes around their head and apply adequate pressure to capture the EEG signals and collect data that is non noised.

In our experiment the electrodes are laid on the pillow and user has to sleep on the set up. The OpenBCI Kit then acquires the data and displays it on the computer through the companion software.

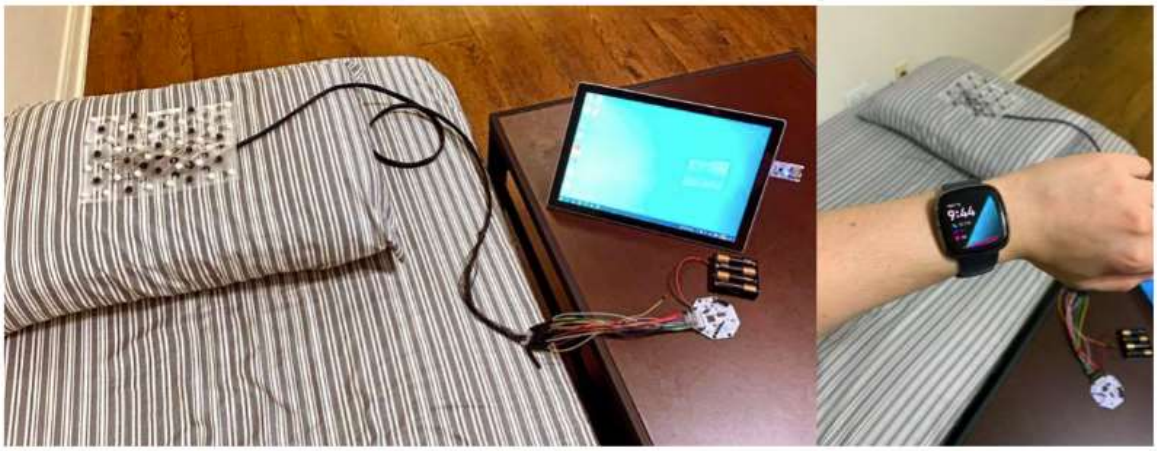
4.2 Fitbit Sense

Fitbit Sense is a variant of Fitbit device with an innovative smartwatch. It has functions that understand the stress level and heart level of the user.

Engineering Principle:

It uses a combination of movement and heart-rate patterns to analyze sleep phases. The values change as you move through the different stages.

5 Procedure



5.1 Experiment Set-Up

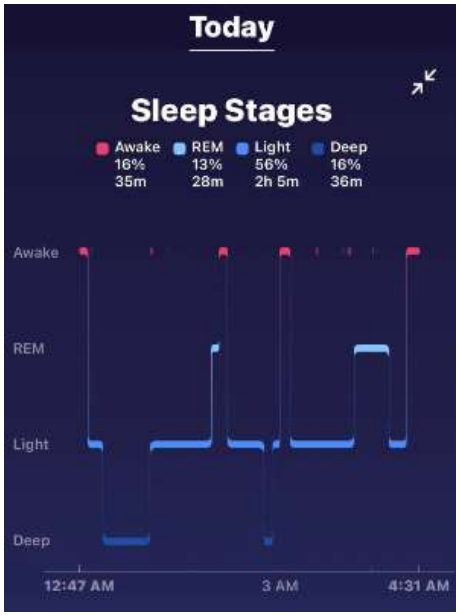
The pad consisting of the electrodes is placed in the middle on the relatively soft pillow, soft pillow is used to guarantee the comfort and the appropriate pressure is applied on each electrode. The wires connecting to the electrodes are coming out and connect to the pins of the Cyton Board, which is powered by the 5Vbatteries. The Dongle is plugged into a personal PC that is responsible for receiving the data transmitting from the Cyton Board and displaying them on the PC. At the same time, the user also must wear the Fitbit Sense on the wrist. Hence, both devices can simultaneously collect user's data during sleep. Moreover, the room temperature should be adjusted comfortably for to user to achieve the best sleep, and other electronic devices have to shut down to limit the electrical noises that potentially could affect the data of the OpenBCI Kit.

5.2 Experiment Procedure

The user must now sleep on the electrodes and the recordings are logged into a csv file which helps the user to look after the user wakes up.

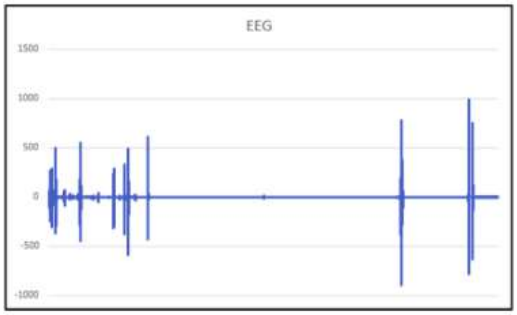
5.3 Experiment Results

- Fitbit Results:



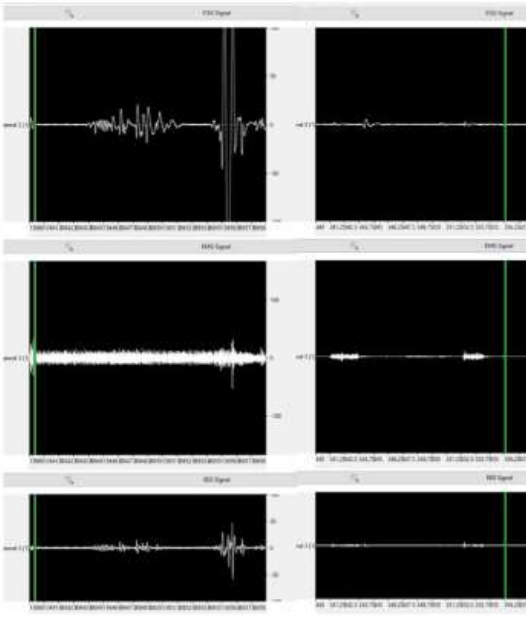
There are many false detections even though there were no wakeups during the sleep duration.

- OpenBCI Kit Results:



There were no detections of false waking-ups. But the OpenBCI Kit's signals could be noised by other artifacts.

- Abnormalities in Results:



There were many fluctuations in the EOG and EMG. These abnormalities indicate that the eyes were moving, and the teeth were grinding during the user's sleep.

5.4 Experiment Evaluation

- The OpenBCI Kit performs better than the Fitbit since the Fitbit indicated false wakeups.
- The OpenBCI Kit is less comfortable than Fitbit.
- The OpenBCI Kit can detect abnormalities as is captures EMG and EOG, while Fitbit only detect variations on heart rate.
- The OpenBCI Kit's signals could be noised by other noises, but Fitbit cannot be noised by other artifacts.

6. Solutions for Bad Sleep

- Increase in bright light exposure during the day.

  Natural sunlight and bright light during the day helps maintain a healthy circadian rhythm, which improves sleep quality and duration.

- Reducing blue light exposure un the evening.

  Blue light tricks the brain into thinking that its still daytime which affects the circadian rhythm and reduces hormones like melatonin, a hormone produced by the pineal gland in your brain that is responsible for regulating body's circadian rhythm to manage your natural sleep cycle.

- Avoid intake of caffeine and food late in the evening.
  Eating late at night negatively affects both sleep quality and the natural release of HGH and melatonin. Though caffeine has many advantages, consuming it late in the day simulates the nervous system and stops the body from naturally relaxing during the night.

- Keep a regular sleep-wake cycle.

  Body's circadian rhythm functions on a set loop by aligning itself with sunrise and sunset. Irregular sleeping patterns alter the circadian rhythm and levels of melatonin.

- Sleep in a dark, quiet room with a comfortable temperature.

  Minimize external noise, light, and artificial lights from devices and ensure that the room is quiet, relaxing, and clean. Increase in body and bedroom temperatures can decrease sleep quality and increase wakefulness.

- Avoid exercising 2-3 hours before bedtime.

  Exercise helped people with insomnia by reducing time to fall asleep, total night wakefulness, and anxiety and increasing the total sleep time. Though exercising helps for a good night sleep, exercising close to bedtime can cause sleep problems as it(exercising) increases alertness and hormones like epinephrine and adrenaline.

7. Conclusion

The OpenBCI kit gave more accurate results than a Fitbit but it was far less comfortable (than the Fitbit). Monitoring our sleep quality regularly helps us to improve it. A better sleep quality means better physical and mental health.

8. Citations

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