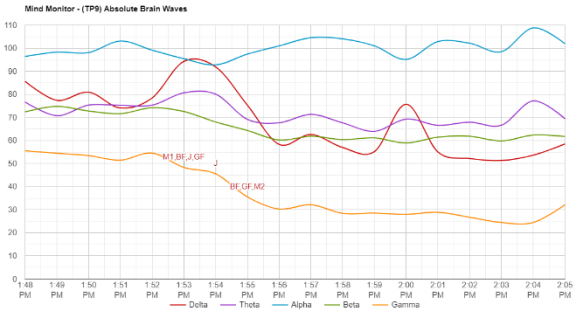
The EEG and Graphs on the Cheap



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Document Purpose

This purpose of this document is to give a brief history and description of an EEG, and also show some of the less expensive models available, along with the easiest software I could find for creating graphs. I do not go into the different brain states (Delta, Theta, Alpha, etc.) as this was covered in class.

What is an EEG

EEG or electro-encephalo-graphy is a way to measure changes in the electrical activity of the brain with metal electrodes (no voltage is sent only received). The signals are digitized, amplified, and then sent to a computer where you can process the information and create graphs.

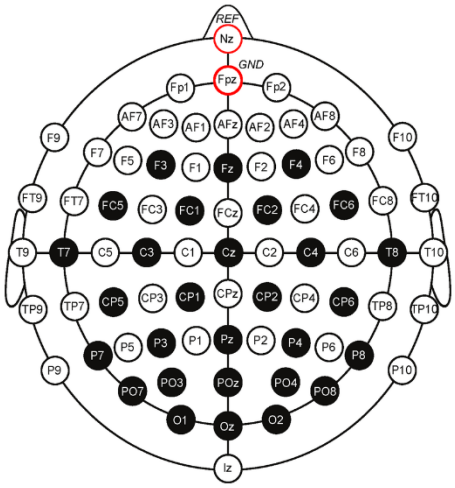
Brief History of EEG

In 1875 Richard Caton was the first physician to publish his findings of electrical activity in the brains of mammals. Adolf Becks experiments in 1890 on dogs and rabbits led to the discovery of brainwaves and EEG to become a scientific field. The first human recordings were done in 1924 by Hans Berger on a boy who already had a hole drilled in his head to treat a tumor. Hans went on to devise a way to record the brain waves without drilling by using non-invasive electrodes and then invented the machine that graphs the waves called the electroencephalogram. His research was largely ignored until 1934 when a couple of electrophysiologists confirmed his findings and went on to start clinical applications, centered around epilepsy, and the EEG has been progressing ever since.

Modern and Emerging Applications

Modern uses for an EEG include many medical applications including diagnosing seizures, epilepsy, head injuries, dizziness, headaches, brain tumors and sleeping problems. The applications in research include education, how people learn and how to improve focus, learning disabilities like ADHD, psychological treatment (cognitive behaviour therapy), and many others. It is also used in advertising to see how people respond to different ads, web sites, or physical store layouts. Controlling objects in a video game or a prosthetic limb, and of course military applications are also emerging. A quadriplegic racer named Rodrigo Hubner Mendes became the first person ever to drive an F1 car by using only his brainwaves in 2017. A lot of these newer devices include heart rate, pupil movement and dilation, breath rate, and more to provide even more feedback. My personal interest is in measuring the different brain states (delta, theta, alpha, beta, and gamma) and how to improve binaural beats audio tracks for things like sleep, relaxation, meditation, etc.

Sensor Placement



The internationally recognized placement map for the electrodes is called the 10-20 system. Electrodes are placed at 10% and 20% points along lines of longitude and latitude. Important points in this system are the Nasion (Nz - the depression between the eyes at the top of the), the Inion (Iz -the bump at the back of the head), and the left and right preauricular points just in front of the ears.

As more electrodes were added to give a higher resolution, the Modified Combinatorial Nomenclature (MCN) system was introduced. As an example the Muse uses the TP9, TP10, AF7, and AF8 locations which are behind the ears and on the forehead.

EEG Hardware and Software

There are many devices available from $99 to over $25,000. The lower cost models have fewer electrodes, are less sensitive, and have less sophisticated software versus their more expensive counterparts. Some devices are headsets, others that require more electrodes are caps, and these can be wired or wireless. There are also two types of electrodes, the dry ones, and wet ones that require gel to be applied first, giving a more accurate (lower impedance) reading. Recently, more manufacturers are emerging with lower cost EEG devices targeted to the consumer and smaller education or research groups. The following is a list of some of those lower cost units.

Neurosky Mindwave Mobile 2

Number of Sensors: 1

Cost: $ 99

Although it only has one sensor for the forehead (FP1 position), and an ear clip for grounding and reference, the price makes it attractive. There are over 100 brain training games and educational apps available from the NeuroSky online store. Some apps are free, some under 10 dollars, the only expensive app was the research tools which cost $499.

Other technical specs:

- Battery Life: 8 hours
- Outputs 12 bit Raw-Brainwaves (3 - 100Hz) with Sampling rate of 512Hz
- Sensor: FP1
- Platforms: Windows, Mac, iOS, Android

Emotiv: EPOC+, Insight

Epoc+

Number of sensors: 14

Cost $699

Insight

Number of sensors: 5

Cost $420

Emotiv have many units available including the EPOC+ and the Insight. There are different software packages available, but their main one for research and education (enables unlimited downloads with import/export capabilities) is based, on a subscription model that costs between $29 - $200 a month. They also have a neat looking BrainViz application ($70) which apparently shows the brains frequency bands in colour coded 3D.

Insight Technical Specs:

- Battery Life: 8 hours
- Outputs 14 bit with Sampling rate of 128 Hz
- Channels: AF3, AF4, T7, T8, Pz
- Platforms: Windows, Mac, iOS, Android

Muse

Muse S

Number of sensors: 4

Cost $350

Muse 2

Number of sensors: 4

Cost $250

Muse has two models, the Muse 2 and the Muse S, both of which can be bundled with meditation software subscriptions, or you can just use the basic free app that comes with them. They have four EEG sensors, two on the forehead and one behind each ear. Unlike the original Muse 1, these units also have reference sensors for heart rate / heart rate variability and breathing rate.

Muse 2 Technical Specs:

- Battery Life: 5 hours
- Outputs 12 bit with Sampling rate at 256 Hz
- Channels: TP9, TP10, AF7, and AF8
- Platforms: Windows, Mac, iOS, Android

Muse Graphing Software

The Muse device is made by InteraXon, and at one point they had an SDK (software development kit) for among other things, capturing live data streams for the muse and graphing them. Unfortunately, that was discontinued in early 2019 and is no longer available, as they are concentrating more on their own software. They do have a service called Muse Direct Cloud which enables the muse (and concurrently streaming Muse devices) to store the streaming raw data, as well it has import export function. It costs about $5 a month but does not provide any reporting or graphs on its own, it just captures the streaming data from the muse and stores it in their cloud.

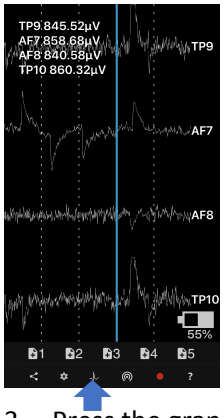
There is a piece of software called Matlab that among other things can do reporting and graphing of EEG data, but it appears fairly complicated and requires some programming knowledge and time to get it operational.

Mind Monitor

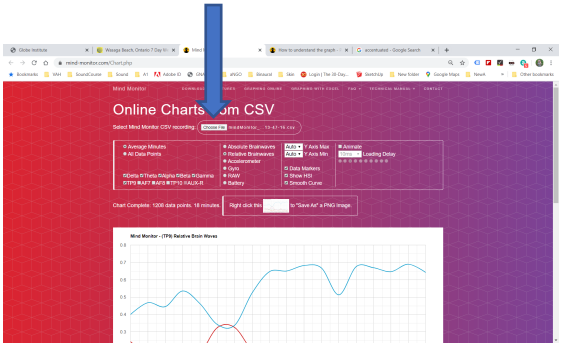
I chose an app to pair with my Muse 1 called Mind Monitor which costs about $15 on the Apple App store. It allows you to either record the raw brain wave data and either stream or send the data via dropbox or email to get it to your PC. It has multiple real time graphs as well as a spectrogram, and there is even a charting website available for the raw data files created by this app. It is written by James Clutterbuck and he also has a support forum available.

Steps To Create A Graph

1. Need a Muse device, The Mind Monitor Software, and a (free available) Drop Box account
2. Turn on the Muse, load the app, and they should sync.



3. Press the graph select button and go to the raw data graph (pictured above) to check each sensor and how good a contact it has. The thinner or less wavy the line the better. Reposition the muse until you get a good fit.
4. Press the graph select button and select which graph you want to view in real time, or just leave it on the raw data graph.
5. Press the red, recording button to start recording. When done press it again. Note: The first time you press it, it should ask for your dropbox credentials, if not they can be entered via the settings icon.
6. Go to your dropbox, double click on the zip file you just created, and then drag the CSV file to a folder that you want to store it in. File sizes are pretty small, a 13 minute session only took 171kb zipped, 450kb for the unzipped CSV file.
7. Open the site https://mind-monitor.com/Chart.php and click on “choose file” at the top and select your CSV file. The graph is then displayed.

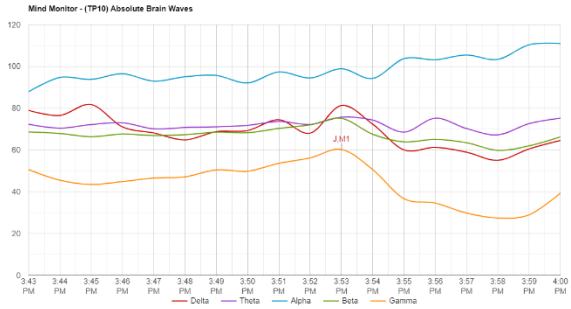


Interpreting Graph Data

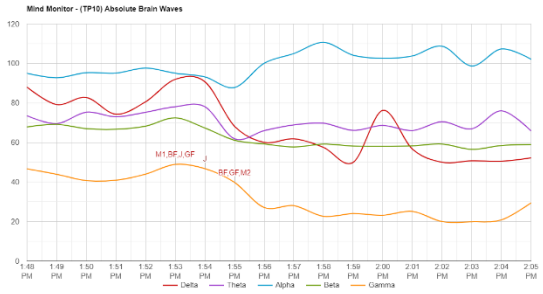
Although the software is very good and easy to use, the biggest downside and frustration I have with this product is interpreting the data. James admits he is a programmer, not a neuroloscientist, therefore getting answers on specific brain wave states is lacking. From his forum these were the most helpful comments I could find:

- “From a meditation stand point, what you should see is that your average Alpha will be higher during meditation than it is during normal activity. You may also see that during meditation the other brainwaves will be lower. It is this effect that people sometimes refer to as being "in" a particular brainwave state.”
- “My personal research has shown that relaxation results in High Relative Alpha, meaning High Alpha and/or lower other waves. You can switch to Relative mode by selecting "Relative Brainwaves" at the top, then the Higher Alpha is, should correlate to higher relaxation, relative to your own personal baseline.”

My Graph Examples

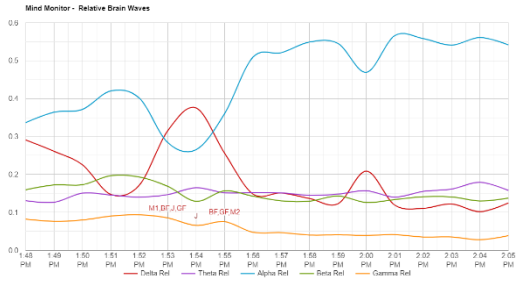


Played puzzle video game until marker (M1) then listened to Youtube video with theta waves and closed eyes. Alpha increased, all others decreased.

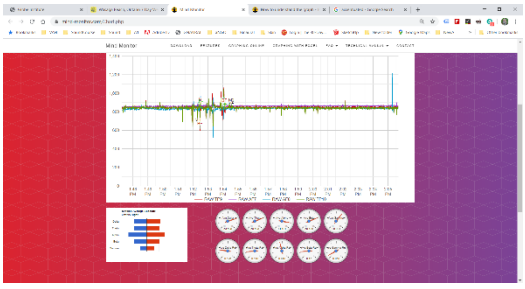


Played puzzle video game until marker 1 (M1), hooked up earphones, then from marker 2 (M2) on listen to a Theta binaural beats track, was almost falling asleep. Alpha increased relative to the others.

Note: J=Jaw clench, BF=Bad fit, GF=Good fit



Here is the same data as above, except showing the waves relative to each other. Not too different except the difference in Alpha is accentuated.



This is also the same data, it just shows the signal quality of each sensor during the session (spiky is bad). Also on the graphing web page it also shows the brain states average in each hemisphere, and there are dials for the brain states for average, and average relative.

Conclusion

As far being able to see a definitive brain state pattern in the graphs, it will take more time for me to investigate. I was definitely a little disappointed with not seeing “Theta” or “Delta” state popping out at

me, however, I am not a Neurologist either, and at least I got something as a start. Hopefully as technology progresses there will be a better and easier solution for the Newbie consumer soon.

Links:

Neurosky: Ultimate Guide to EEG: http://neurosky.com/biosensors/eeg-sensor/ultimate-guide-to-eeg/

Emotiv: Introductory Guide to EEG: https://www.emotiv.com/eeg-guide/

IMOTIONS: The Complete Pocket Guide: https://imotions.com/guides/electroencephalography-eeg/

Mind Monitor Youtube (The Best 3rd Party Brainwave Recording App) Cody Rall MD : https://www.youtube.com/watch?v=OX-4rpCegjk

Mind Monitor Online Charting: https://mind-monitor.com/Chart.php

Mind Monitor Forum: https://mind-monitor.com/forums/viewforum.php?f=19

Muse Forum: https://community.choosemuse.com/