BACKYARD BRAINS

Neuroscience for Everyone!

Heart and Brain SpikerBox:

Record from your Brain!

You've seen spikes from individual neurons, your heart, your muscles, and even plants. Here, finally, we tackle the much sought after, often misunderstood, signal of neuroscience: the Electroencephalogram (EEG). See the electrical rhythms of your own brain! Try to Exploit them!

Time 1 hour Difficulty Intermediate

What will you learn?

With this experiment, you can learn about the cardiovascular system through the use of electrocardiograms (EKGs). You will have an understanding of the communication taking place between your brain and your heart, and you will see and listen to the contractions of your heart.

Required Download

- SpikeRecorder - search for it in Google Play, Apple Store, or the Backyard Brains Website

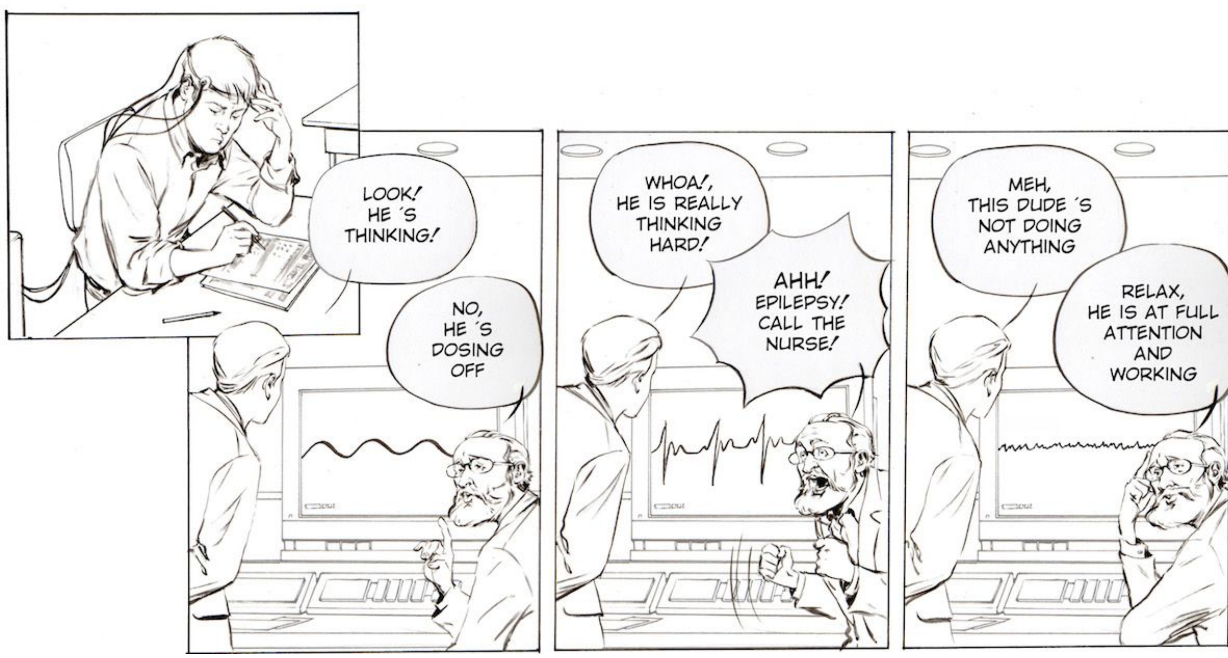
---

Background

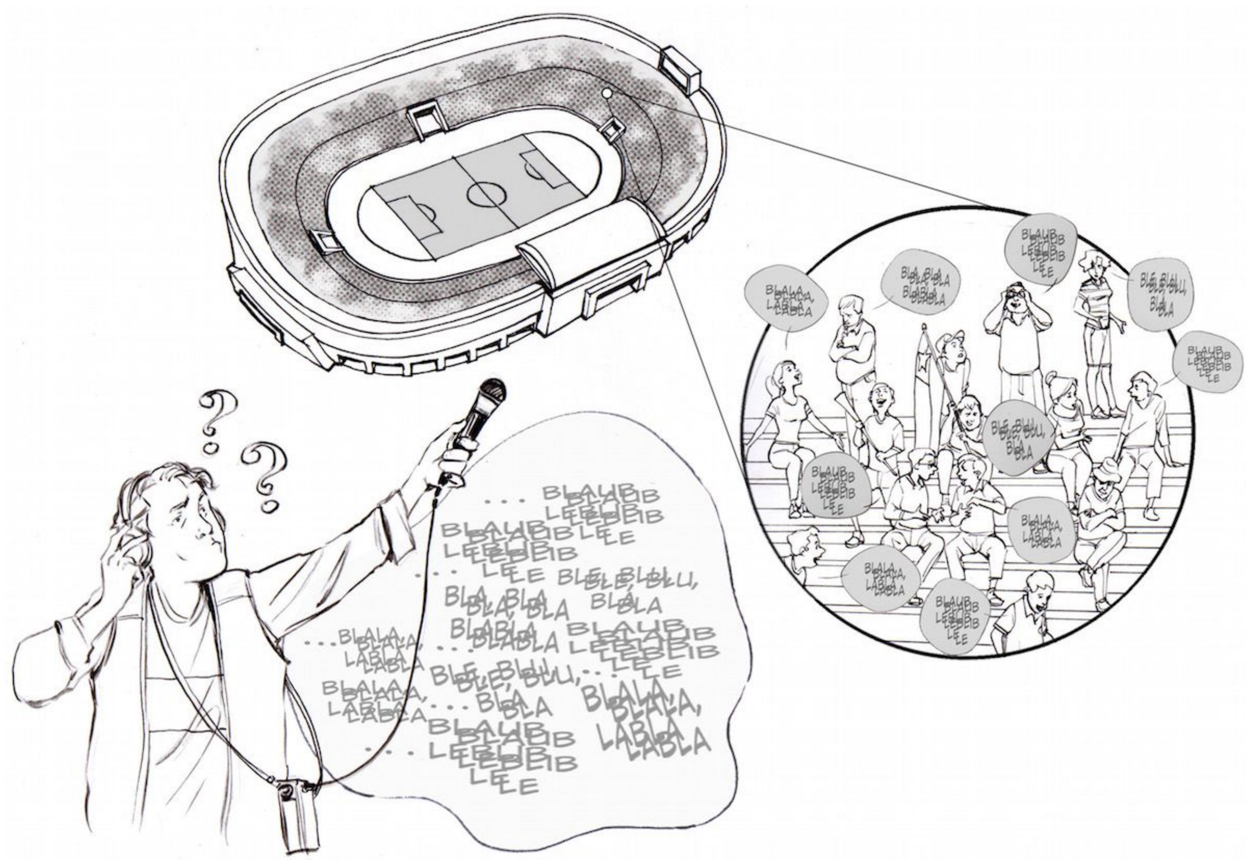
Your skull and skin in your head protect the valuable, wonderful brain of yours, but they are excellent electrical insulators, making it difficult to record from individual neurons in the human brain. To do so, you need to drill holes in the skull and insert electrodes directly into the brain, something only done during brain surgery when it is absolutely necessary in cases of intractable epilepsy or tumors. To record individual neurons, your electrodes have to *be in direct contact* with the neural tissue. For this reason we use the nerves of cockroach legs when demonstrating neural electrical activity. If instead you wanted to record the response of a human visual cortex neuron (located in the back of your head) in response to light...

However, when broad collections of neurons are all doing the same thing at the same time, we can see this "synchronous" activity with electrodes placed on the surface of the scalp on the back of your head. When you close your eyes, your visual cortex is not receiving complex information from your eyes (only darkness), and the visual cortex enters an idling mode of synchrony, called "alpha," which is strong enough that we can detect it non-invasively.

The relationship between synchrony and data processing in the brain can be hard to understand, and relates to information theory (you can dive into our hero Claude Shannon's work to learn more), but, in general, the more synchronous the neurons in your brain are, the less data processing is occurring. This leads to the paradox that the stronger the electrical signal we can record on the surface of your scalp, the less interesting things your brain is doing (like deep sleep) or we have a dangerous situation (like epilepsy---when all the neurons in an area are firing rapidly and at the same time, leading to convulsions and more dangerous consequences).



Often, when you are intensely concentrating, many neurons in your brain are calculating many different things. The "information capacity" of your brain is high, with many different conversations occurring between neurons. This shows up in the EEG as a very weak signal, difficult to extract meaning from. Imagine a stadium during half-time where everyone is having conversations between themselves. If you are outside the stadium, all you hear is a formless hum of noise. There are many interesting things being said (probably), but you can't detect it outside the stadium.



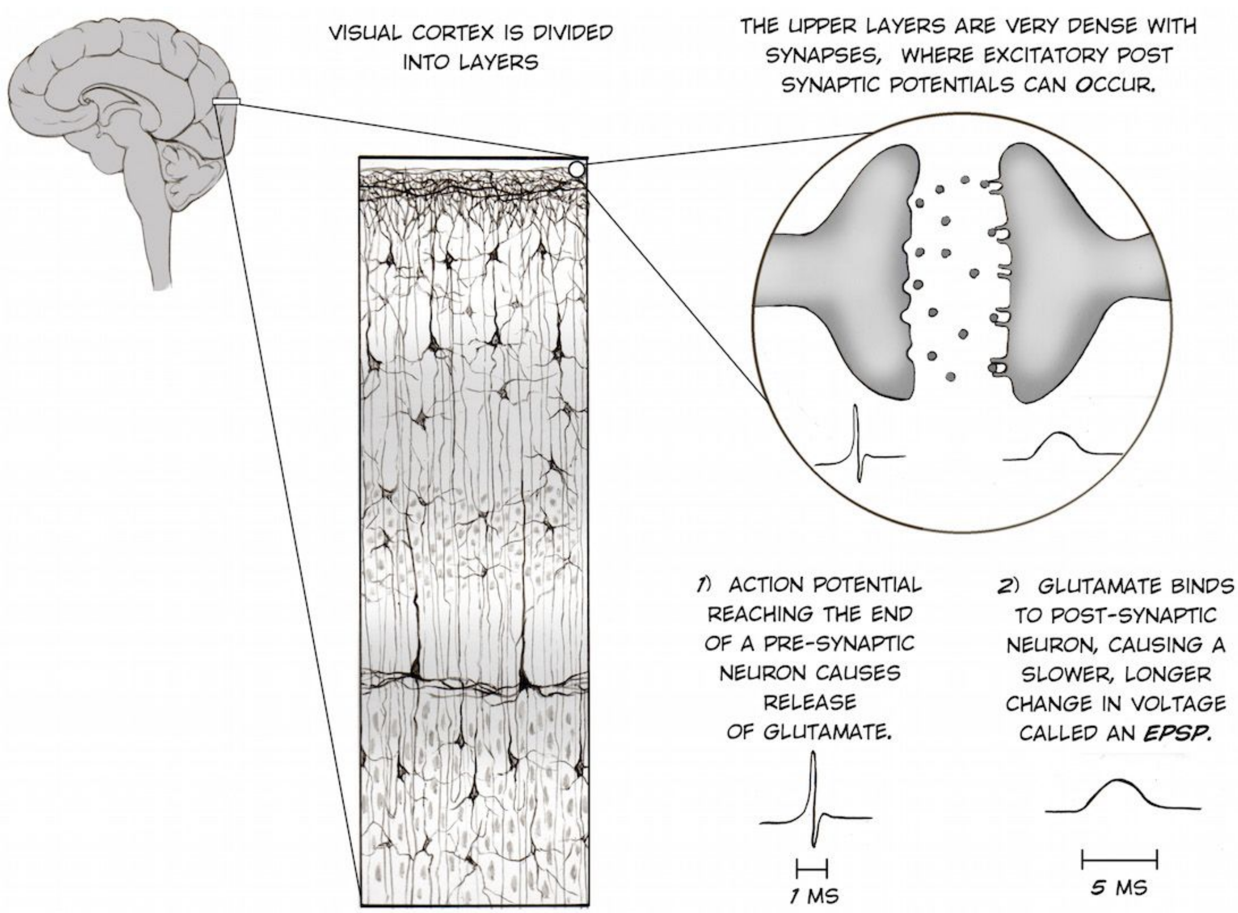
However, imagine when all the participants in the stadium are doing the same thing, such as the singing of a national anthem.* We can certainly hear the song, though distorted, outside the stadium. This is analogous to the slow waves your brain generates while in deep sleep or the alpha waves the visual cortex generates when your eyes are closed.

The loudest event we can detect outside the stadium is when a "goal" occurs, as a huge population inside the stadium all scream very loudly at exactly same time. When large populations of neurons in your brain do this (all firing action potentials at the same time), it is called epilepsy, and it is very dangerous.

With both the national anthem and the goal events, we can say people in the stadium are very "synchronized" with "low information." We can observe similar synchrony in the brain, but we do not need to go to sleep (that's for another experiment...stay tuned) or experience an epileptic event. We can place electrodes over the back of your head, and observe the electrical activity of the visual cortex when you open or close your eyes. When you close your eyes, there is low information being sent to your visual cortex (it's dark). What results is that the visual cortex enters a state of synchrony, called "alpha rhythms," which we can observe using our new Heart & Brain SpikerBox. These "alpha waves" were first observed by the German scientist Hans Berger in 1924 (published in 1929).

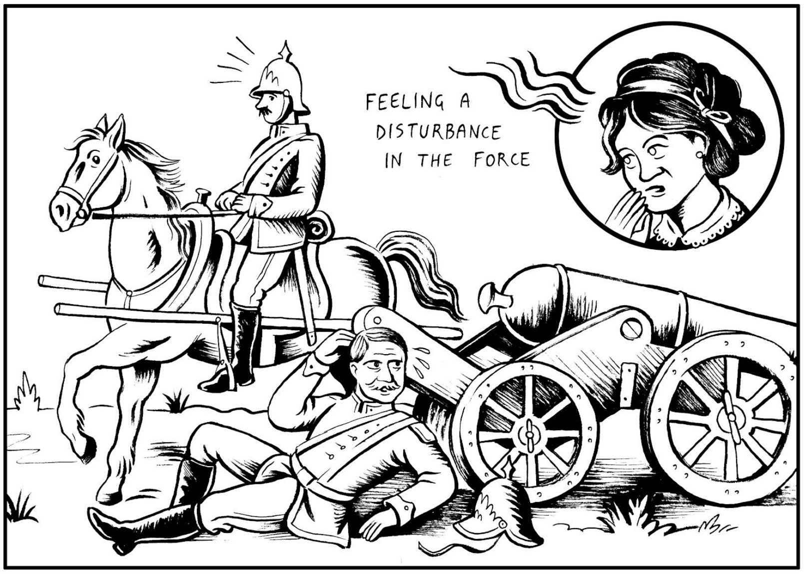
The Theory.

So what are we actually recording in the electroencephalogram (EEG)? We are observing the "oscillating slow fields" of neurons in the upper layers of the cerebral cortex: specifically, the "excitatory post-synaptic potentials." These post-synaptic potentials are the small changes in electrical potential caused by neurotransmitter binding in the neuron's synapses. These changes in electrical potential lead a neuron to be more likely or less likely to fire action potentials, and are important in encoding information in the brain. If you would like to go down the rabbit hole, the core reference is the exquisite and challenging "Mitzdorf 1985."



If many EPSP's are occurring at the same time and in the same area of your brain, such as when your eyes are closed and the visual cortex neurons are all in the same "idling" state, we can observe the adding up of these EPSP's in the EEG.

Neuroscience for Everyone!



Alpha waves, and EEG for that matter, were discovered in an unlikely way. The German psychiatrist Hans Berger (1873-1941) suffered a frightful military horse riding accident in the 1920s. This wouldn’t have been much to note, except his sister telegrammed him from miles away expressing she had recently felt a sudden feeling of fear and safety for her brother. Following this coincidence, Berger was determined to discover how, by his account, he was able to use “spontaneous telepathy” to convey information about his health to his sister. While he failed to determine a telepathic medium, he did make a historical breakthrough along the way by discovering electrical activity in the brain with the electroencephalogram (EEG). Berger developed a tool to record the electrical current of the brain from the surface of the scalp using rubber bands and silver foil - not so different from the sweatbands and buttons you are using!

100 years changes surprisingly little. We are interested in many of the same questions that brain scientists were interested in during the time of Hans Berger, and we still use some of the same methodology. We still don’t have an explanation, necessarily, for the “psychic phenomena” Berger and his sister experienced, but with these foundational skills, we can begin to perform many more simple EEG experiments which can help us better understand the nature of the brain.

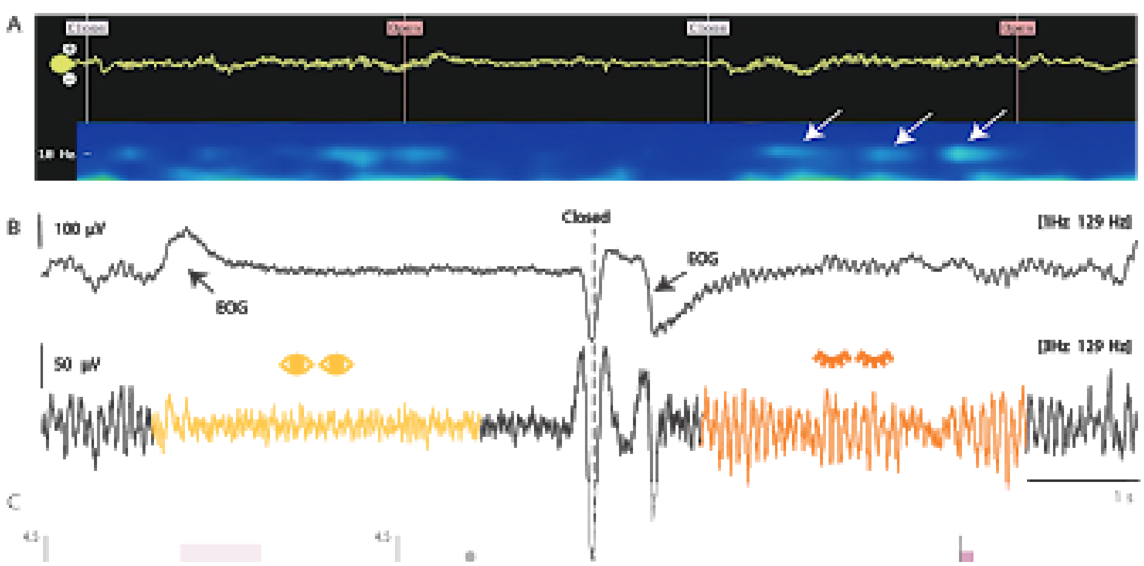
Procedure

In this "Introduction to the EEG" experiment, we are going to monitor our visual cortex electrical signals in response to eyes open and closed in a normal lighted room.

1. You first need to put the EEG headband on. Place the fashionable item on your head, with the two electrodes centered on the top back of your head (over the visual cortex). The smooth side of the electrodes should be in contact with your scalp. This experiment works even if you have hair, but moving your hair "out of the way" of the electrodes will be helpful.
2. Add globs of electrode gel underneath the metal patches in the headband.
3. Now, add an electrode sticker on the bony protrusion behind your ear (the mastoid process). Adding some conductive gel to this electrode before applying to the ear bone will improve the stability of your signal.
4. Now it's time to connect your electrodes! In Summer 2015 our kits began shipping with a simpler orange cable that has two red alligator clips and a black metal ground clip instead of one red, black, and bare metal ground clip. If you're using the newer kit, place the red alligator clips on the back of your head, and the black alligator clip on ground behind your ear. Which red is in which location does not matter. If you're using the older kit, however, place the bare metal clip behind your ear, and the red and black (again, which is where doesn't matter) alligator clips on the back of your head.
5. Plug your orange interface cable in the orange port on your Heart and Brain SpikerBox.
6. Plug one end of the USB cable to the Heart and Brain SpikerBox and the other end into the computer.
7. Open the SpikeRecorder software, and connect to the USB port in the settings menu. Again, since this amplifier's filter settings are right in the sweet spot of house electrical systems, you will have to be very vigilant of noise in

this experiment. Have your laptop and SpikerBox far from any electrical outlets, away from any fluorescent lights, etc. Also have your laptop running on battery power alone. If the signal seems excessively noisy and unstable, add more conductive gel between the headband electrodes and your scalp, and more gel to the electrode placed behind the end. Use the video above as a guide.

8. Hold still and relax while you are attempting to record EEGs - muscle movements can also be picked up, which causes interference with your EEG reading (yes, we know, getting a stable signal can be difficult, this is why EEG is the last major body electrical signal we tackled!).
9. Now, open and close your eyes, alternating every 10 seconds. A few seconds after you close your eyes, the alpha waves will appear. Obviously, doing this experiment with a friend will be easier and more fun, given the paradox of the signal appearing when your eyes are closed.
10. To record the data, you can press the red record button on the Spike Recorder software.



What do you see? When you look back into the recording from when your eyes are closed, you should see large, rhythmic waves - these will also light up the FFT in the 10hz band.

Discussion / Further Work

1. Are we recording Cardiac Action Potentials from the Pacemaker Cells, or are we recording the muscle contractions of the heart. Why or why not?
2. Our SpikeRecorder Software is designed to be easy to use, but if you want to hack an interface, you can modify our legacy processing sketch that also saves and displays the data. Download it here. To do this, you need to use a different Arduino Sketch, that you can find in this link.

Science Fair Project Ideas

- There are lots of different places you can put the electrodes for this experiment-what effect(s) do the different placements have on the signal you see? Is the signal different if you move the electrodes closer to one another? Closer to the heart?
- Look at the effects of certain states on the amplitude and rate of heart action potentials-Recently run, recently drank caffeine, holding your breath, deep slow breaths vs rapid ones, sitting vs standing, age, general athleticism, etc.
- If it's cold or hot outside, try comparing heart rates when you're inside vs when you're exposed to the weather. Stay safe though!
- What about before and after you're eating? Why might that be? What, if anything, does the movement of your blood have to do with eating?
- What other things do you think would affect heart rate? Experiment some, but make sure to stay safe!