University of Tehran

Faculty of engineering

Electrical and computer faculty

Internship report

Title: modeling the brain as anetwork

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Summary

The subject of this research is the simulation of the human brain as a completely intertwined telecommunication network. In the human brain, messages are transmitted in the form of electrical pulses. Also, the methods of transmitting these electrical signals are in the form of changing the frequency and width of the signal. As will be seen, the methods of transmitting messages within neural network are significantly similar to the methods of digital communication in today's world. The human brain is one of the most complex secrets we are facing with, so far only a few doors have been opened by humans. Nerve neurons in the brain consist of a central part (processor) that are connected to each other by an axon (transmission line). Creating a mapping between these two important topics telecommunications and the connection of brain neurons can, in addition to advancing the human brain-inspired digital communication methods, lead to our greater understanding of the most important processor, the human brain. We hope to improve some neurological diseases by getting to know the brain better and using engineering methods to better understanding.

Chapter one

Activities performed by the student during the internship

1-2 –introduction

In neuroscience, the relevant points in space are the inside and the outside of a cell, which are separated by a membrane that is impermeable to charged particle.

Ions can not flow across this membrane without the help of channels or pumps.

Voltage is a relevant measurement, and neuroscientists always use the outside of the cell as the "ground" or reference point to measure the voltage across the membrane.

- **Membrane potential:** this is a general term that describes the voltage across the membrane at any point in time. The membrane potential of a neuron can vary widely, for example from -90 mv to +60mv.
- **Resting potential:** the membrane potential of a neuron that is specifically "at rest", meaning that is not sending or receiving signals, generally between -60mv and -70mv.

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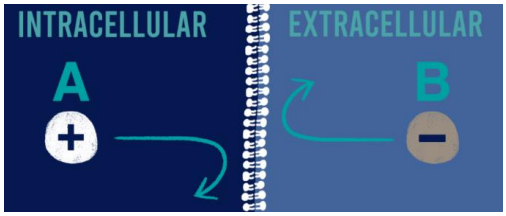
Chapter two



Both outside and inside of the neuron, ions and other particles exist in an aqueous solution and are able to move around. There are many forces that can guide their behavior, two of which are important to us, the diffusion and electrostatic forces.

There are two important balancing point:

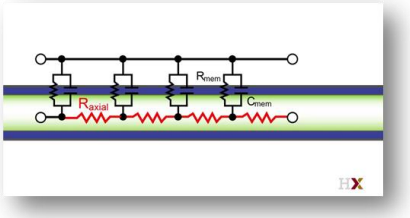
1/ balancing between the number of ions.

2/ balancing between the charges.

Although the cell may reach the resting potential but each ion still can't equalize their number between the outside and the inside of the membrane.

1/ membrane resistive: the resistance to the flow of ions across the membrane.

2/ Axial resistance: the resistance to the flow of ions down the axon.

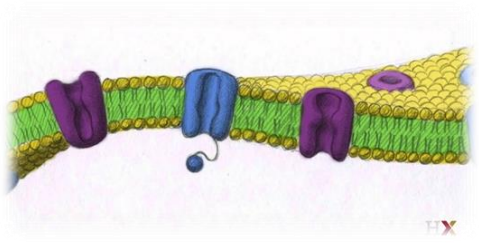


In a resting neuron, there are many ions that can flow across the membrane, and each ion will try to reach its own equilibrium simultaneously.

Given the concentration gradients of the different ions and their "permeability", there will exist a balancing point at which the membrane potential will be stable. At this balancing point, no single ion will be at its own equilibrium, but the total new flow of all charges into and out off the cell will be equal and opposite. Since no particular is at an equilibrium, we instead call this balancing point a "steady state". The resting potential is an example of a steady state.

If the neuron wanted to change its membrane potential by moving around ions alone, it would have to expend tone of energy pumping ions back and forth across the membrane and would probably be vey slow.

-55 mv is a target for membrane potential. Roughly speaking, when the membrane potential reaches a value close to this threshold, the neuron fires something called an action potential to communicate with other neurons. If the threshold isn't reached, the neuron stays inactive.



Ions moving in and out of the cell down their concentration gradients.

This movement was mediated by leakage channels. In a neuron, we have a lot of channels that let potassium through easily but fewer channels that let sodium or chloride through.

The key driver of the resting potential is that the membrane is semi-permeable. Potassium ions are much more numerous inside and they float easily through the membrane. Sodium ions are more abundant outside but they can't move very easily between the two rooms.

Na+ channel alone isn't fast enough if we need to send another action potential quickly.

K+ voltage gated channel largely responsible for the falling phase.

Also known as delayed rectifiers channels

1/ delay kinetics relatives to the Na+

2/ back to the K+ normal potential

Because the channels are open so they try to bring the membrane potential close to their Nernst potential -80mv.

Passive properties: membrane capacitance, membrane resistance, axial resistance

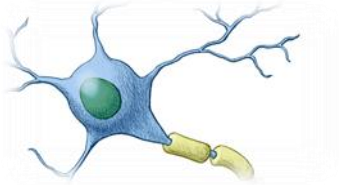
Active properties: voltage gated channel

Action potentials are all-or-nothing signals characterized by large and rapid changes in membrane potential.

Neurons need to combat the effects of current leaking through the membrane. One way to get round this, is simply to make the magnitude of an action potential much larger, but this may not be the best solution.

Raising the amplitude is not an option because the membrane is already near its breakdown potential, because the membrane is so thin the field around it is about 10,000,000 v/m.

If the signaling was relied on diffusion it would take more than a year for you to pick up, you cup of tea!



Myelin, which forms a fatty insulting sheath around neural fibers. Myelin is produced by cells called glia.

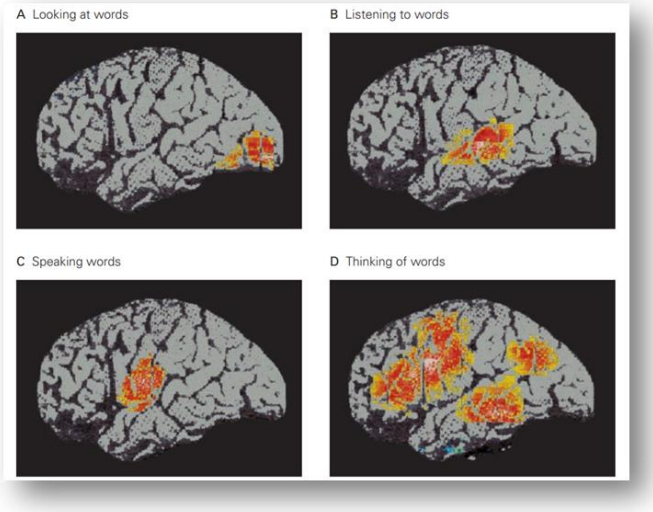
Besides water, myelin is primarily made up of lipids, which gives its characteristic white appearance. That's also that gives rise to the white color of the white matter in the brain.

You might be wondering, if you're covering the membrane with this electrically insulating substance, how do the ion channels still work?

The key to understand how myelin helps with conduction of action potentials lies in their segmentation.

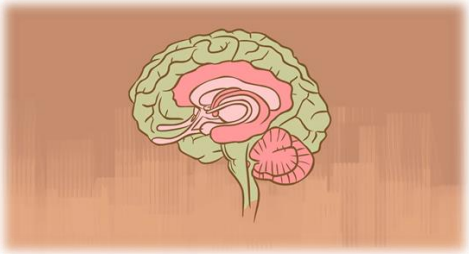
Hirsch and her colleagues made the interesting discovery that processing of one's native language and processing of a second language occur in distinct region within Broca's area. If the second language is acquired in adulthood, it is represented in a region separate from that which represents the native language. If the second language is acquired early, however, both the native language and the second language are represented in a common region in Broca's area. These studies indicate that the age at which a language is acquired is a significant factor in determining the functional organization o Broca's area.

Found that the region of Broca's area concerned with second language becomes stablished and increases in activity only when an individual learns a second language that is "natural", that is, one that shares the universal grammar. If the second language is an artificial language, a language that violates the rules of universal grammar, activity in Broca's area does not increase. Thus Broca's area must contain some kind of constrains that determine the structure of all natural languages.



Damage to the right temporal area corresponding to Wernicke's area in the left temporal region leads to disturbances in comprehending emotional aspects of speech, for example the ability to appreciate from a person's tone of voice whether he is describing a sad or happy event. In

contrast, damage to the right frontal area corresponding to Broca's area loads to difficulty in expressing emotional aspects of speech.



There are several reasons why the evidence for the localization of the brain functions, which seems so obvious and compelling in retrospect, had been rejected so often in the past. Phrenologists introduced the idea od localization in an exaggerated form and without adequate evidence. They imagined each region of the cerebral cortex as an independent mental organ dedicated to a complete and distinct aspect of personality, much as the pancreas and the liver are independent digestive organs.

Specific brain regions are not responsible for specific mental faculties but instead are elementary processing units. Perception, movement, language, thought, and memory are all made possible by the interlinkage of serial and parallel processing in discrete brain regions, each with specific functions.

Thus it is not accurate to think of a mental process as being mediated by a chain of nerve cells connected in series—one cell connected directly to the next—for in such an arrangement the entire process breaks down when a single connection is disrupted. A more realistic metaphor is that of a process consisting of several parallel pathways in a communications network that can interact and ultimately converge upon a common set of target cells.

Three methods for analyzing the brain

EEG (Electro encephalography)

As electrical signals travel down your brain we can place two electrodes and pick up these waves. This method invented 100 years ago. It can tell you when a certain activity occurs. With method we can understand the electrical signals produced by the brain.

fMRI (functional magnetic resonance)

We know that the more active regions of the brain actually use more oxygen for their process so we can easily detect it. Actually fMRI measures how quickly oxygen in consumed by the brain cells. With this method we can locate the regions that are more active during certain tasks.

PET (positron emission tomography)

During a PET scan, a small amount of radioactive material called tracer is injected into the blood stream in order to determine the chemical effect of certain drug in the brain.

Five critical factors that regulate the interaction of synaptic inputs and their ability to initiate an action potential in a target neuron.

→ Distance

→ Non-linear summation

→ Inhibitory input blocking excitatory input

→ Temporal summation

→ Inhibitory input blocking temporal summation

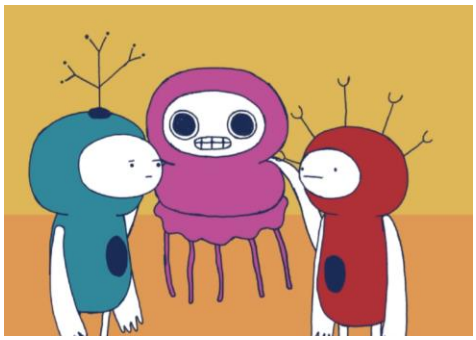
Smaller, thiner processes further from the cell body have higher axial resistance. Decreases length constant. Greater signal loss

F (Driving force) = Em – Ei

Em: membrane potential Ei: ion potential

Let's consider a postsynaptic site containing ionotropic receptors pearmiable to ion x. As you excite that synapse, the postsynaptic membrane gets closer to Ex. However, the closer the embrane potential gets to Ex, the lower the net driving force and the lower the net depolarization added as you open more channels in the same path of membrane. This results in a sub-linear additivity of EPSPs, the amplitude of the combined EPSPs is smaller then the sum of the amplitudes of the individual potentials.

For maximum effect, inhibitory synapses must be closer to the cell body than excitatory synapse. Inhibitory synapse on a dendrite must come between excitatory synapse and the cell body. IPSPs can block EPSPs from reaching threshold and firing an action potential.



Neuromodulation is the process by which the synaptic transmission between two neurons is either enhanced or decreased through the action of a third substance called neuromodulator.

Most neuroodulators act through G-protein coupled receptors.

Changes in synaptic strength can be due to either A, structural, or B, non-structural lterations, the synapse connecting the presynaptic and postsynaptic neuron.

Changing synaptic strength without affecting the structure of the synapses is described as changing its efficacy.

The complexity of neural signaling is due to

1 neurotransmitter release that can have multiple effects on the synaptic cell, each acting on a different timescale.

2 many of the classic fast-acting ionotropic neurotransitters that can also act as neurotransmitters through metabotropic receptors, both pre-and postsynaptically.

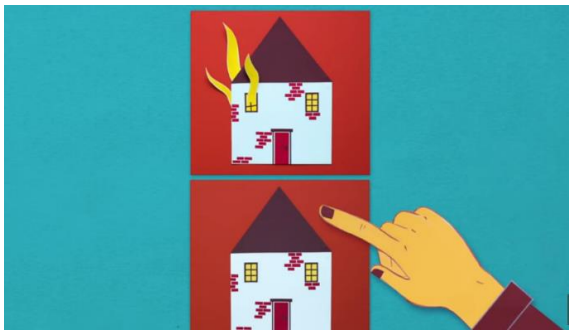
3 single neurotransmitter release that can act almost immediately, while also having long-lasting actions on the timescale of seconds to minutes_sometimes even weeks.

The neurons system is characterized by a relatively small number of neurotransmitters, but an extreme diversity of different kinds of receptors molecules that interact with those neurotransmitters.

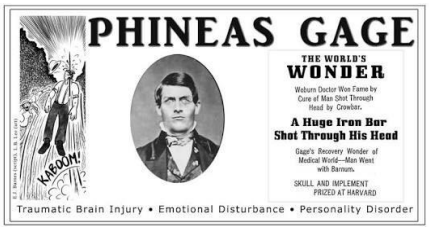
Chapter three
interesting cases:

H.S (consciousness)

One patient called H.S has an injury in her right side of the brain, they show her two pictures of two houses identically look like each other but in the left side of one picture there was a fire flame outside the house. When they asked H.S to tell the differences of those two pictures she said that those pictures are alike but when they asked her which house she would prefer to live, she chose the second house again and again.

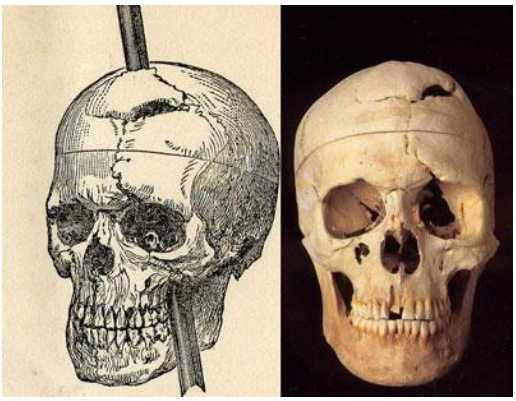


Phineas Gage(localization)

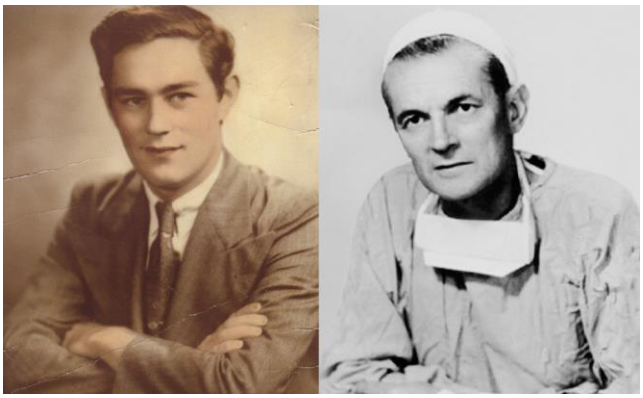


In 1848, Phineas Gage was 25 old, and a foreman who helped to lay railroad tracks in Vermant. He was using an iron rod which was 3.5 feet long and over an inch wide in order to pack sand onto an explosive. And when it went off, he firing the rod At his head. Under a huge surprise in 19 century supply, he survived and made a very fast recovery after his injury. But according to one of his best friends who met him after his injury "not the same Gage". He was one of the best in his work but after his injury He was not in his glorious days. The part of his brain that was responsible for decision-making and emotional processing was damaged and that can explain his difficulty to think fast and his lacking of social communication.

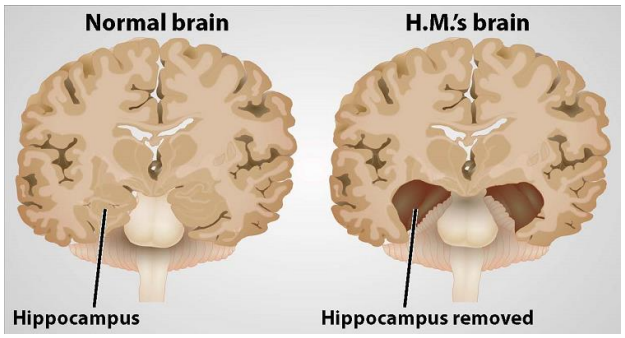
He also lost 4% of his brain's gray matter and 11% of his white matter. Due to the fact that white matter is mostly rapped with myelin sheath that are recoverable so we can understand his astonishing recovery.



Henry Molaison(localization & consciousness)



On September first 1953, William Scoville(a daredevil known for risky surgeries) used a hand crank and a drill saw to bore into a young man's skull, cutting away vital pieces of his brain. The young man was Henry Moliason, the famous patient known as "H.M". Scoville decided to remove H.M's hippocampus, a part of the limbic system that was associated with emotion. After operation his memory was shot. Although H.M couldn't form new memories, he still retained information. It showed that short-term memory and long-term memory uses different brain regions.



Memory steps:

After immediate sensory data is temporarily transcribed by neurons in the cortex, it travels to the hippocampus, the hippocampus then transfers the memory back to the cortex for permanent storage.

In a now famous experiment Milner asked H.M to trace a star while he could only see his paper and pencil through a mirror. Surprisingly, he improved over repeated trials, even though he had no memory of previous attempts. His unconscious motor centers remembered what the conscious mind had forgotten.

Milner found that declarative memory of names, dates and facts id different from procedural memory.

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