ENHANCING LEARNING -
A CASE STUDY OF MIND'S RESPONSES TO EXTERNAL STIMULI
INTERFACING WITH BRAIN WAVE SENSORS

by

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Abstract

Improving learning, especially in effectiveness and value, arousing interest of learners and augmenting attention during training or a variety of procedures is an aspiration. Exploring brain's activity is not yet fully defined and remains a huge research area. This project attempts to approach and understand the diversifications of brain's responses while interfering with different situations. The aim is to observe and notice brain's reactions to an external stimulus. Neural activity is related with mental state while their differentiations emit characteristic brainwaves. The electrical impulses in the brain can be measured using Brain Wave Sensors. Colour or Sound can be used as External Stimulus. Attention's and Meditation's status are states of Human Mind being observed. Outcomes of this project may have a beneficial use in education or relevant ranges.

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Acknowledgements

I would like to thank my family who had great pattience during the period of this thesis and their true interest for my well being, as well as real friends with deep concern about me.

Dedication

To all people who beleive that they can acheive their goals at the end.

Preface

"If you want to find the secrets of the universe, think in terms of energy, frequency and vibration." Nikola Tesla

Using an EEG-monitoring Headset during the Case Study of this Thesis, Brainwaves of people were captured, and measurements for levels of their Attention and Meditation have been listed. As external Simulus a digital pallette of twenty Colors was deploied. Outcomes from observations and analysis of recorded measurements for chosen voluntiers' level of Focus are documented at the end.

Research also about Brainwave Sensors Technology, Brain Computer Interfaces and Brainwave Entrainment have been done and are presented in the thesis.

Chapter 1 - INTRODUCTION

Exploring brain was in the past and still is a huge research area. It is not yet fully defined although a great amount of researchers are looking for answers about brain's activity and function.[1]

A great amount of brain neurons exist inside human brain and it is thanks to them and their performance that everything run inside human body. It is known that in the human body, brain is the most complex organ and it is the one that controls all actions and reactions of the body. This happens by receiving different stimuli through the nervous system.

There is a whole mechanism of how a stimulus manages to provoke a reaction of the brain using the nervous system, and the basic part of this is explained on chapter 2 of this thesis. The key element on brain's stimulation and relevant to the stimulus reaction is information transferring through nervous system and the neurons after all.

Messages relocate through nervous system in the form of electric pulses arising at the moment a stimulus appears. As soon as a stimulus surpasses the threshold stimulus sensory neurons generate information about the stimulus and the frequency of action potential. [2] When action potentials are generated they travel through neural network and finally reach the brain. Different areas of the brain respond depending on the kind and location of the stimulus. So the response mechanism is generated by the brain.

1.1 Neuron

Firstly we have to refer to brain's great amount of neurons the main cells that carry information to and through the brain.

The term neuron was coined by German anatomist Heinrich Wilhelm Waldeyer. In the early 20th century through the work of Spanish anatomist Santiago Ramón y Cajal, neuron position was first recognized to be the primary functional unit of the nervous system. [3] Ramón y Cajal proposed that "neurons were discrete cells" which communicated with each other "via specialized junctions, or spaces between cells". [3]

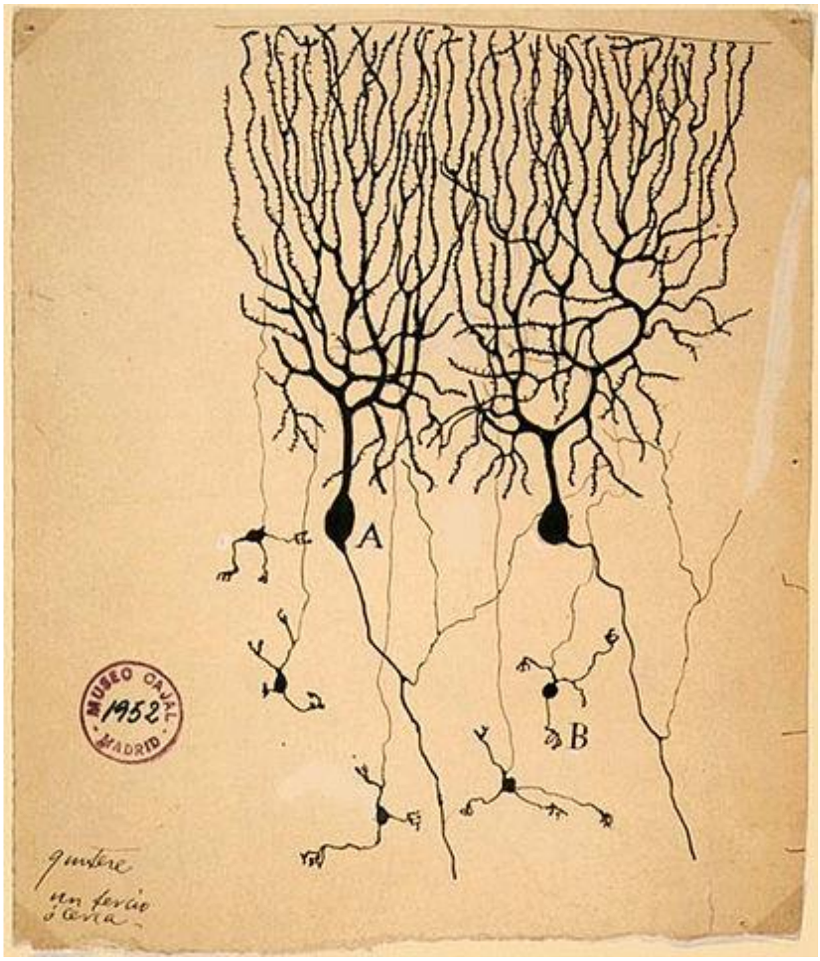

Figure 1 Image of two Purkinje cells (labeled as A) drawn by Santiago Ramón y Cajal in 1899. Large trees of dendritesfeed into the soma, from which a single axon emerges and moves generally downwards with a few branch points. The smaller cells labeled B are granule cells.

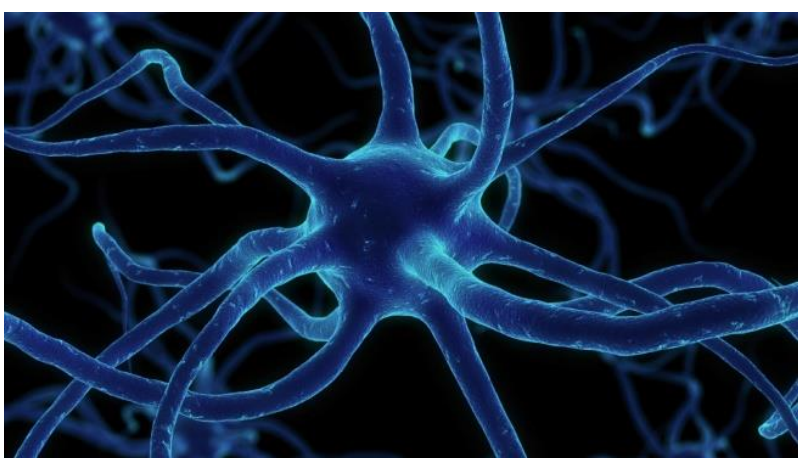

Figure 2 A Neuron as it can be seen nowadays

This became known as the "neuron doctrine", one of the central tenets of modern neuroscience. [3]

Figure 3 Santiago Ramón y Cajal (1852-1934)

Ramón y Cajal wanted to observe the structure of individual neurons and improved silver staining procedure known as a method of Golgi, which had been developed by his opponent, the Camillo Golgi. [3] Improvement Cajal was concerned a technique, still in use also called "double impregnation". Stains silver impregnation is a very useful method for neuroanatomical studies since, for unknown reasons, stains a very small percentage of cells in a tissue, such that one is able to see the complete micro structure of individual neurons without much overlap other cells the dense brain. [4]

Figure 4 Ramón y Cajal in his laboratory

1.1.1 Historical Setting

It was in 1839 when Theodor Schwann suggested that the tissues of all organisms are composed of cells. [5] [6] In fact Schwann extended on the suggestion of good friend Matthias Jakob Schleiden a year before, that all plant tissues are composed of cells. The nervous system is formed as an exception. Although nerve cells had been described in tissue from numerous investigators including Jan Purkinje, Gabriel Valentin, and Robert Remak, the connection between nerve cells, and other features such as dendrites and axons were not clear. The connections between the large cell bodies and smaller features that could not be observed, and it was likely that neurofibrils will stand as an exception to cell theory as non-cellular components of the living tissue. Technical limitations of the microscope and preparing tissue was largely responsible. Chromatic aberration, spherical aberration and dependence on natural light all played a role in limiting the performance microscope in the early 19th century. Web usually slightly mash in water and squeezed between a glass slide and cover slip. There was also a limited number of pigments and extenders available before the mid-19th century.

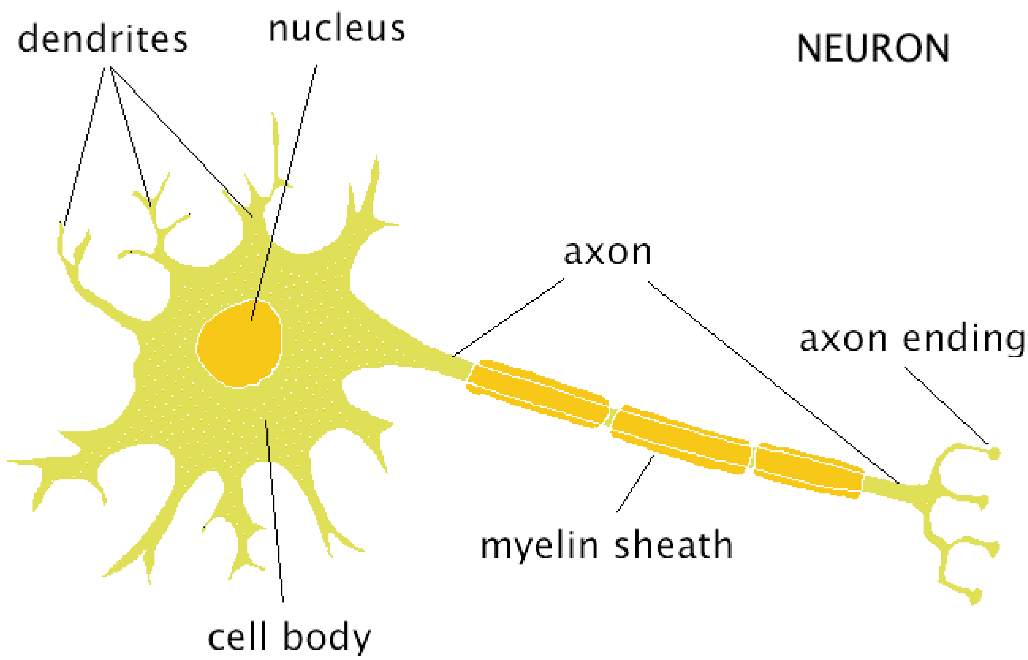

Figure 5 Neuron: Main Parts

A landmark development came from Camillo Golgi invented a technique of silver staining in 1873 which he called la Nera reazione (dark reaction), but better known as Golgi stain or Golgi method, in his honor. Using this technique, the nerve cells with highly branched dendrites and axis could be visualized clearly against a yellow background. Unfortunately Golgi described the nervous system as a continuous single network to support a concept called lattice theory. It was reasonable at the time, because under the light microscope nerve cells is simply a grid only thread. Santiago Ramón y Cajal began investigating the nervous system in 1887 using Golgi stain. In the first issue of Revista de quarterly Histología Normal y Patológica (Maios, 1888) Cajal felt the nerve cells were not continuous in the brains of birds. Cajal discovery were the deciding factors for the discontinuity of the nervous system and the presence of large numbers of individual nerve cells. Golgi and Cajal were jointly awarded the Nobel prize in 1906 for Physiology or Medicine, which resulted in a permanent conflicting ideas and confrontations between the two scientists. [7] [8] The issue is resolved finally in the 1950s with the development of electron microscopy, which was clearly shown that the nerve cells were isolated cells are connected via synapses to form a nervous system, validation so the theory neuron. [9] [3]

1.1.2 Neuron doctrine

Theory neuron is an example where concealed low theories absorbed in higher level theories explaining the data base as part of a higher order. As a result, the doctrine of the neuron has multiple components, each of which were the subject of theories low level, debate, and the collection of primary data. Some of these elements imposed by the theory of which Waldeyer-Hartz [10] is trying to use cells to explain the direct comments and other elements that try to explain the observations, so that it is compatible with the theory of cells.

Elements of the Neuron Doctrine as mentioned in Wikipedia [11] follow:

- "Neural units: The brain is made up of individual units that contain specialized features such as dendrites, a cell body, and an axon.
- Neurons are cells: These individual units are cells as understood from other tissues in the body.
- Specialization: These units may differ in size, shape, and structure according to their location or functional specialization.
- Nucleus is key: The nucleus is the trophic center for the cell. If the cell is divided only the portion containing the nucleus will survive.
- Nerve fibers are cell processes: Nerve fibers are outgrowths of nerve cells.
- Cell division: Nerve cells are generated by cell division.
- Contact: Nerve cells are connected by sites of contact and not cytoplasmic continuity. Waldeyer himself was neutral on this point, and strictly speaking the neuron doctrine does not depend upon this element. The heart is an example of excitable tissue where the cells connect via cytoplasmic continuity and yet is perfectly consistent with cell theory. This is true of other examples such as connections between horizontal cells of the retina, or the Mauthner cell synapse in goldfish.
- Law of dynamic polarization: Although the axon can conduct in both directions, in tissue there is a preferred direction for transmission from cell to cell.
- Later elements that were not included by Waldeyer, but were added in the following decades are:

- Synapse: A barrier to transmission exists at the site of contact between two neurons that may permit transmission.
- Unity of transmission: If a contact is made between two cells, then that contact can be either excitatory or inhibitory, but will always be of the same type.
- Dale's law: Each nerve terminal releases a single type of transmitter."

1.1.3 Neurons in the Brain

The number of neurons in the brain dramatically vary from species to species. [12] An estimate (published in 1988) locates the human brain by about 100 billion (1011) neurons and 100 trillion (1014) synapses. [12] A lower rating (published in 2009) is 86 billion neurons. 16,300 million of them are in the cerebral cortex, and 69 billion in the cerebellum. [13] In contrast, the nematode worm Caenorhabditis elegans has only 302 neurons, making it an ideal experimental subject scientists were able to map all the neurons of the organization. The fruit fly Drosophila melanogaster, a common theme in biological experiments, has about 100,000 neurons and presents many complex behaviors. Many properties of neurons, the type of neurotransmitter that used for the synthesis of ion channels, maintained in all species, allowing scientists to study processes occurring in more complex organizations a much simpler test systems. [14]

The average brain weighs about 1.3 pounds and consumes 20 percent of the body's energy budget. Much of this energy powers 86 billion nerve cells in the brain, or neurons, which carry tiny electrical currents that can travel close to 120 meters per second. A typical neuron transmits signals of approximately 7000 cells and neighboring cells in addition. These neurons are assembled into structures responsible for specific tasks.

Figure 6 Neuron in Brain

1.1.4 Nerve regeneration

A huge number of synapses exist inside the human brain. They are 1011 (one hundred billion) neurons and each one of them has on average 7000 synaptic connections with other neurons. It has been estimated that the brain child of three years has approximately 1015 synapses (one quadrillion). This number decreases with age, stabilizing by adulthood. Estimates vary for an adult, which range from 1014 to 5 x 1014 synapse (100 to five hundred trillion). [15]

A research in young and aged mice at laboratory of Genetics showed that the decline in neurogenesis in aged mice was reduced with exercise. Furthermore according to the results "fine morphology of new neurons did not differ between young and aged runners, indicating that the initial maturation of newborn neurons was not affected by aging." [16] [17]

Further scientific research nowadays reveals that neurogenesis still takes place in elderly people's brain.

The neurons do not undergo cell division. In most cases, neurons derived from specific types of stem cells. Astrocytes are star-shaped glial cells, they have also been observed to turn into neurons because of stem cell pluripotency characteristic. In humans, neurogenesis largely ceases during adulthood; but there is strong evidence that in two brain areas significant numbers of new neurons are produced. These areas area the hippocampus and olfactory bulb.

It has been shown that neurogenesis may sometimes occur in the adult vertebrate brain, a finding that led to the conflict 1999. [18] However, subsequent studies on the age of the human neurons suggests that this process takes place only for a minority of the cells and the vast majority of neurons comprising the neocortex formed before birth and continue without replacement. [19]

It is often possible for regional axes to regenerate if cut. A variety of types of stem cells that the body contains as recent studies have shown have the capacity to differentiate into neurons. A report in the journal Nature, the researchers suggested that had found a way to convert human skin cells into the labor market nerve cells using a process called cross-over which "cells are forced to adopt new identities." [20]

1.1.5 Computing power/Computational Power

History has thought that neurons are relatively simple devices and that huge brain computing power comes from having too many of them. Indeed, the investigation of artificial intelligence has followed this line. However, it is now increasingly apparent that even single neurons can perform complex calculations. [21]

Figure 7 Neurons firing

1.1.6 Mechanisms for disseminating action potentials

In 1937, John Zachary Young suggested that the squid giant axis could be used to study neuronal electrical properties. [22] As they were greater than but similar in nature to human neurons, squid cells were easier to study. By inserting electrodes into the giant squid axes, precise measurements were made by the membrane potential.

The cell membrane of the axon and soma contain voltage-gated ion channels that allow the neuron to generate and propagate an electrical signal (an action potential). These signals are generated and multiplied by the ions bearing load including sodium (Na +), potassium (K +), chloride (Cl) and calcium (Ca2 +).

Several stimuli can activate a neuron leads to electrical activity, including pressure, strain, chemical transmitters and changes of the electrical potential across the cell membrane. [23] Stimuli cause specific ion channels in the cell membrane to open, resulting in a flow of ions through the cell membrane, altering the membrane potential.

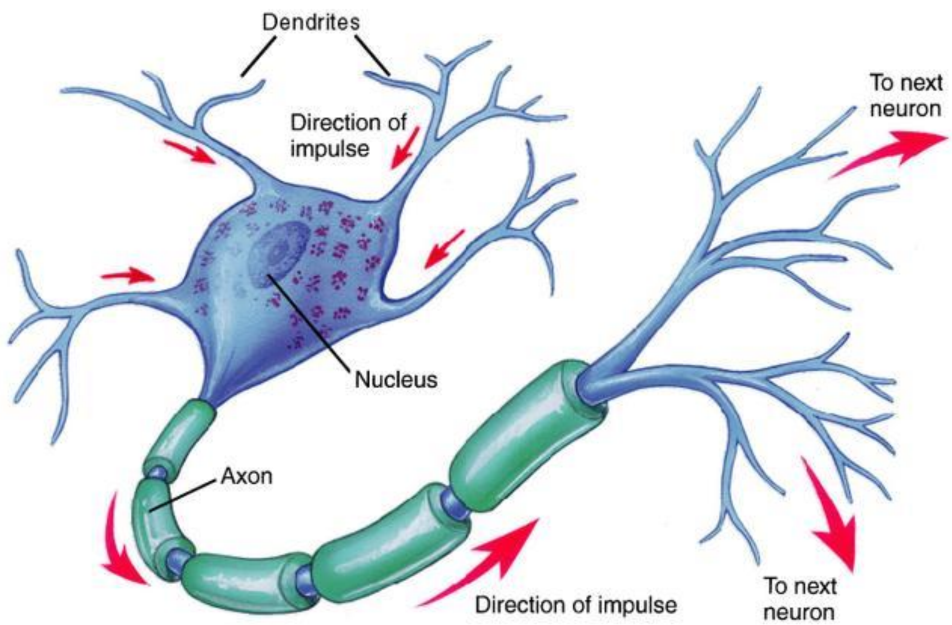

Figure 8 Neuron: Direction of Impulse

Regarding electricity in human body and the role of it some practices of this knowledge in the past. Even ancient Egyptians used electricity for their benefit. More specifically they used electric fish [24] on the painful regions of their body in order to reduce pain and be relieved. [25][26]

On the other hand John Wesley opened free clinics in the mid eighteenth century around London and successfully healed over 20 types of illnesses by electrifying patients.[26]

As for Benjamin Franklin he is well known as scientist with many abilities and skills. [27], [28] He used electricity in many ways although he was not totally convinced that using electricity for healing human body was a totally successful method. [27], [29], [28]

1.2 Stimulus and Brainwave Entrainment

1.2.1 Origin

In previous years there have been a lot of studies and researches about external stimuli and the ways human body generally and especially brain respond to them.

Stimulus was originally used, back to 1680s, as a medical term, while the general sense is from 1791 and psychological sense is first recorded 1894. [30] Origin of stimulus is in late 17th century: from Latin, 'goad, spur, incentive'. [31] As mentioned in Oxford Dictionaries' site, stimulus is "a thing or event that evokes a specific functional reaction in an organ or tissue: e.g. areas of the brain which respond to auditory stimuli" or "a thing that rouses activity or energy in someone or something; a spur or incentive" [31]

Researches for different types of stimuli and brain stimulation are accomplished during the past years as well as if training human brain to desirable mental state is possible.

A brief allusion can be found in chapter 2 "Neurons and Brainwaves" where brainwave entrainment is featured (2.3.4 "Brainwave Entrainment"). Brainwave Sensors Technology was the asset to realize research work. It involves Electroencephalography (EEG) and Brain Computer Interfaces (BCI). BCI sometimes also called: mind-machine interface (MMI), direct neural interface (DNI) or brain–machine interface (BMI).

Below is one of the first recordings [32] of brain activity:

Figure 9 First Recordings of Brain Activity

and a more modern EEG (ElectroEncephaloGraphy) recording [33]:

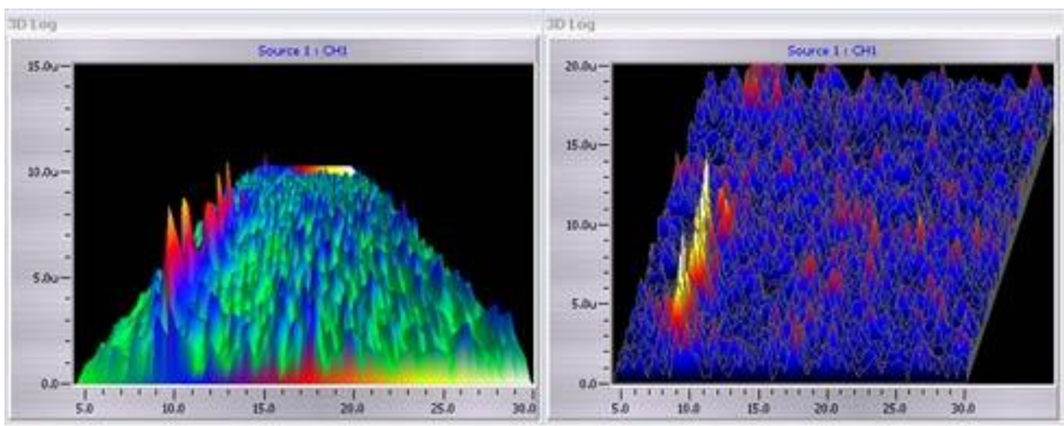

Figure 10 A modern EEG (ElectroEncephaloGraphy) recording

Brainwave entrainment is not something new. In the fact "Ceremonial chambers acoustically tuned to specific brainwave frequencies have been found dating back to the Bronze Age, and the ancient Greeks used flickering sunlight shining through a spinning wheel to induce altered states." [34] as mentioned in Brainworks' website, one among the first neurofeedback clinics in the UK.

After 1970 brainwave entrainment techniques have been developed using computer encoded audio beats, strobe lights, low-energy electromagnetic fields.

1.2.2 Research work

Internal or external stimuli can provoke brain response. Different kind of stimulus compared to brain cells' operation exist and researchers designate them. Brainwave Frequencies and the effects they have on the brain have been studied by scientists over the past 40 years.

Mindfulness meditation for instance rebuilds the brain, by increasing gray matter in hippocampus. A study [35] conducted in 2010 at Harvard Medical School showed that meditation mindfulness rebuilds the brain, increasing gray matter in the hippocampus, a brain region that plays an important role in learning and treatment of memory and other brain regions involved to self-knowledge and introspection. [36]

Performing altruistic acts and practice kindness can change your brain. Another study [37] at the University of Zurich in Switzerland confirmed that performing altruistic acts can change your brain. The research team conducted the experiment using 30 volunteers and two games, during which the participants were asked to decide how much money they would give one another. It was found that the grey matter in the right side of their temporoparietal junction was unusually large. The researchers concluded that people who are kind and perform altruistic acts actually have more developed brain regions and grey matter than those who do not.

Claude Frasson in the University of Montreal has done researches whether and how emotions affect brain’s function. He suggests and concluded that controlled fear for example have effect in ability of understanding and gaining knowledge. Using technology of brainwave sensors he manages to study brainwave entrainment. [38]

In Monroe Institute [39] also, from the extensive research done and on the strength of Monroes' findings [40], Robert Monroe says that "inducing brainwave frequencies through the use of binaural beats causes a wide range of effects. Lots of other scientists have also noted that lower brainwave frequencies are accompanied by deep tranquility, flashes of creative insight, euphoria, intensely focused attention, enhanced learning abilities, spiritual awareness, and so much more."

An innovative gene regulation device operated via brain waves, have been developed by researchers from Switzerland. Martin Fussenegger, biotechnology and biomechanics professor of Biosystems Department at the Federal Institute of Technology (ETH) Zurich, led researchers and developed a gene network that uses brain waves to control gene expression, or the translation of genes into proteins.

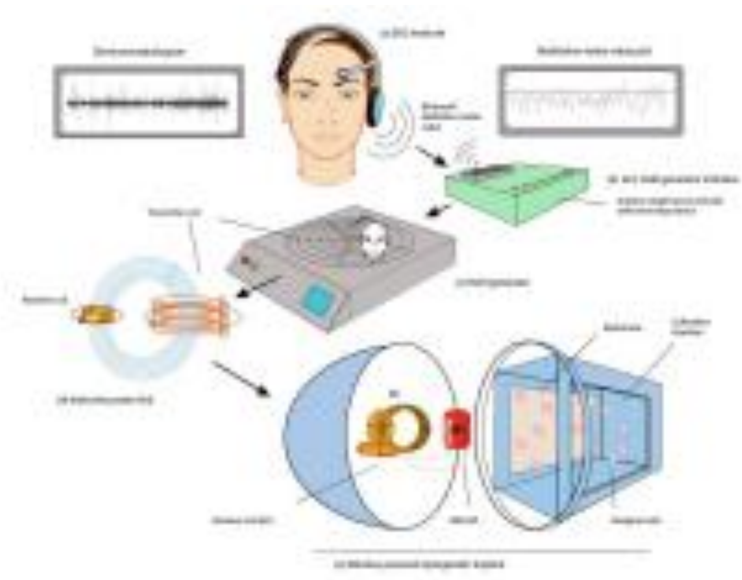

Figure 11 This diagram shows how the implant takes thoughts, interprets them, and transforms them into electricity to light up a near-infrared LED. (Illustration: Folcher M et al. Nature Communications 2014)

This technology has been successfully tested on human cells grown in the laboratory and in mice laboratory. The results were published online 11 November 2014, in the journal «Nature Communications». [41]

1.2.3 Color as Stimulus

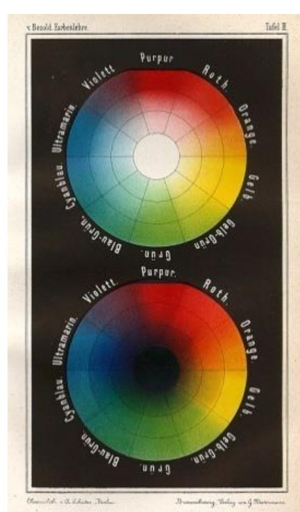

Figure 12 Color Wheel, Bezold Farbentafel, 1874

Among variety of stimuli the visual stimulus also affects brain response and activity. Color is thought to be the most important visual experience for human. [42] Researches have been done either on visual choice reaction time [43], relationship between colours, attention, and memory performance [44], contributions of color to recognition memory for natural scenes [45], on how color enhances visual memory for natural scenes [46] or general the effects of color on memory [47]. Emotions and feelings also is widely recognized that are strongly affected by colors (Hemphill, 1996; Lang, 1993; Mahnke, 1996).

So color in our lives becomes very important. After all life began in the jungle and through human DNA information related to colors passed after a long time ago to us nowadays. Staying alive that previous time might be equal to distinguish correctly the information given in color terms either for feeding or even for surviving. Picking the right color, eg in food selection in order to choose the correct colored plant which was eatable and not the poisonous one, had an important significance.

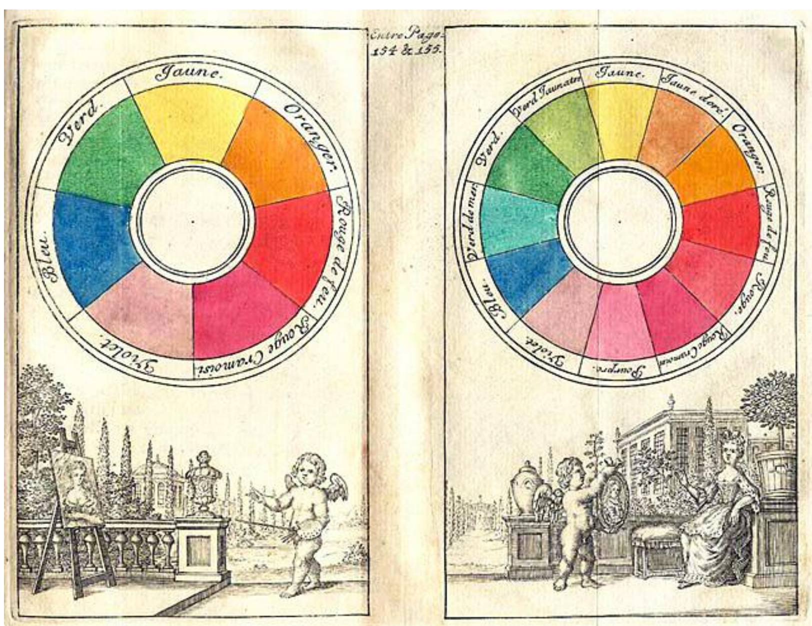

Figure 13 Color Circles, Boutet, 1708

We have to pay attention on how color can be perceived. When we look at an object, color of that object reflects down to the eye. The color of the object surface reflects certain colors, and absorbs the rest, hence the reason we are able to perceive the colors reflected only.

In computer games also color has an important role in order to attract player's attention. [48]

A very well presented depiction of brain's operation when color is used as external stimulus gives Julianna Maisano in her Research Study Presentation on Color Constancy [49]: "There are two different types of photoreceptors located within the retina of the eye, rods which enable us to distinguish between light and dark, and cones which allow us to see color. When the perceived stimulus enters the visual field, the photoreceptors within the eye transduce the sensed stimulus into an electrical signal. The electric signal is directed from the optic nerve to the brain, where a more detailed version of the presented stimulus is perceived. The surface reflectants determine the objects color, however, reflected light is ambiguous in nature." [49]

As for memory performance researchers Mariam AdawiahDzulkifli and Muhammad FaizMustafar in their review mention as conclusion that "An important aspect in successful and efficient cognitive functioning is the abilities to utilize the system to the fullest. Research on memory has provided a vast strategy that can be used to ensure successful retrieval. There appears to be a basis for associating colour and its significant effect on memory abilities. In other words, colour has the potential to increase chances of environmental stimuli to be encoded, stored, and retrieved successfully. The choice of colours and the manipulative aspects can, however, influence the extent to which colours can influence human memory performance." [44] Or according to Dr. Radonjić, color is a proxy for achieving a goal. [44] And his findings also suggest that as humans we use color constancy when performing naturalistic tasks (Radonjić et al., 2015). [50] This very significant review with further more interesting information and suggestions for research about color and the use of color as stimulus, can be seen in Appentix D where a detachment of the review [44] is quoted.

1.2.3.1 Educational Environment

In the educational environment, higher demand has been for excellent academic performance. The extent to which students use their cognitive skills are also important and can contribute to better academic performance [51]. The cognitive abilities of students referred to the way students perceive, pay attention, remember, think, and understand the lessons. There must be strategies to facilitate the learning process and the colors can play a role in motivating students to learn and benefit from their educational experiences there.

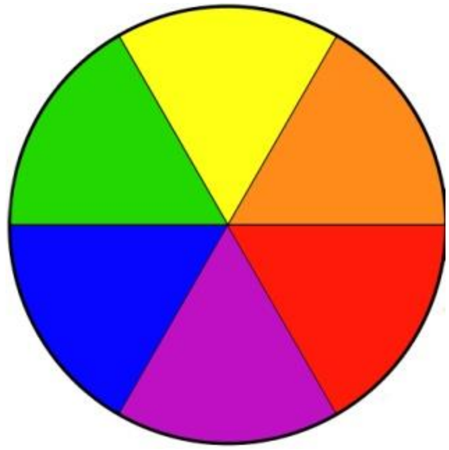

Figure 14 Colour Wheel

1.3 Description of Thesis

Exploring brain's activity as we see is not yet fully defined and remains a huge research area. This thesis attempts to approach and understand the diversifications of brain's responses while interfering in situation. The major concern is how the human brain reacts to an external stimulus.

Frame of Work

- The intention was to observe and notice brain's reactions.
- Resources to accomplish this purpose are Brain Wave Sensors, such as the Mindwave EEG-monitoring Headset of NeuroSky and accompanied or new relative Software.
- Attention's and Meditation's status are states of a Human Mind intended to be observed.
- Different types of External Stimulus are included in thesis' research such as internal or external (or auditory, visual, olfactory etc).

Outcomes

- Results of Attention's and Meditation's status observations.
- Importance and Influence on Mind's reactions with regard to type of External Stimulus

Possible Approaches to Education

- Effects on Learning ability
- Temporal school lessons' scheduling according to brain's best period of activity for different kind of learning areas: Theoritical Courses (e.g. Literature, Philosophy), Practical Courses (e.g. Mathematics, Physics)

In Appendix A there is an abstract delineating this thesis that had been sent when call for papers emerged, to 9th International Conference: on New Horizons in Industry, Business and Education, that took place in Skiathos in 2015 [52] concerning Topic of Interest: Science and Education. [53] It was organized by the Department of Informatics Engineering of the Technological Educational Institute of Crete (GR). [54]

Chapter 2 - NEURONS AND BRAINWAVES

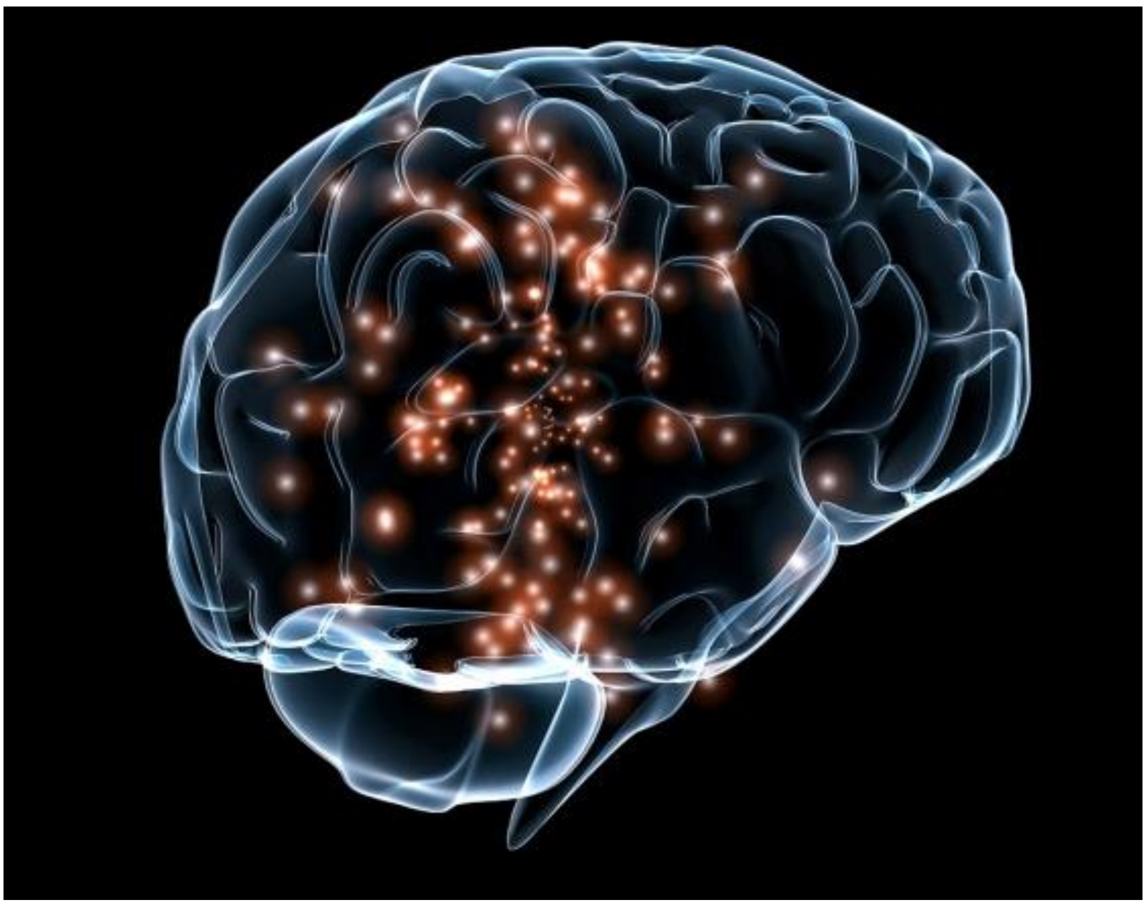

Figure 15 Neurons in the Brain

2.1 Neurons

2.1.1 Definition of Neuron

Figure 16 A Neuron

By defining the neuron is a structural and functional unit of the nervous system. It is also known as a neuron or nerve cell. We can say it is a cell that carries messages between the brain and other parts of the body and that is the basic unit of the nervous system. Neuron receives and sends electrical signals over long distances within the body.

Medical Definition of neuron can be mentioned: "one of the cells that constitute nervous tissue, that have the property of transmitting and receiving nervous impulses, and that are composed of somewhat reddish or grayish protoplasm with a large nucleus containing a conspicuous nucleolus, irregular cytoplasmic granules, and cytoplasmic processes which are highly differentiated frequently as multiple dendrites or usually as solitary axons and which conduct impulses toward and away from the nerve cell body" [55]

2.1.2 Main Parts of Neuron

2.1.2.1 Cell, Axon, Dendrites

A cell body (soma), dendrites and the axon comprise a typical neuron.

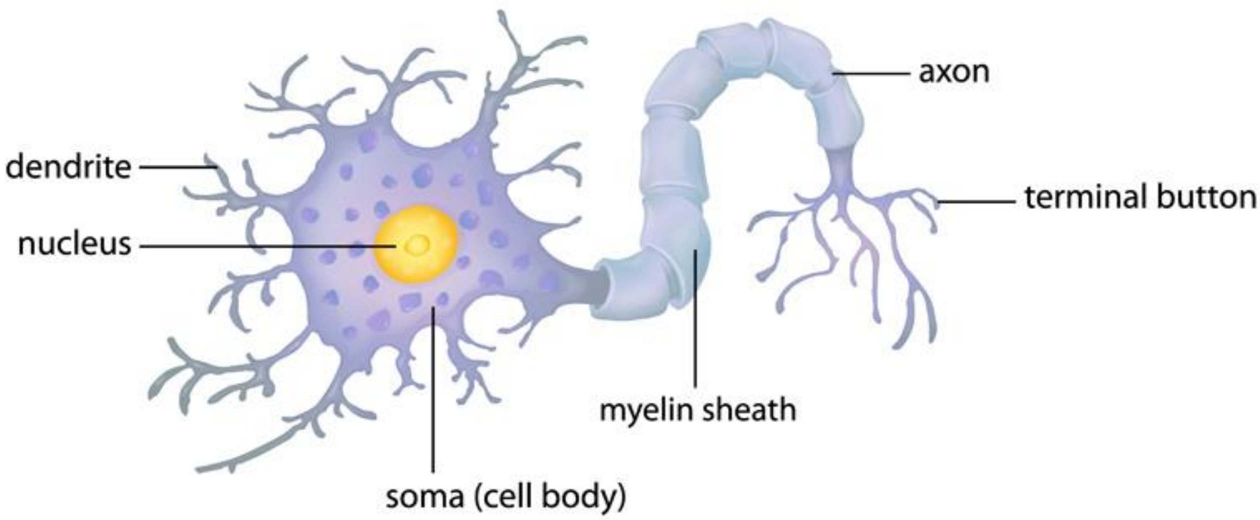

Figure 17 Neuron: Main Parts

The cell or soma or cell body.

This is the main part of neuron and includes all the necessary components of the cell. These components are: nucleus (containing the DNA), mitochondria (for energy) and endoplasmic reticulum and ribosomes (for building proteins). The existence of cell body is critical for the neuron. If it dies, the neuron dies.

Axon

This long, cable like projection of the cell carries the electrochemical message (nerve impulse or action potential) along the cell. Depending on the type of neuron, the axes may be covered with a thin layer of the myelin sheath, as an insulated electrical wire. Myelin is made of fat and protein, and helps to speed transmission of the nerve impulse down a long shaft. Neurons typically are myelinated peripheral nerves (sensory and motor neurons), while non-myelinated neurons in the brain and spinal cord.

Dendrites or nerve endings.

These small, branch, like projections of the cell make connections with other cells and allow the neuron to talk with other cells or perceive the environment. Dendrites can be located at one or both ends of a cell.

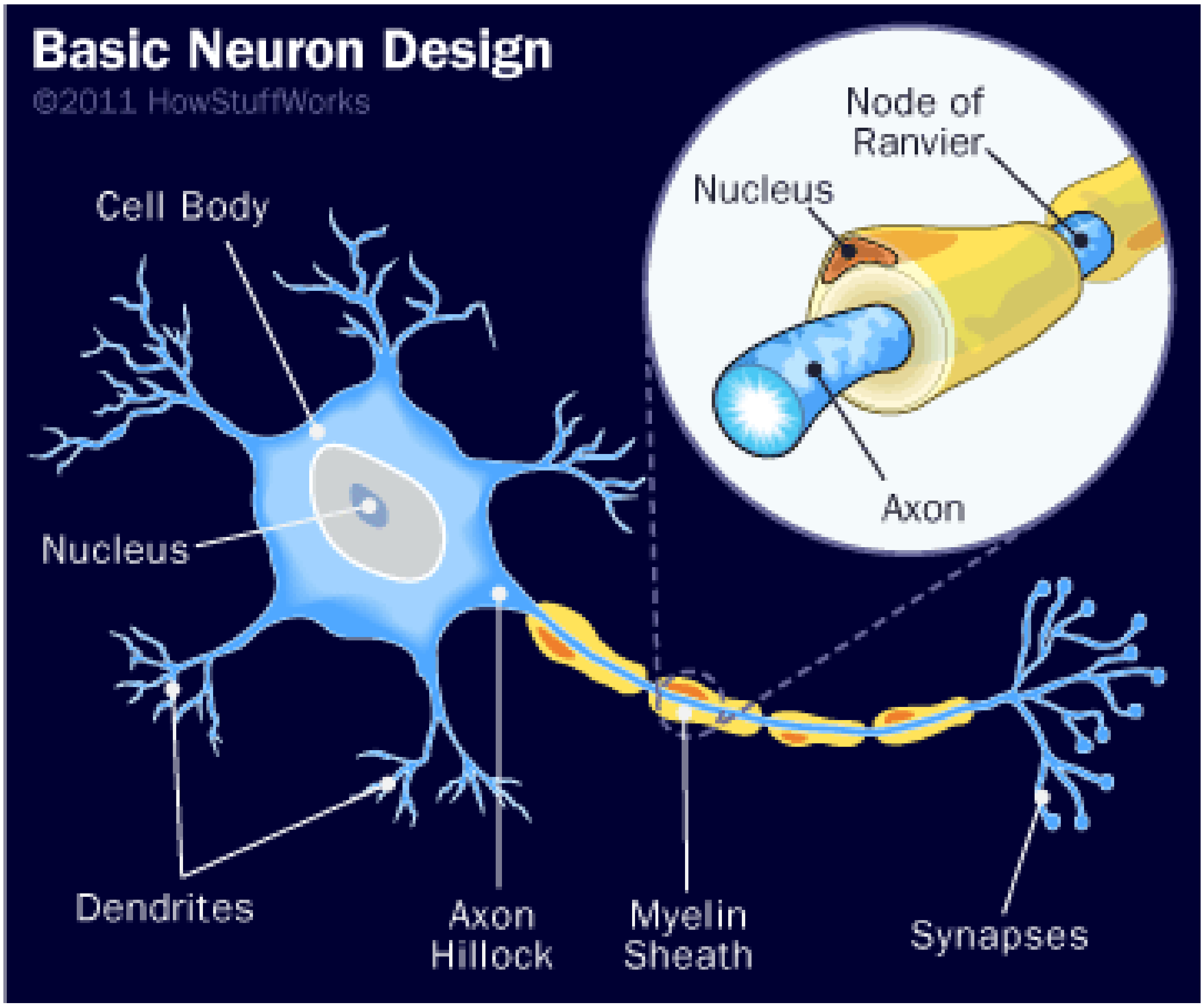

Figure 18 Basic Neuron Design

We use also the term neurite to describe either an axon or dendrite, particularly undifferentiated stage. Dendrites the thin formations that emerge from the cell body, often extend for hundreds of micrometers branching multiple times. As a result a complex "dendritic tree" augments. A shaft (also called myelinated nerve fibers when) is a special cell expansion (process) obtained from the cell body to a position called elevation axis and travels for a distance, about 1m in humans, in other species even more. Nerve fibers are often grouped in bundles, and peripheral nervous system, tow bundles composing the nerves (such as strands of wire constituting cables. The cell body of a neuron frequently causes multiple dendrites, but never to more than one axis, although the axon may branch hundreds of times before it terminates. In the majority of synapses, signals are sent from the axis of a neuron to a dendrite of another. There are, however, many differentiations since neurons that lack dendrites exist, neurons with no shaft synapses that connect an axis to another axis or a dendrite to another dendrite, etc.

2.1.2.2 Functioning: Anatomy and Histology

Figure 19 Neuron as it can be seen nowadays

There are several types of neurons, which are very different in shape. Attribute neurons are the large asymmetry in FIG. Neurons comprising: Soma, most central part of the cell between the dendrites and the axon and includes the cell nucleus.

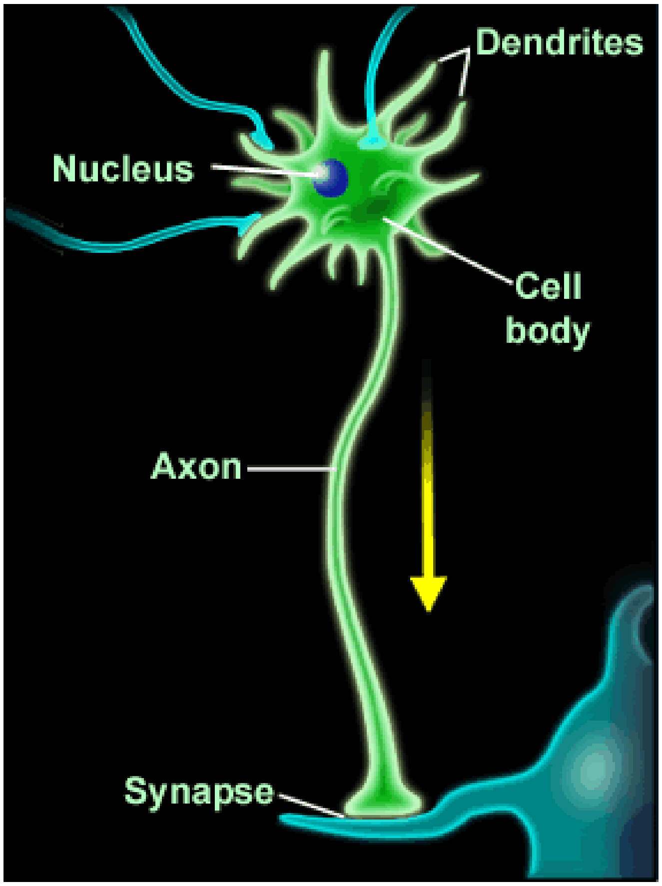

Figure 20 A Neuron

In axons called neurites as we already mentioned or just axis, a fine fiber can be up to tens of thousands of times greater in length than the diameter of the body. This structure carries the nerve signals from the neuron.

Figure 21 Neurons firing

Each neuron has only one axis, but this axis may be branched sharply, so to achieve communication with multiple target cells.

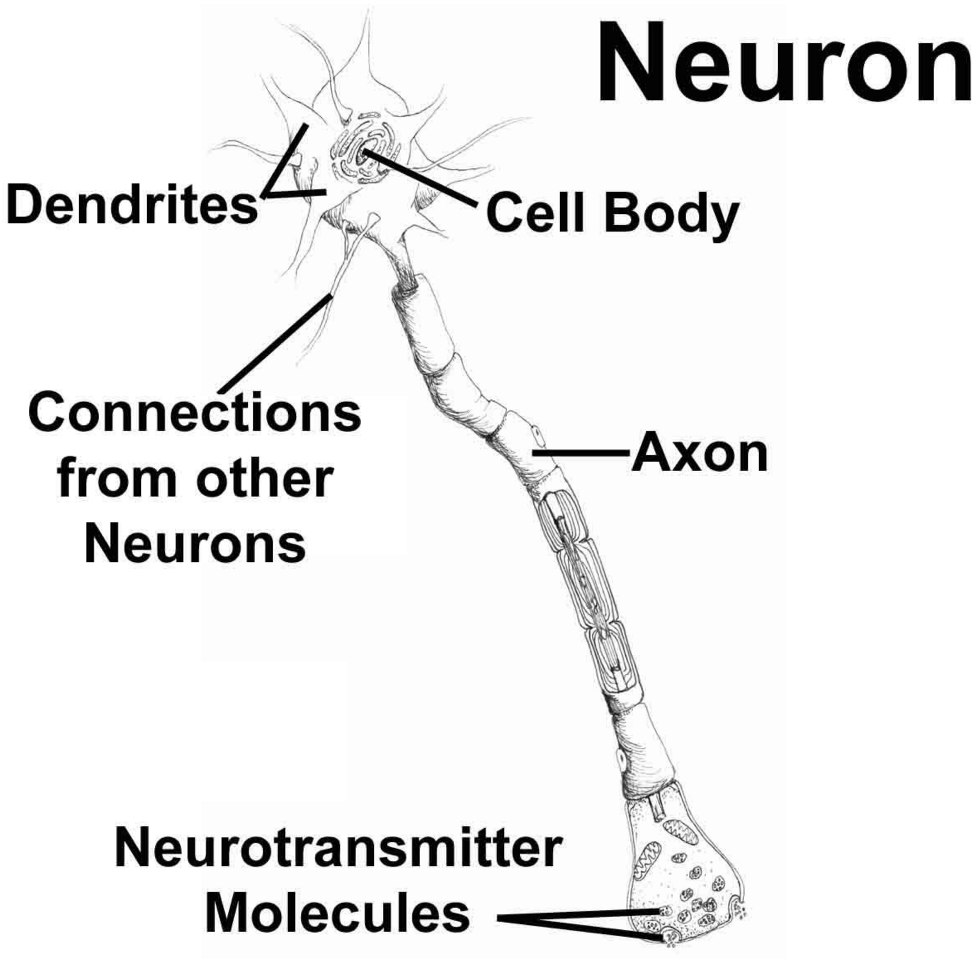

Figure 22 A Neuron

When the shaft ends are important ultimately buttons required for transferring information to other dendrites of other neurons. Most axons are insulated with myelin. The dendrites on short protrusions or branched apofyades cells.

Each neuron has many dendrites with many ramifications.

Figure 23 Brain Neural Netwrok

These structures form the network in which the neuron employs signals from other cells. These waves reaching dendrites of each nerve cell axons by (one or more) of other nerve cells. This attached, branching and cooperate with each other nerve cells, in groups, in order to achieve the purpose for which they were constructed, dissemination of stimuli from the periphery to the center (brain) and vice versa. At the edge of dendrites is presynaptic knobs and synapses, and then the cell is receiving or transmitting signals.

Both the axon and dendrites have a typical size of about 1 micron, while the body is approximately 25 microns, it is substantially higher than the core contains. The axon of a motor neuron can be greater than 1 meter in length, by connecting, for example, the base of the spine to the toes.

Figure 24 Active Brain

The number of nerve cells is enormous and cannot be measured or estimated accurately. The old anatomists have estimated that in the human brain there are two trillion neurons.

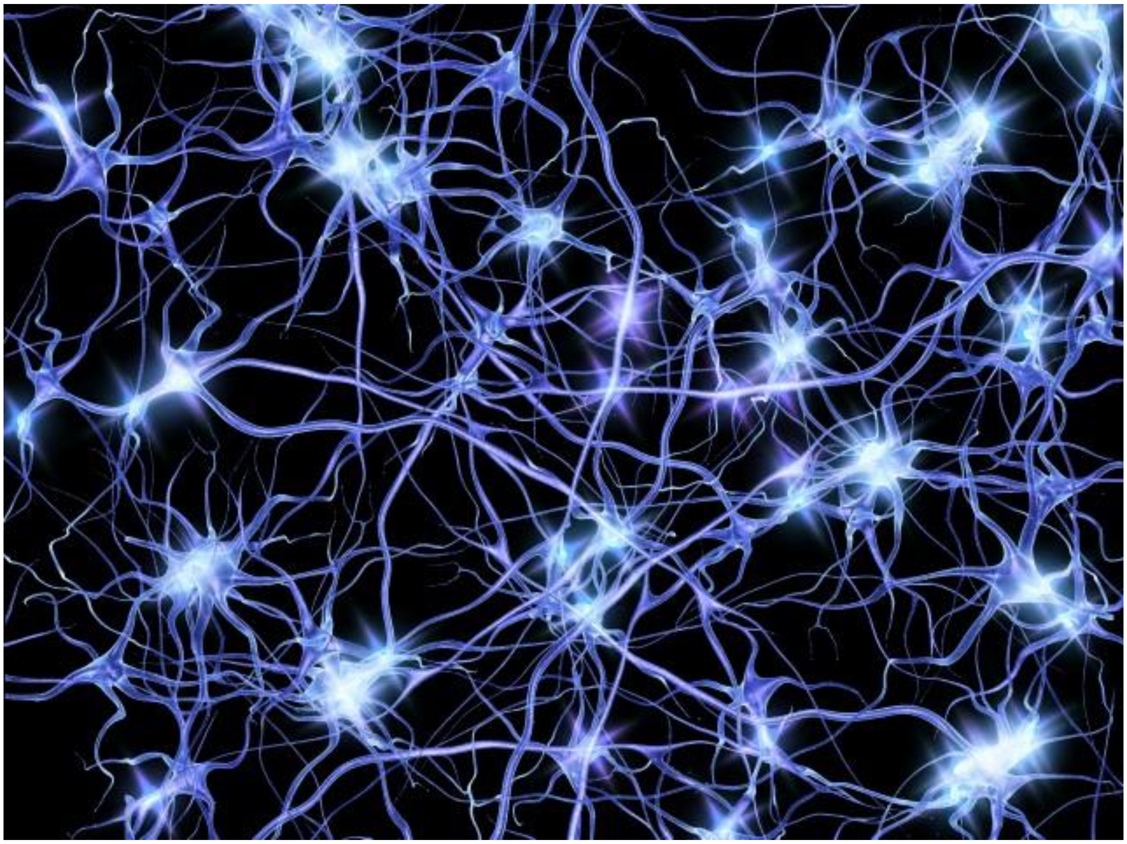

Figure 25 Neural Network of the Brain

2.1.3 Connectivity among Neurons

2.1.3.1 Electric Pulse, Spike

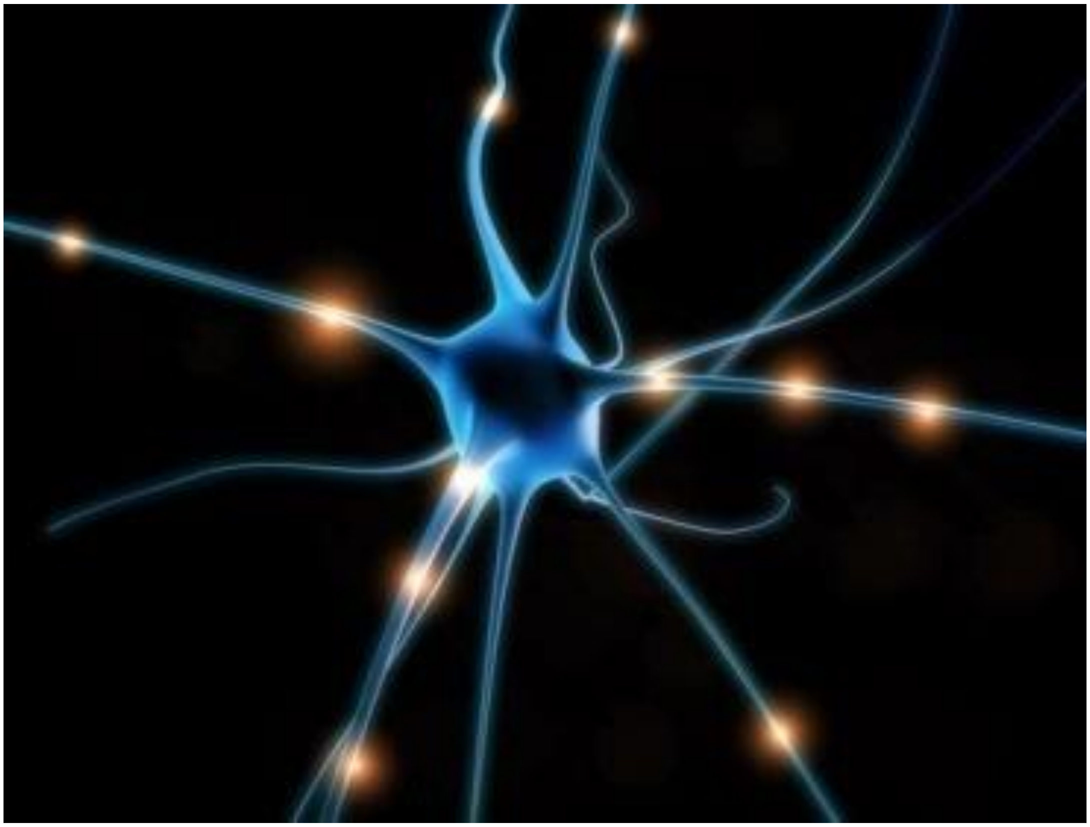

Figure 26 A Neuron firing

Each neuron consists of a cell body comprising a core and a large number of organelles, and one or more apofyades. These are called "dendrites" when they collect the signals sent to the cell and "axon" when it transmits impulses from the cell body.

At this point arises the need of understanding a bit the way electricity exists inside human body.

Membrane Voltage/ Membrane Potential

At a biological cell there is electric potential internally and externally of it. The difference in electric potential between the interior and the exterior of a biological cell is called membrane potential (or transmembrane potential or membrane voltage).

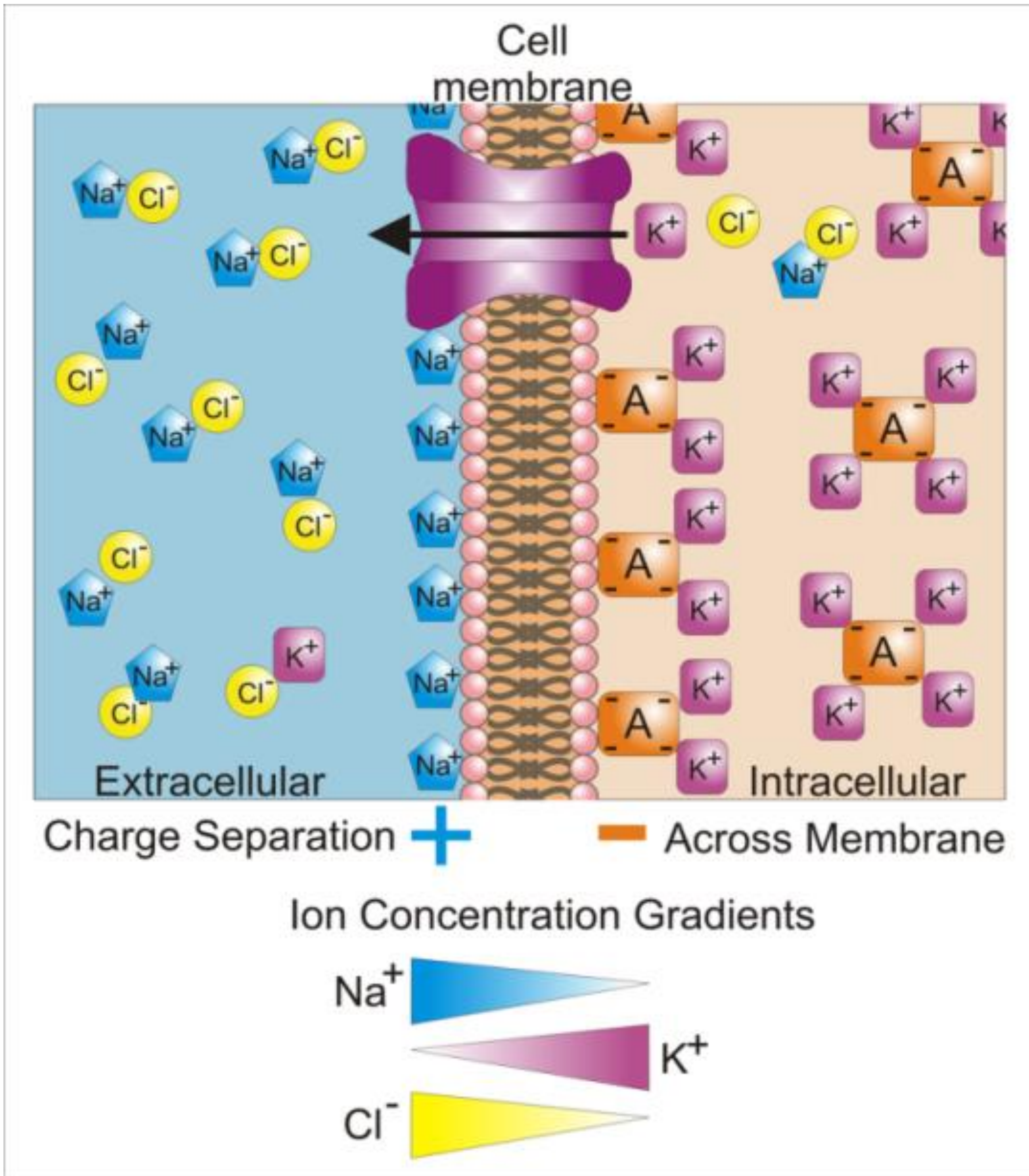

Figure 27 Basis of Membrane Potential

"Differences in the concentrations of ions on opposite sides of a cellular membrane lead to a voltage called the membrane potential. Typical values of membrane potential are in the range +40 mV to –70 mV." [56]

Basic function of a cell regarding potentials is needed for this thesis so more analytic description and details for membrane potential are not mentioned although a large relevant bibliography exist indeed. [57], [58], [59], [60], [61] Action Potential

When the electrical membrane potential of a cell rapidly rises and falls, following a consistent trajectory and the event is short-lasting it is called an action potential. [62]

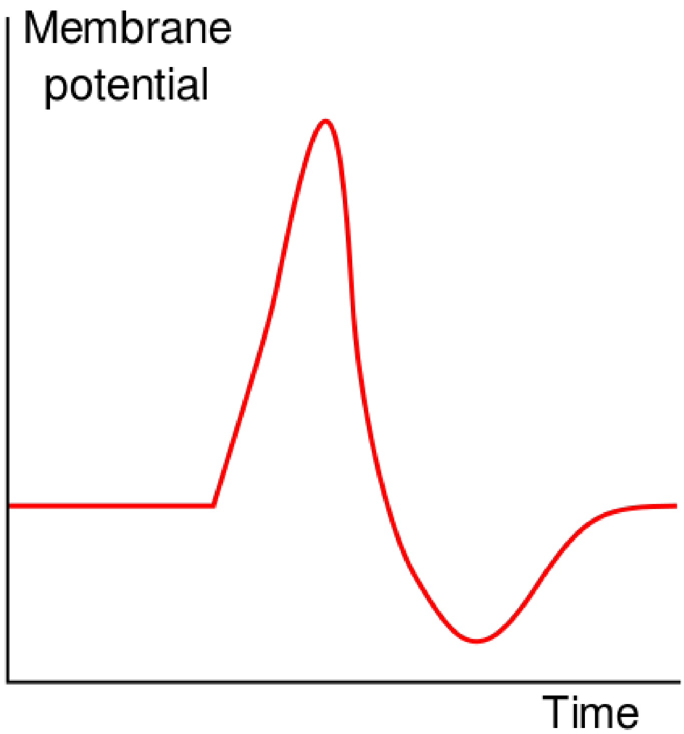

Figure 28 Action potential, basic shape

"Shape of a typical action potential. The membrane potential remains near a baseline level until at some point in time it abruptly spikes upward and then rapidly falls." [63]

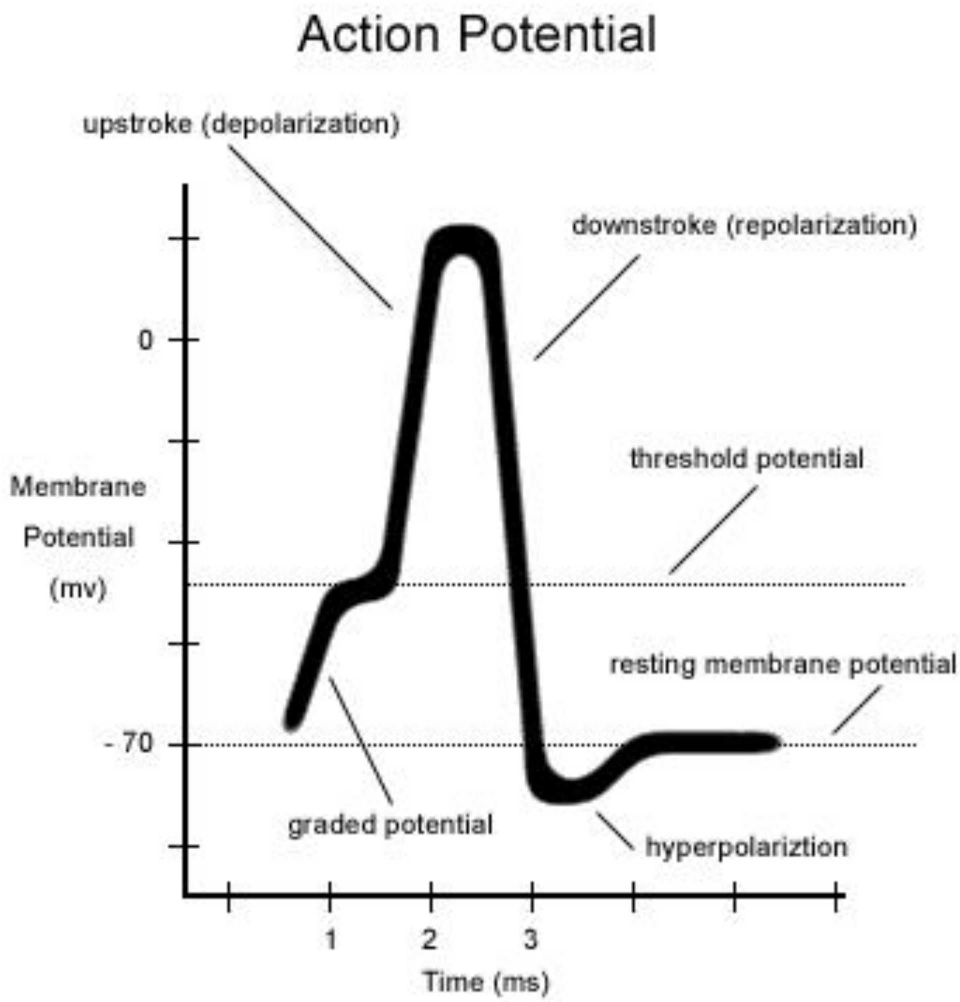

Figure 29 Action Potential

Action potentials occur in several types of animal cells and they are called excitable cells, as well as in some plant cells. Excitable cells include neurons, muscle cells, and endocrine cells. In neurons, they play a central role in cell-to-cell communication.

Action Potentials in Neurons, Nerve Impulses, Spikes

Action potentials in neurons are also known as "nerve impulses" or "spikes", and the temporal sequence of action potentials generated by a neuron is called its "spike train". A neuron that emits an action potential is often said to "fire".

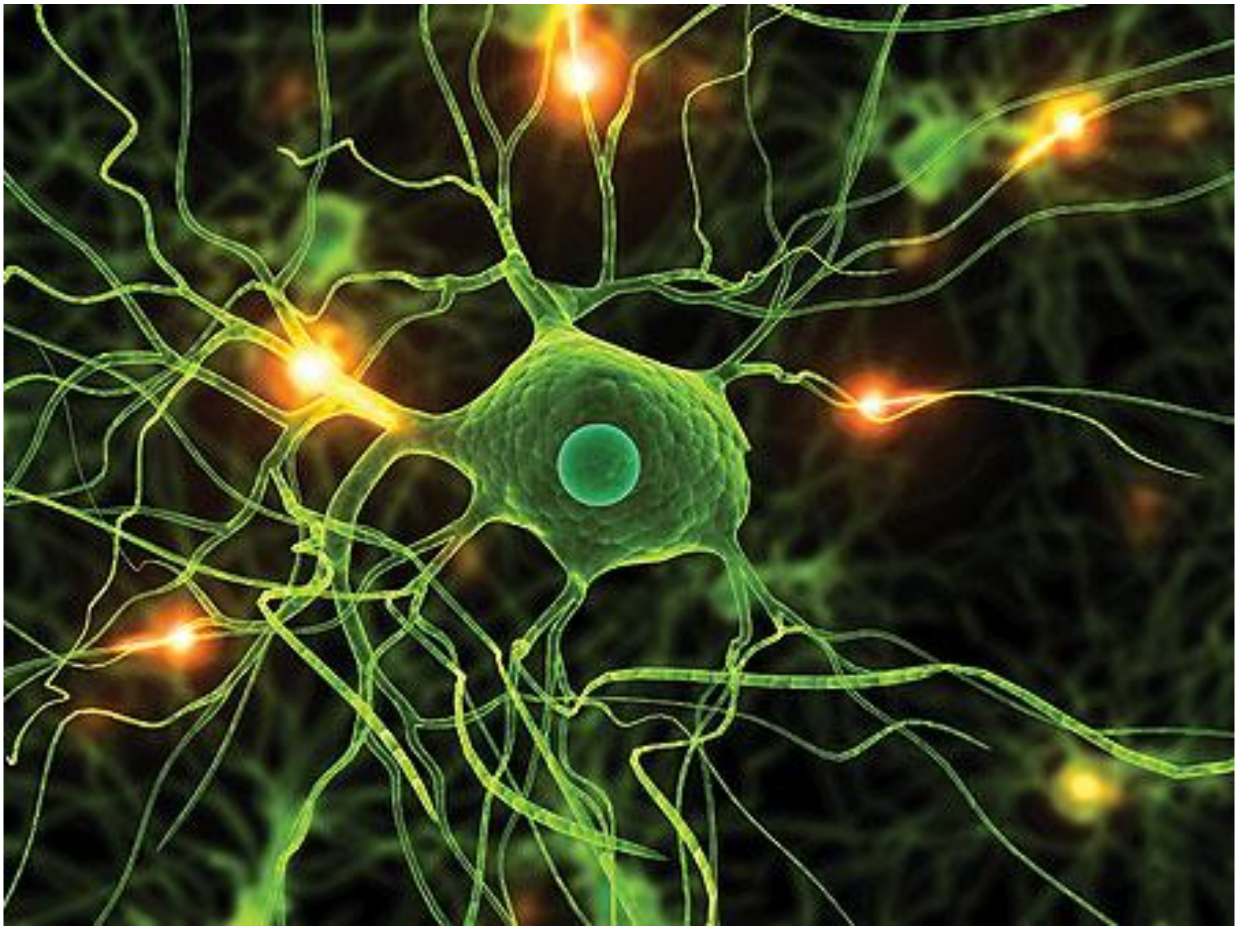

Figure 30 Neurons firing

" Approximate plot of a typical action potential shows its various phases as the action potential passes a point on a cell membrane. The membrane potential starts out at -70 mV at time zero. A stimulus is applied at time = 1 ms, which raises the membrane potential above -55 mV (the threshold potential). After the stimulus is applied, the membrane potential rapidly rises to a peak potential of +40 mV at time = 2 ms. Just as quickly, the potential then drops and overshoots to -90 mV at time = 3 ms, and finally the resting potential of -70 mV is reestablished at time = 5 ms." [63]

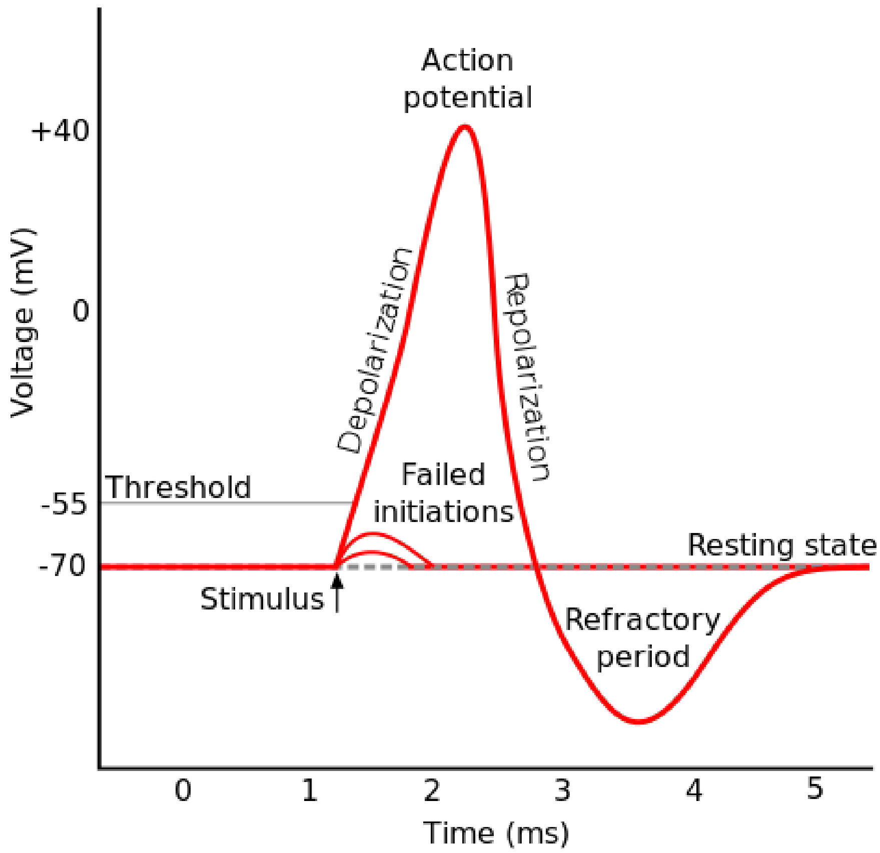

Figure 31 Action potential

Figure 32 Neurons firing

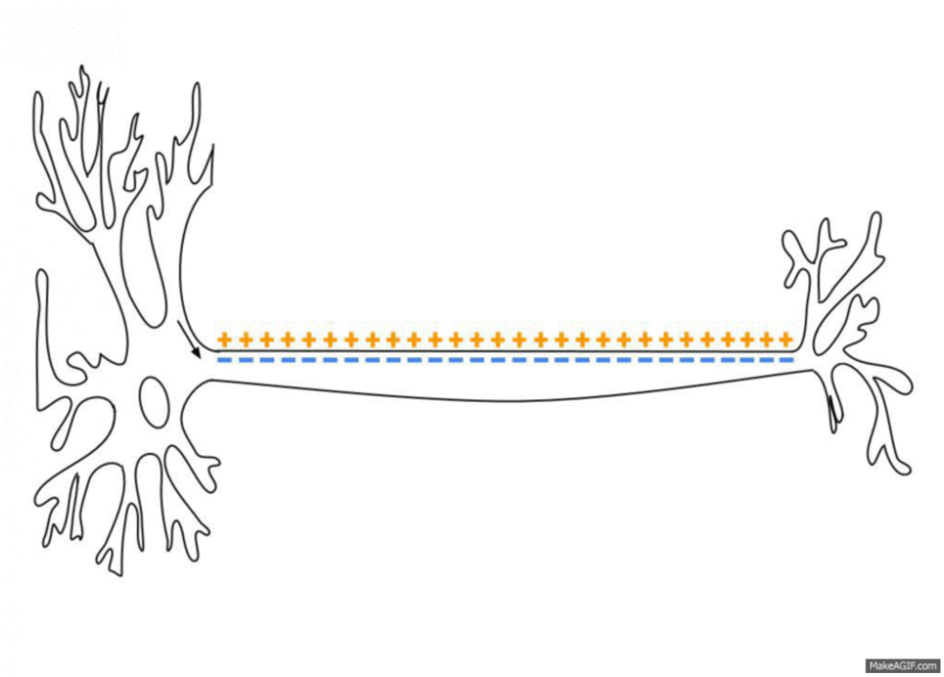

Figure 33 Action Potential

" As an action potential travels down the axon, there is a change in polarity across the membrane." [63]

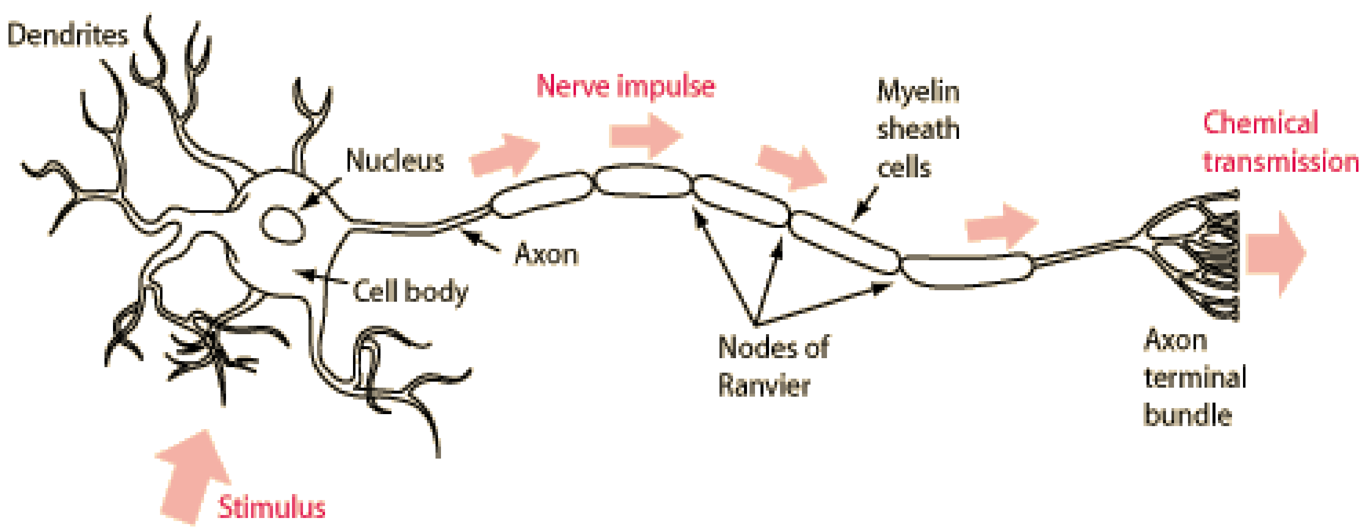

Figure 34 A Stimulus, Nerve Impulse and Chemical Transmission

So when a stimulus occurs the neuron reacts. A nerve impulse arises inside the neuron and travels down the axon carrying the information needed to be transferred.

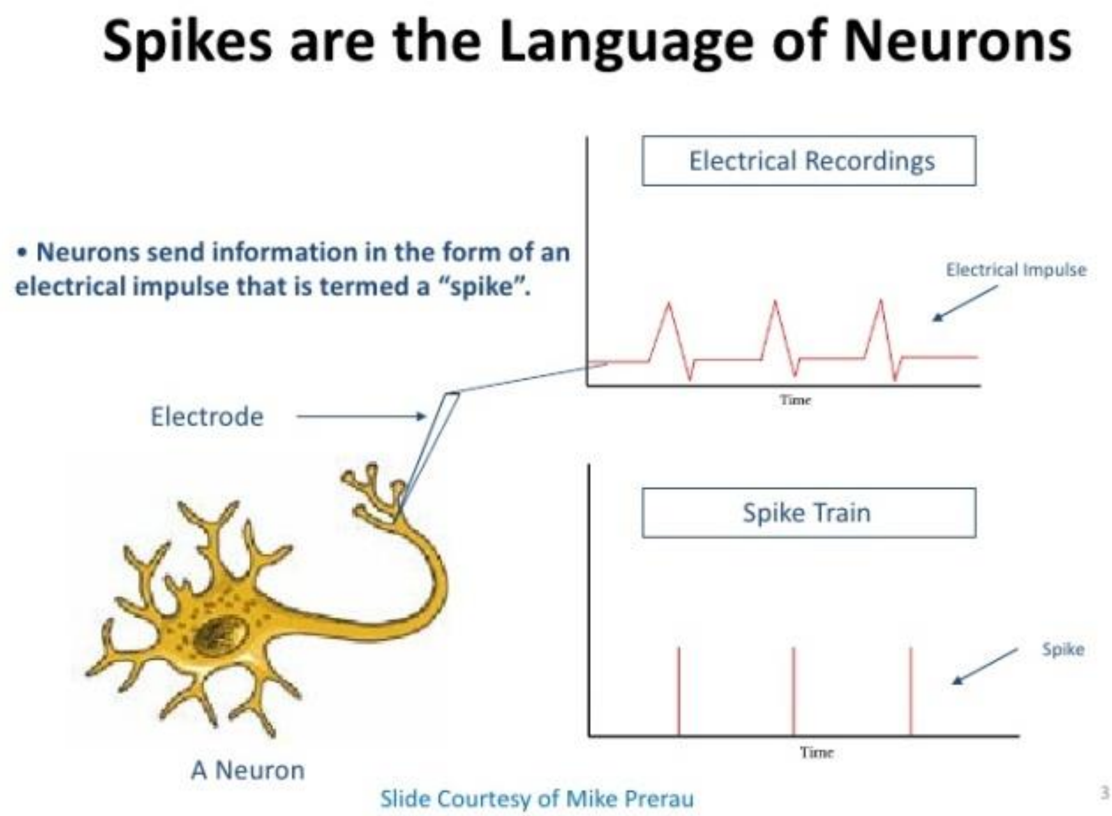

Figure 35 Neuron and Spikes

The axons of peripheral nervous system cells are covered by a myelin sheath, a sheath formed from a long chain of cell Svan (Schwann): this system ensures the propagation of electrical pulses (Spike) along the axon at a speed of about 100 m/Sec. The number of pins per second (Fi = Spike/s) is defined as "voiding frequency" or the frequency of the neuron ribs.

Electric pulses (spikes) caused by a trigger mechanism and depolarization of the neuron membrane.

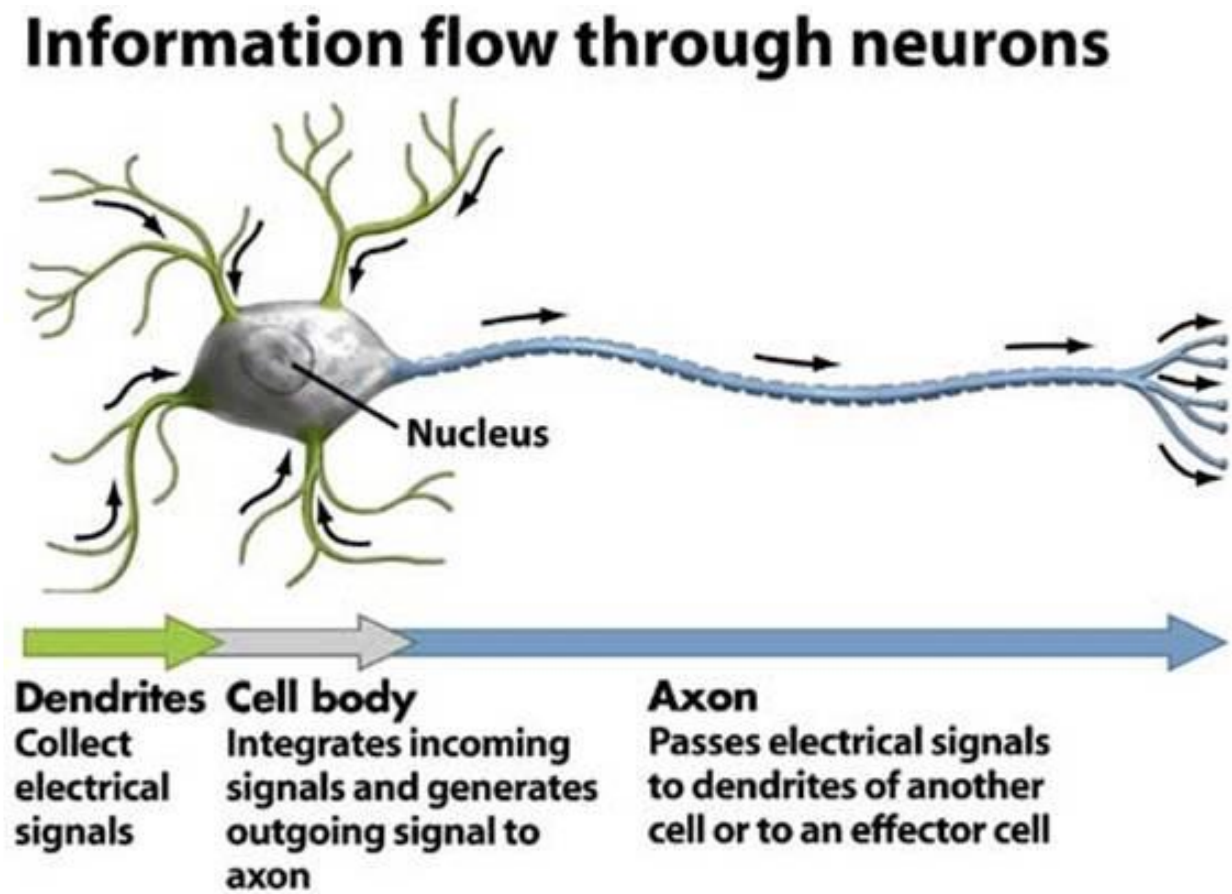

Figure 36 Neuron: Functioning

We can see above that it is dendrites that collect the incoming electric signals from other neurons. Then cell body integrates incoming signals and generates outgoing signal to axon, which passes the electric pulses to dendrites of another cell through synapses.

Among the sheaths is a gap, in which the axon is naked.

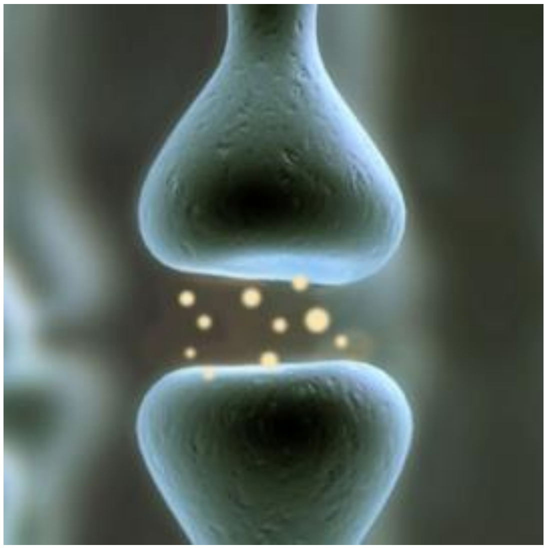

Figure 37 The Synaptic Gap at a Synapse

This point is called rabbi node and is rich in sodium channels. In each node the signal is amplified again. The axons of the central nervous myelinated cell system made by special glial cells, oligodendrocytes.

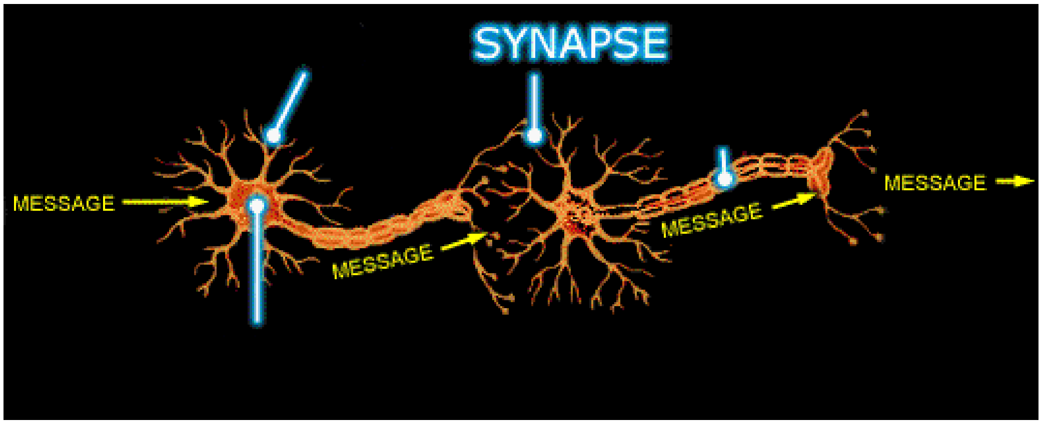

Figure 38 The Route of a Message through Neurons

Finally the information that initially occurred by external stimulus, travels and arrives at the end of axon. There is the point that the message has to be transmitted from sending neuron to the receiving neuron.

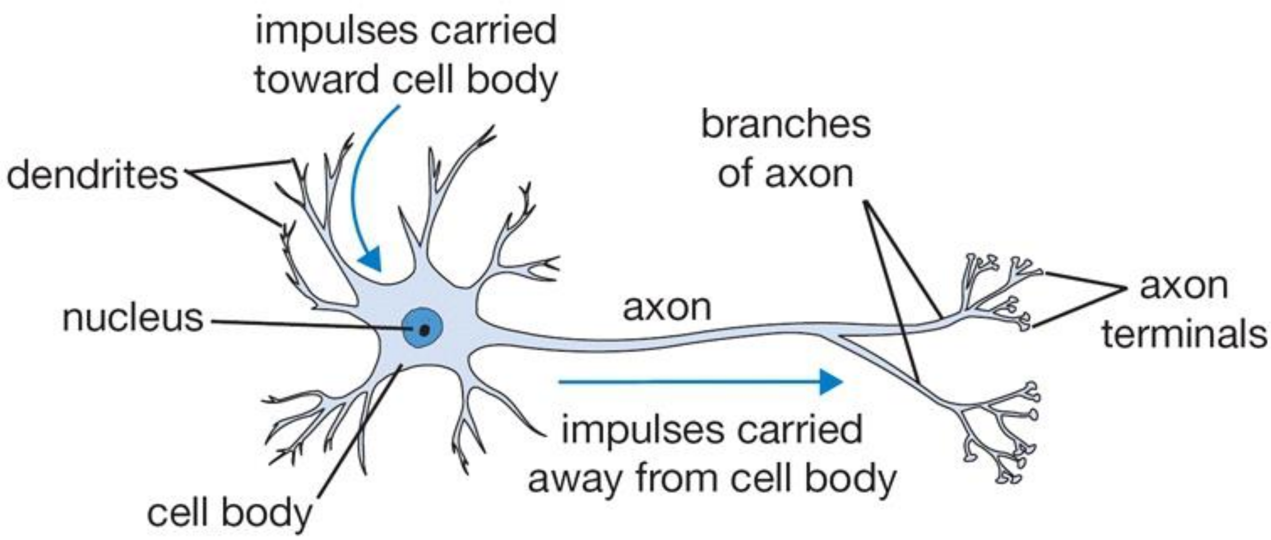

Figure 39 A Neuron and Impulse

Information's transmission is succeeded by electrical and chemical signals. These signals between neurons occur through synapses, specialized connections with other cells.

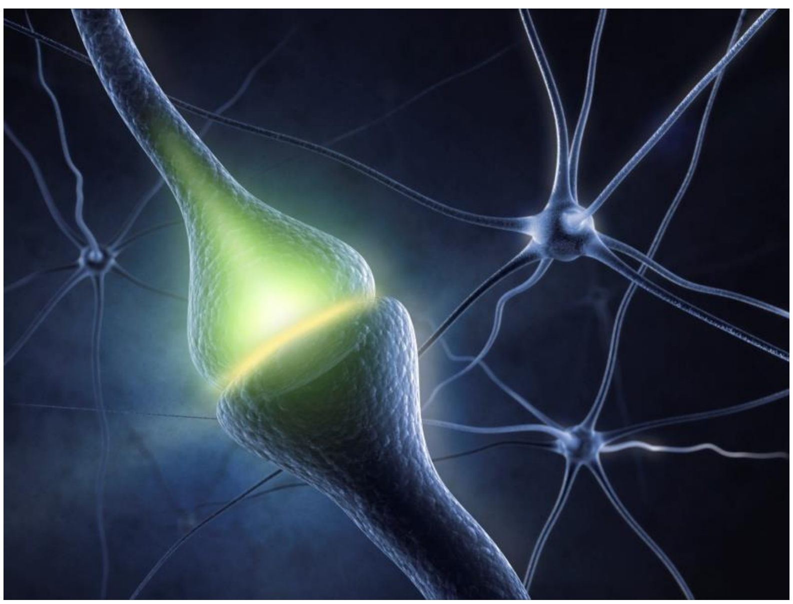

Figure 40 Synapse or Syndesis or Synapsis

2.1.3.2 Synapse (or Syndesis or Synapsis)

Definitions:

"a)a region where nerve impulses are transmitted across a small gap from the end of one nerve cell to another nerve cell, or to a muscle.

Also called synaptic gap, the gap itself.

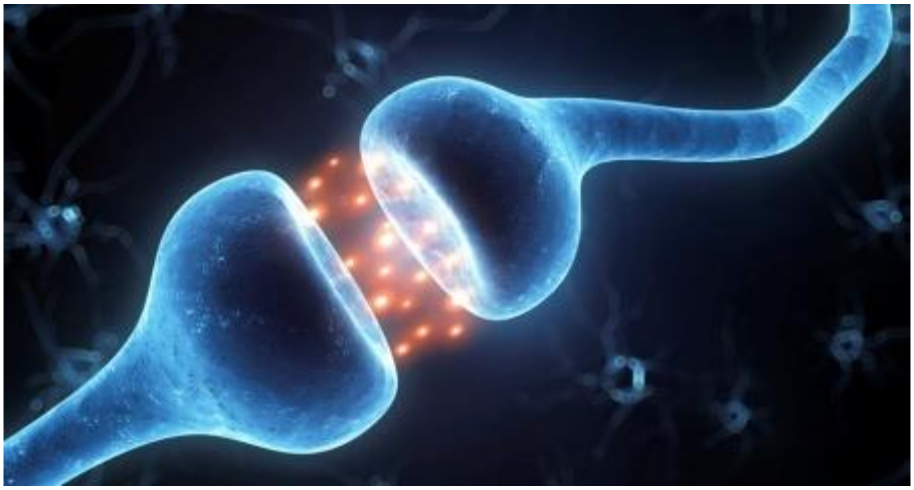

Figure 41 The Synaptic Gap at a Synapse

b) a region where nerve impulses are transmitted and received, encompassing the axon terminal of a neuron that releases neurotransmitters in response to an impulse, an extremely small gap across which the neurotransmitters travel, and the adjacent membrane of an axon, dendrite, or muscle or gland cell with the appropriate receptor molecules for picking up the neurotransmitters.

c) the point at which a nerve impulse is relayed from the terminal portion of an axon to the dendrites of an adjacent neuron" [64]

Also called syndesis, "the pairing of homologous chromosomes, one from each parent, during early meiosis.

Etymology:

a) 19th Century: from New Latin, from Greek sunapsis junction, from sunaptein to join together, from syn- + haptein to connect

b) 1645–55; Neo-Latin Greek sýnapsis junction, equivalent. to synap- (stem of synáptein to make contact, equivalent. to syn- syn- + (h)áptein to touch) + -sis -sis" [65]

Synapses may be excitatory or inhibitory and either increase or decrease the activity of target neurons. Some neurons also communicate via electrical synapses, which are direct, electrically conductive connections between the cells.

Figure 42 Neurons: Synapses in the Neural Network

Neurons communicate with one another and with other neurons through synapses , where the top ends of the shaft dendrites, body or, more rarely in the shaft other neurons. So neurons' communication is accomplished through synapses, where in the terminal axon or in passing boutons (terminals located along the axis) of a cell impinges upon another neuron dendrite, soma or, less frequently, axon.

In chemical synapses, the process of synaptic transmission is as follows:

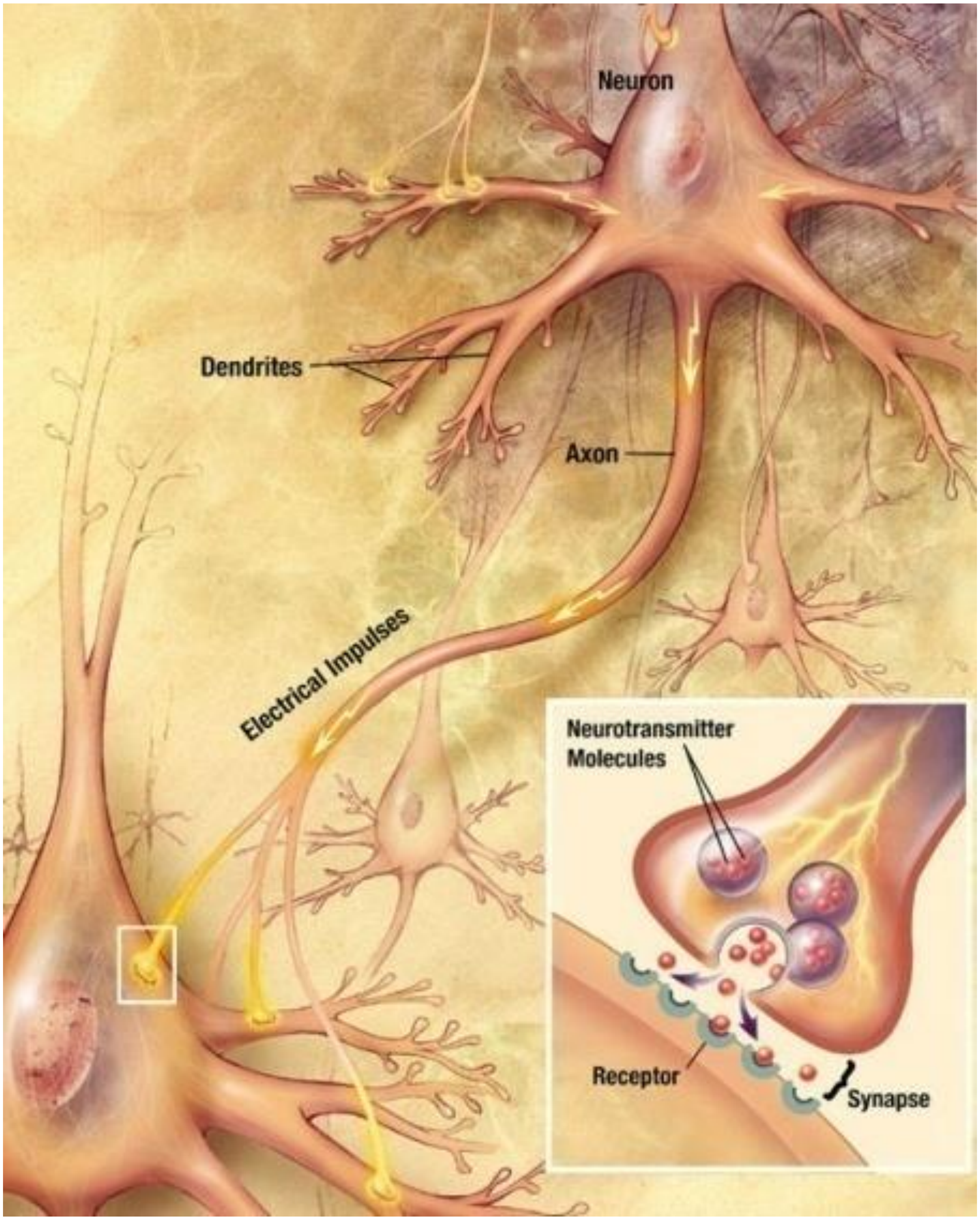

Figure 43 The Process of Synaptic Transmission, in Chemical Synapses

When an action potential arrives at the terminal axis, opens voltage-gated calcium channel, allowing calcium ions to enter the terminal. Calcium causes synaptic vesicles filled with neurotransmitter molecules to fuse with the membrane, releasing their contents into the synaptic cleft. The neurotransmitters diffuse across the synaptic cleft and activates receptors on postsynaptic neuron. High cytosolic calcium at the terminal axon also activates mitochondrial calcium uptake, which, in turn, activates the energy metabolism of mitochondrial ATP production to support continuous neurotransmission. [66] [67]

So neurons communicate via synaptic connections.

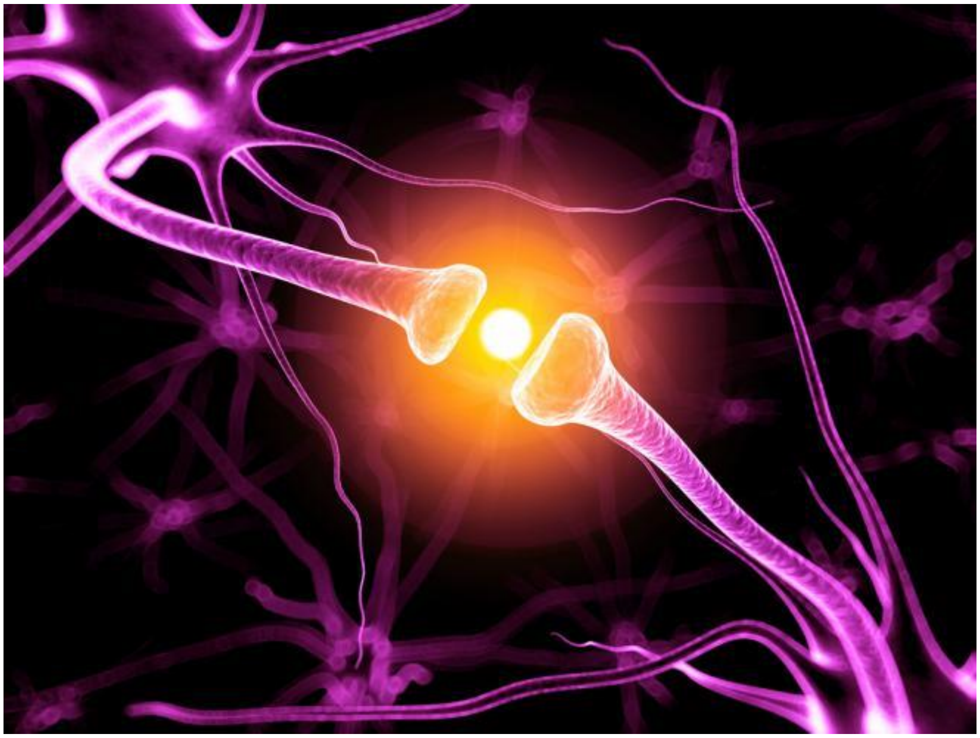

Figure 44 Synaptic Connection in Neurons of the Brain

Contact chemicals is achieved by rapid secretion of neurotransmitter molecules. The pre-synaptic neuronal cell (the one that releases the neurotransmitter) can result in post - synaptic cell (which takes the neurotransmitter) an electrical stimulation sent to axial lofidio create a potential energy which is then transmitted as an electrical stimulation along the shaft.

Upon arrival at the end of the axon will cause the release of the neurotransmitter in the synaptic gap. Neurotransmitters generally can either induce or prevent induction of induction of the target cell. The potential energy will be produced in the target cell, if the molecules of neurotransmitter acting on post synaptic receptors causes the target cell to reach the threshold potential.

The following image shows how electric signal from the sending neuron transforms to chemical signal in order to travel through synapse and reach the receiving neuron.

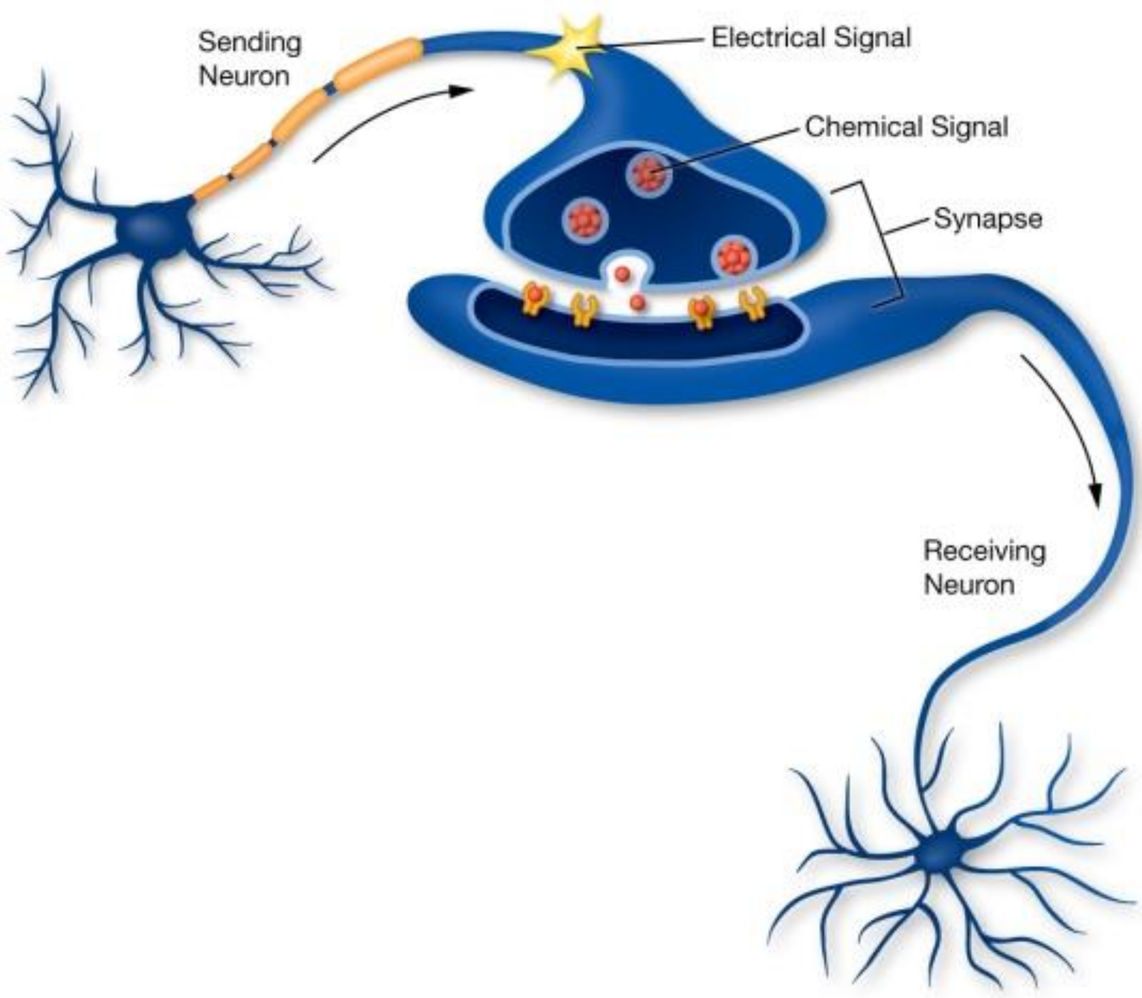

Figure 45 Neuron: Communicate via the Synapse

As described at University of Utah, Health Sciences' department "Information from one neuron flows to another neuron across a small gap called a synapse (SIN-aps). At the synapse, electrical signals are translated into chemical signals in order to cross the gap. Once on the other side, the signal becomes electrical again. One sending neuron can connect to several receiving neurons, and one receiving neuron can connect to several sending neurons." [68]

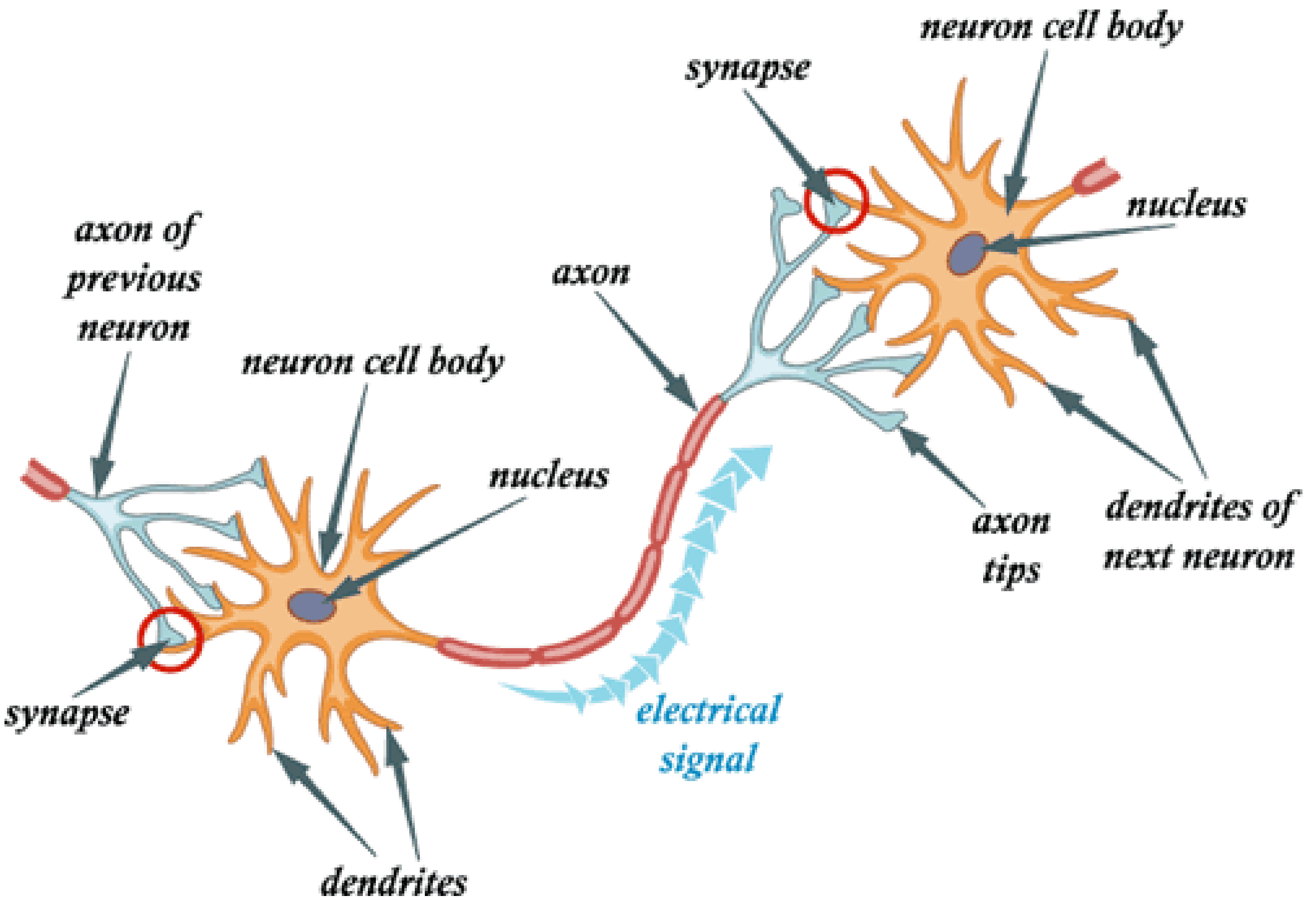

Figure 46 Neuron: Way of Electrical Signal through Axon and Communication with other Neuron through Synapses

By this way cell-to-cell communication inside human body is accomplished and neurons exchange of information closely enough through synaptic gaps form at the end a complex network.

Figure 47 Neurons in a Neural Network

2.1.4 Brain's Neural Network

So a neuron is an electrically excitable cell that processes and transmits information by electrical and chemical signals.

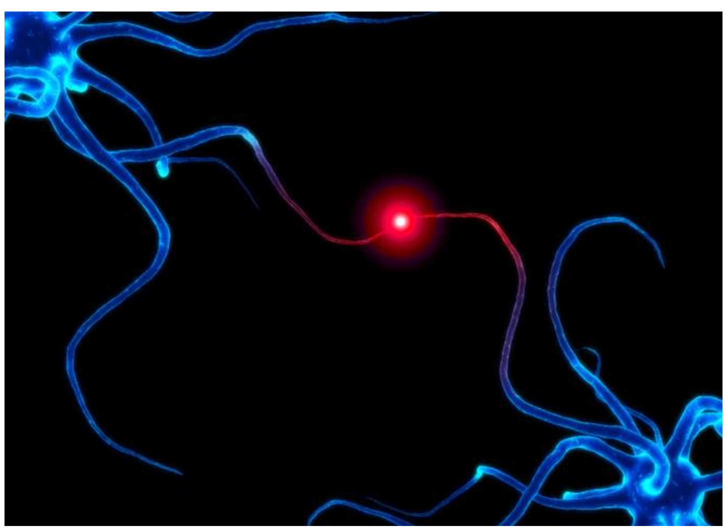

Figure 48 Two Neurons Firing and Connected through Synpase

Neurons may be joined together to form neural networks such as the neurons inside the brain.

One sending neuron can connect to several receiving neurons, and one receiving neuron can connect to several sending neurons.

Figure 49 Synaptic Connection, Brain Neurons

Neurons are the basic components of the brain and spinal cord of the central nervous system (CNS) and in the ganglia of the peripheral nervous system (PNS).

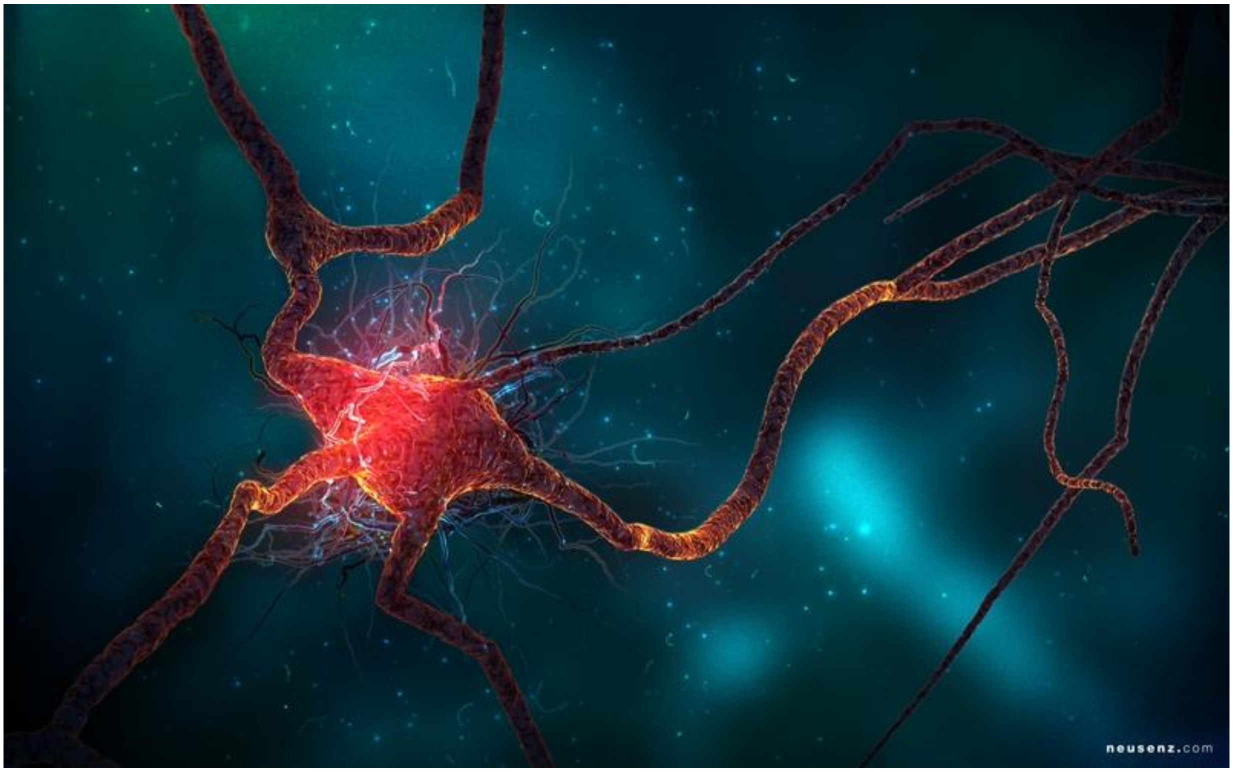

Figure 50 Neuron

Specialized types of neurons include: sensory neurons respond to touch, sound, light and all other stimuli affecting cells of the sensory organs that then send signals to the spinal cord and brain motor neurons that receive signals from the brain and spinal cord causing muscle contractions and affect glandular output, and inter neurons that connect neurons to other neurons within the same area of the brain, spinal cord or neural networks.

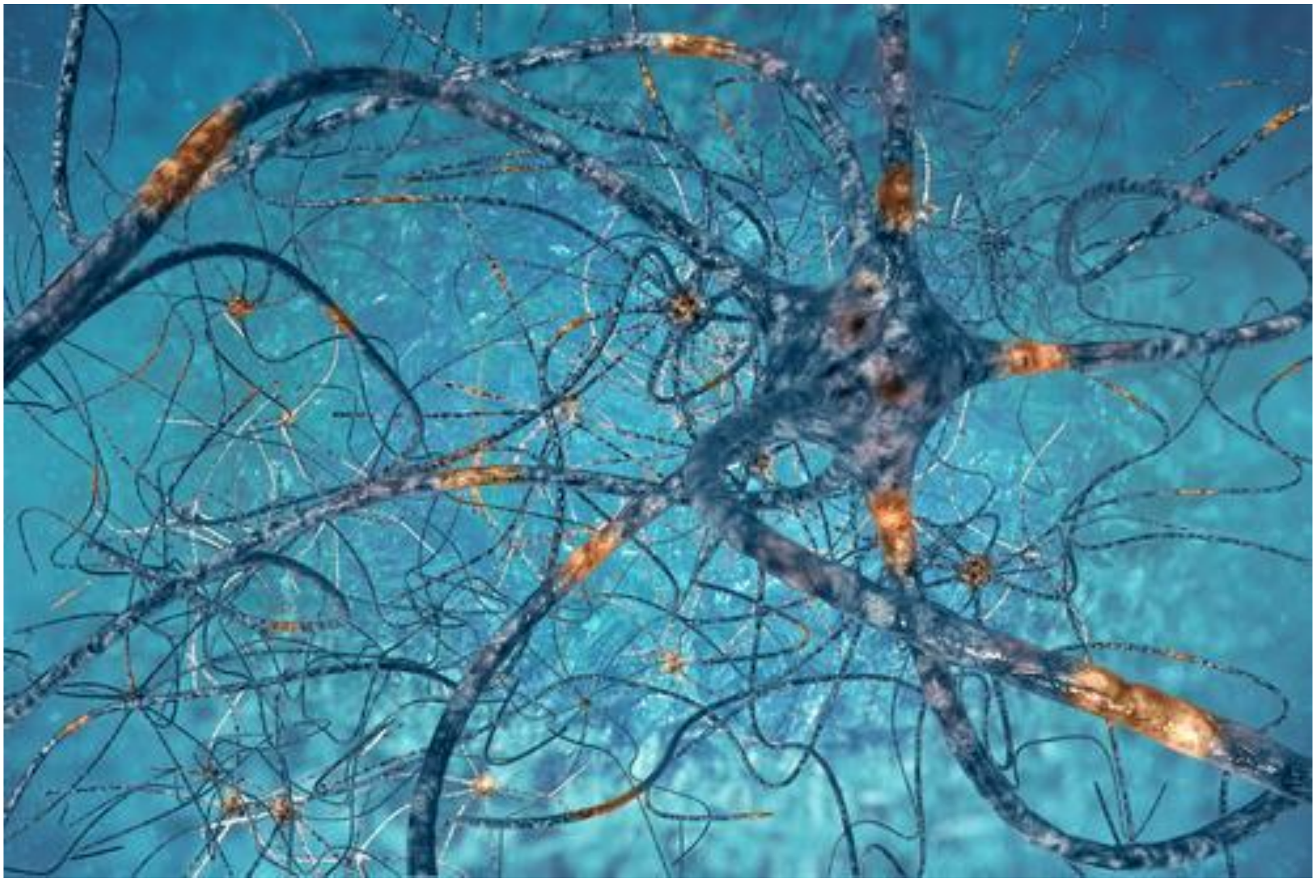

Figure 51 Neural Network

The human neural network was imitated in order to create artificial neural networks based on syndesis of many neurons. At the image we can see a biological neuron and an artificial one, where the five synapses at dendrites of the soma are represented by five inputs in the input layer.

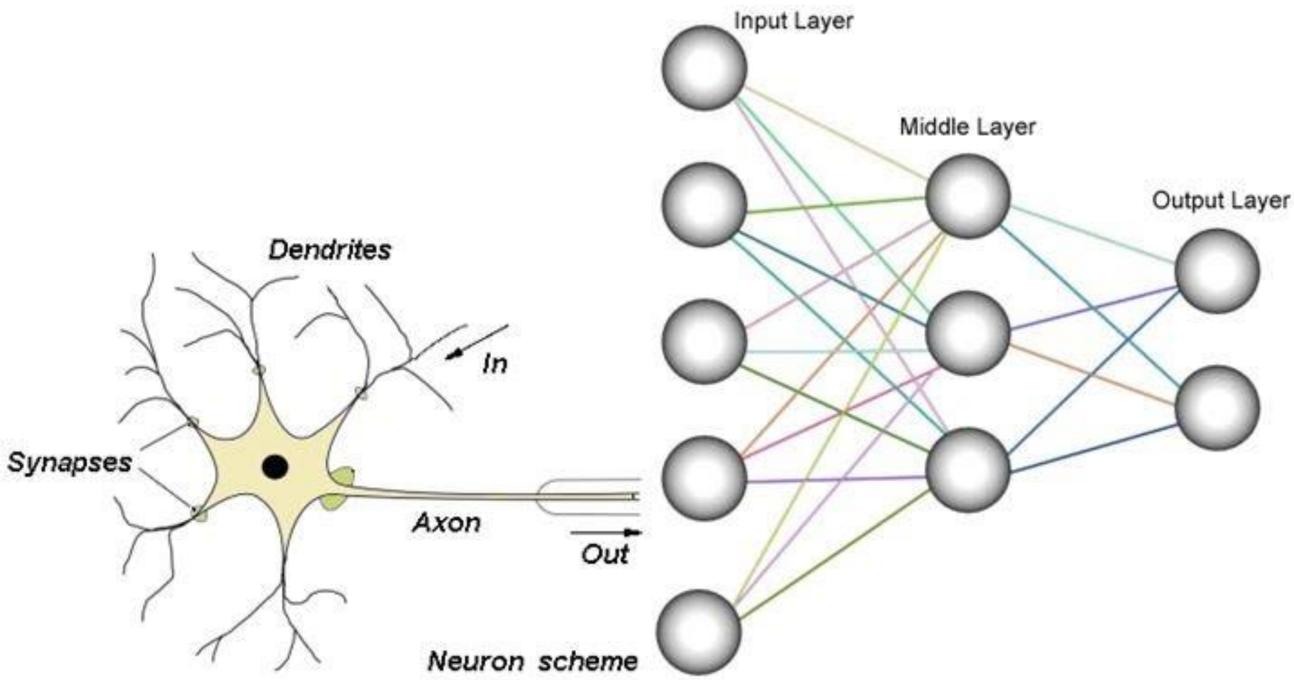

Figure 52 Neural Network, Biological & Artificial Neuron

Neural Coding

Neural coding deals with how sensory and other information are represented in the brain by neurons. The main objective of the neural coding study is to characterize the relationship between the stimulus and the individual or set of neuronal responses, and the relationships between the electrical activity of neurons in total.

When the neurons in the brain's neural network fire the occurring image is amazing as the one follows that shows neurons in the brain firing off in real-time.

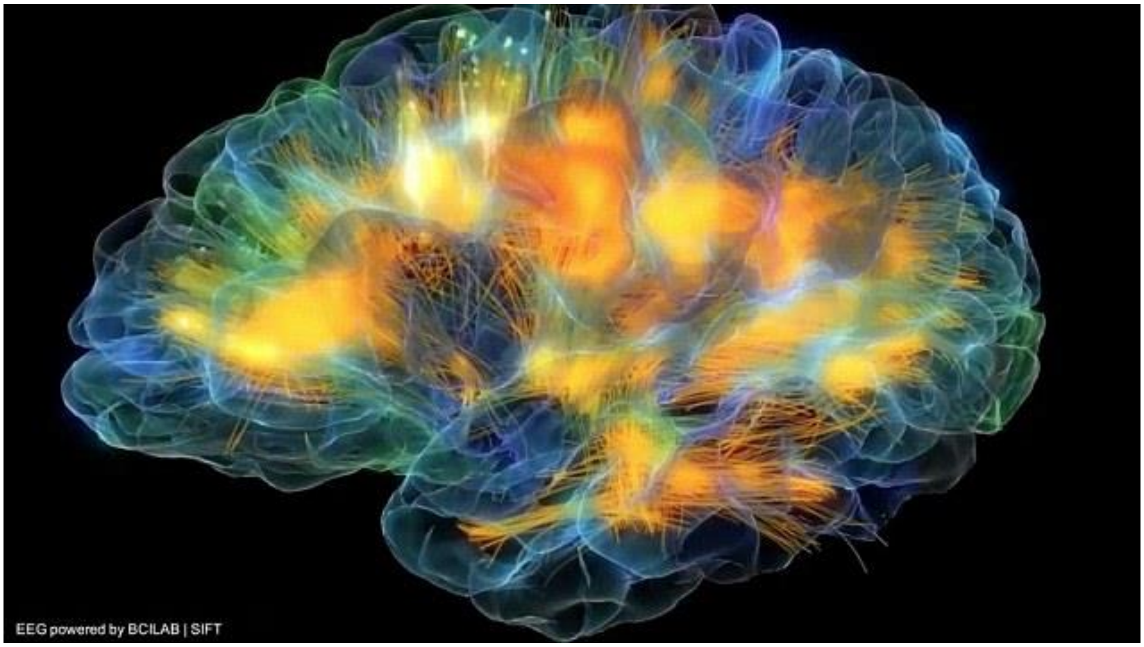

Figure 53 Neurons firing off in real-time

2.2 Brainwaves

2.2.1 Electricity in human body

Figure 54 Active Neurons in the Brain

"If our body is entirely based, say, the movement of chemicals to tell our hearts to speed when something is chasing us probably would have died before a long time." [69]

It is more than true that chemicals do exist inside us. But they are not the only ones or the basic ones in charge to carry information through our body.

Figure 55 Electricity in Human Body

Electricity is the key to survival. Electrical impulses arise produced by our own cells. They are fast and allow an almost instantaneous response to control messages. Since nearly all our cells are able to produce electricity we end up like a huge network of electric circulation. At the end message is being delivered. Considerably fast and safe messages travel from sender to receiver. They might be different parts inside human body. Electricity still finds the route to the target.

Designs of these helpful electric signals in our body happens to differentiate. Each category has its own composition forming the so called Brain Wave Patterns.

2.2.2- Electric Signals in the Brain

Figure 56 Brain Visualizer

As mentioned above our body produces electricity. Especially human brain with its billions of neurons is plethoric to electric signals. They are produced under the vital need of information transferring across human body. Brain cells, the neurons, have active role in it. The neural network inside the brain is always in state of readiness to respond to stimulus if and whenever is needed.

2.2.3 Brainwave Patterns

Figure 57 Active Neurons in the Brain

Usually neurons produce and move forward electrical signals transmitted by brain synapses known as neural signals.

Figure 58 Neurons Firing and Communicating through Synaptic Gap

The combination of millions of neurons sending signals at the same time produces an enormous amount of electrical activity in the brain.

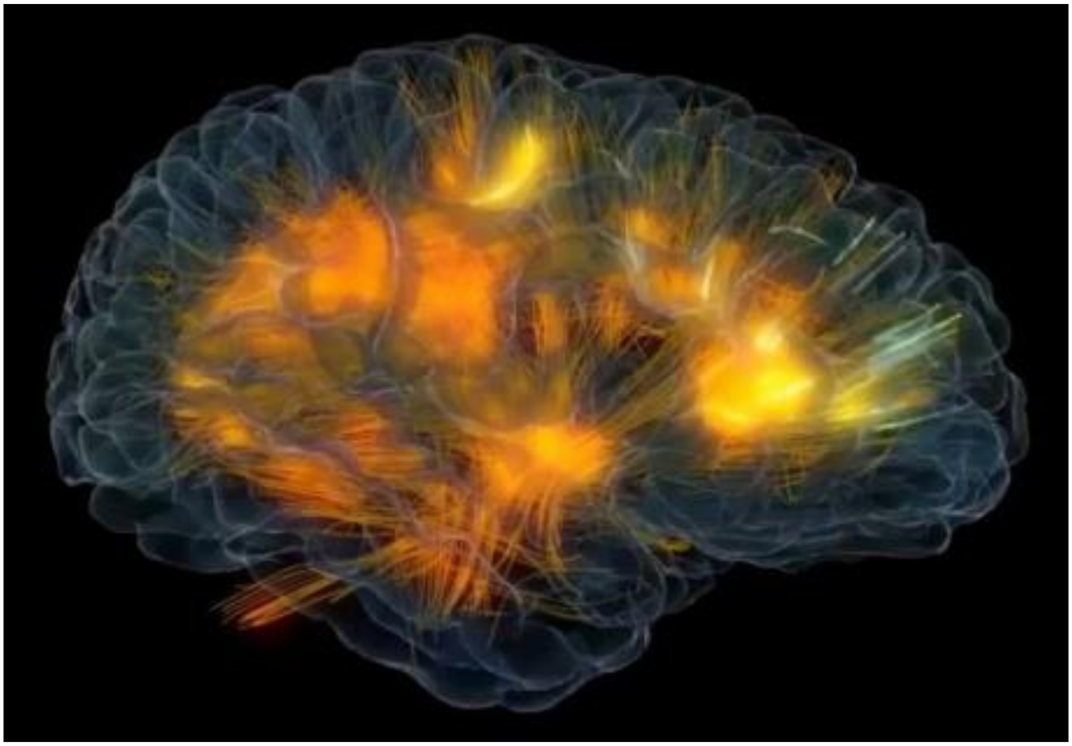

Figure 59 Brain Visualization

These synchronized electrical impulses from plenty of neurons, communicating with each other produce Brainwaves.

So when the nerve cells of the brain "fire" electrical signals and oscillate in distinctive arrangements, the combined electrical activity is often called a pattern of brain waves (brainwave pattern), due to the cyclical, "wave-like" character/nature.

Figure 60 Brainwave Patterns

The Brainwave patterns can be detected using sensitive medical equipment(such as EEG), measuring the power levels in areas of the scalp. They are divided into bandwidth to describe their functions but they are best thought as ‘continuous spectrum of consciousness’. These patterns are closely connected to our thoughts, emotions, moods, biological chemistry, everything we do, and really, everything we are. The root of our behaviors is the communication between neurons within our brains. [70]

Figure 61 Active Brain

"With the discovery of brainwaves came the discovery that electrical activity in the brain will change depending on what the person is doing." They change also "according to what we are feeling." [70]

For instance, "the brainwaves of a sleeping person are vastly different than the brainwaves of someone wide awake. Over the years, more sensitive equipment has brought us closer to figuring out exactly what brainwaves represent and with that, what they mean about a person's health and state of mind." [70]

Brainwave Frequencies

When we measure brainwave patterns we notice the Bandwidth, meaning specific areas of frequencies evoking and referring to similar characteristic. They are divided into Bandwidth to describe their functions.

For instance Delta is slow, loud and functional while Gamma is quick, subtle and complex. It is a handy analogy to think of brain waves, such as musical notes - the low-frequency waves, such as a deep penetrating drum beat, while higher frequency brain waves are like a fine high frequency flute.

Our brain waves change depending on what we are doing and feeling. When slow brainwaves are dominant you can feel tired, slow, slow, or dream. Higher frequencies are dominant when we feel wired or hyper-alertness.

Brainwave speed is measured in Hertz (cycles per second) and divided into zones delimit slow, medium and fast waves.

The oscillation of spikes in the brain emit the following Brainwave Frequencies having a name per Bandwidth:

Delta (0.5-3Hz), Theta (3-8Hz), Alpha (8-12Hz), Beta (12-38Hz),

Gamma (38-42Hz)

We have to mention although that the range of the human ear is 20Hz – 20.000Hz so the useful Brainwave Frequencies are 0.3 - 40Hz.

Figure 62 Brainwaves

Since they all refer to different thoughts, emotions and behaviors we consider them as ‘Continuous Spectrum of Consciousness". [70]

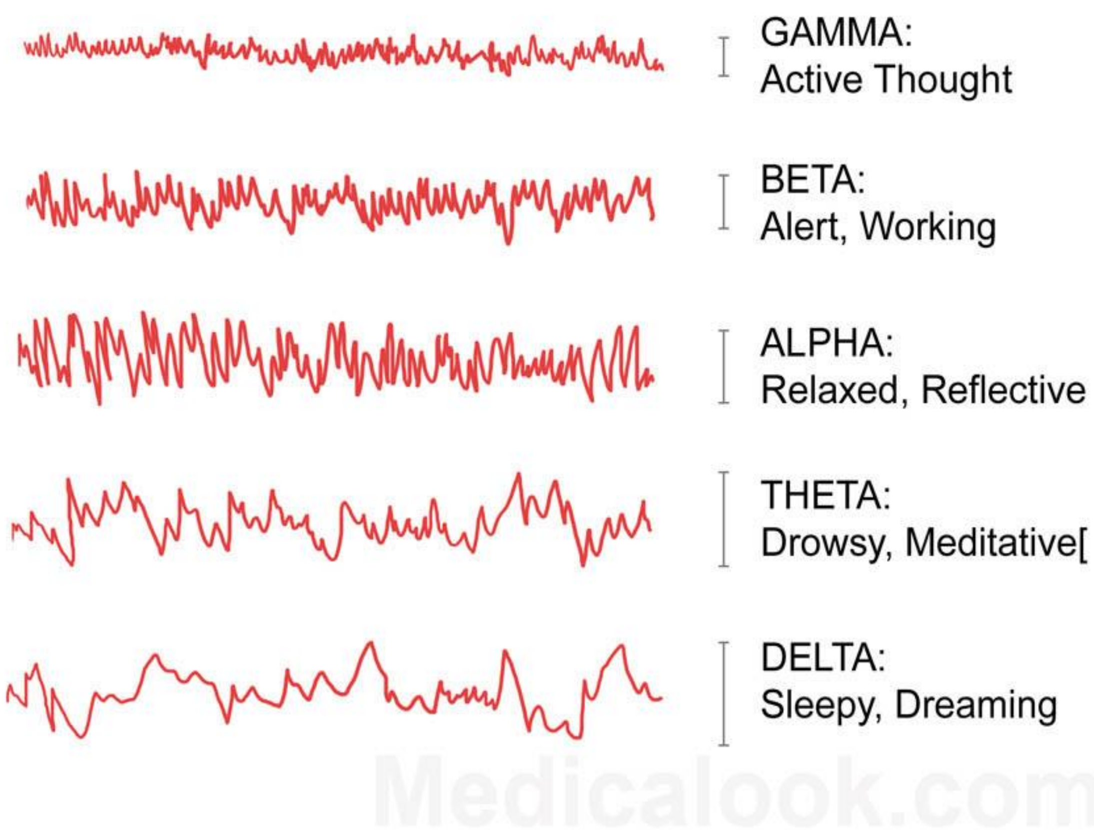

Figure 63 Brainwave Patterns

Each one corresponds to certain mental and emotional state while brain functions. These associated mental activity depending on the Bandwidth frequencies can be seen at the chart above as well as in Appendix B.

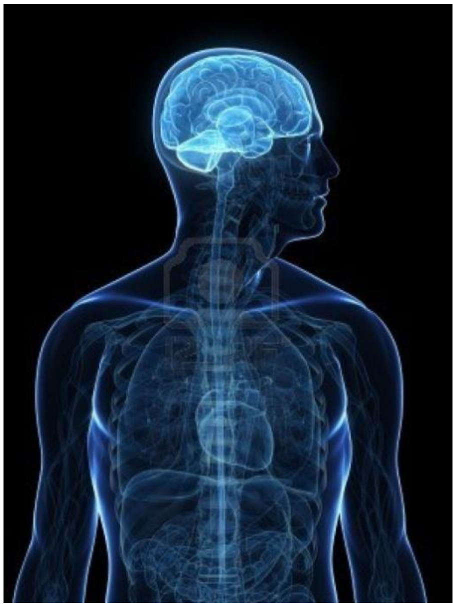

Figure 64 Avtive Brain

2.3 Brainwaves' Sensors Technology

Figure 65 Brain and Child

Sensors placed on the scalp are used in order to detect Brainwaves.

Figure 66 Brain-Computer Interface

We have already mentioned (2.1 Neurons) that in the brain exist billions of cells that use electricity to communicate with each other. When millions of neurons are combined in order to send signals at once then an enormous amount of electrical activity in the brain is produced. If sensitive medical equipment measuring electricity levels over areas of the scalp (such as an EEG) is used, this electric activity can be detected.

Figure 67 EEG-Neurofeedback Brain Training

EEG stands for Electroencephalography "a diagnostic method of examining the electrical impulses of the brain using electrodes attached to the head and to a recording device to make an electroencephalogram". [71]

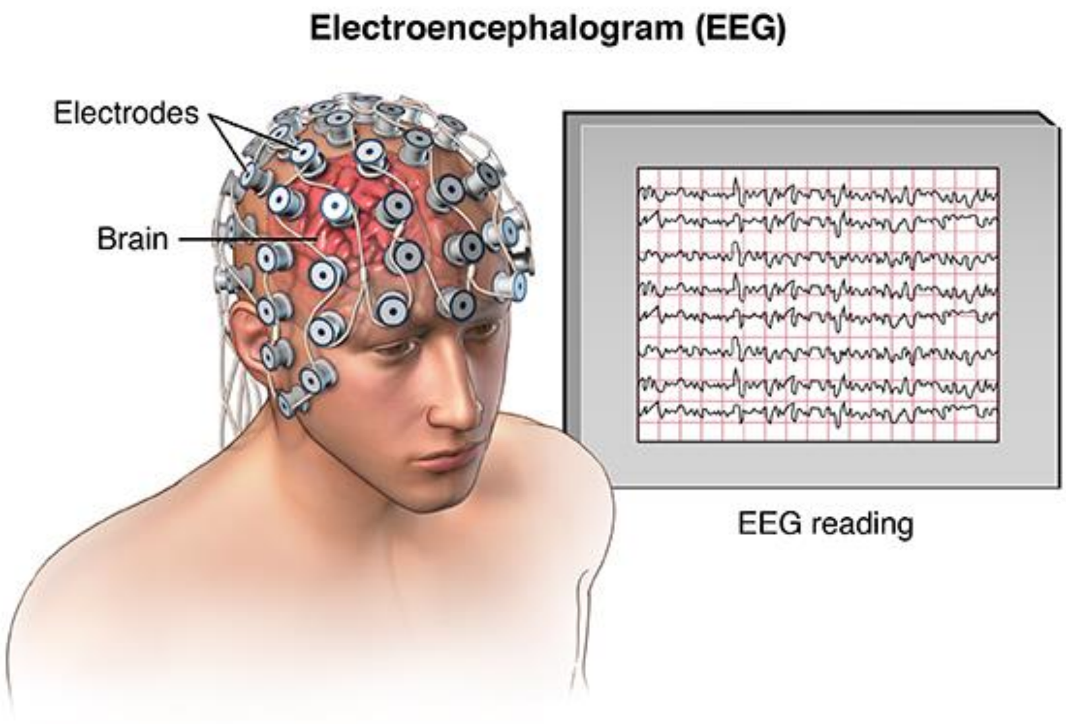

Figure 68 Electroencephalography

In electroencephalography an instrument that "measures electrical potentials on the scalp and generates a record of the electric activity of the brain is needed, called electroencephalograph". [71]

Figure 69 Brain with EEG

So the rates of brainwaves can be measured generally with brainwaves' sensors and connected to a computer and a relevant software they produce the image of them.

Figure 70 Glass Brain visualizes real-time source-localized activity recorded via EEG.

Since brainwave patterns change according to what we are doing and feeling brainwaves' sensors' technology provides a way to depict a certain reaction of the brain in reference with a stimulus.

Figure 71 NeuroSky MindWave Headset

The brain then, can be activated and changes its status. Observing brain waves that occur is a perfect way to notice these fluctuations. When a stimulus 'arrives' reactions are caused in the state of the brain cells.

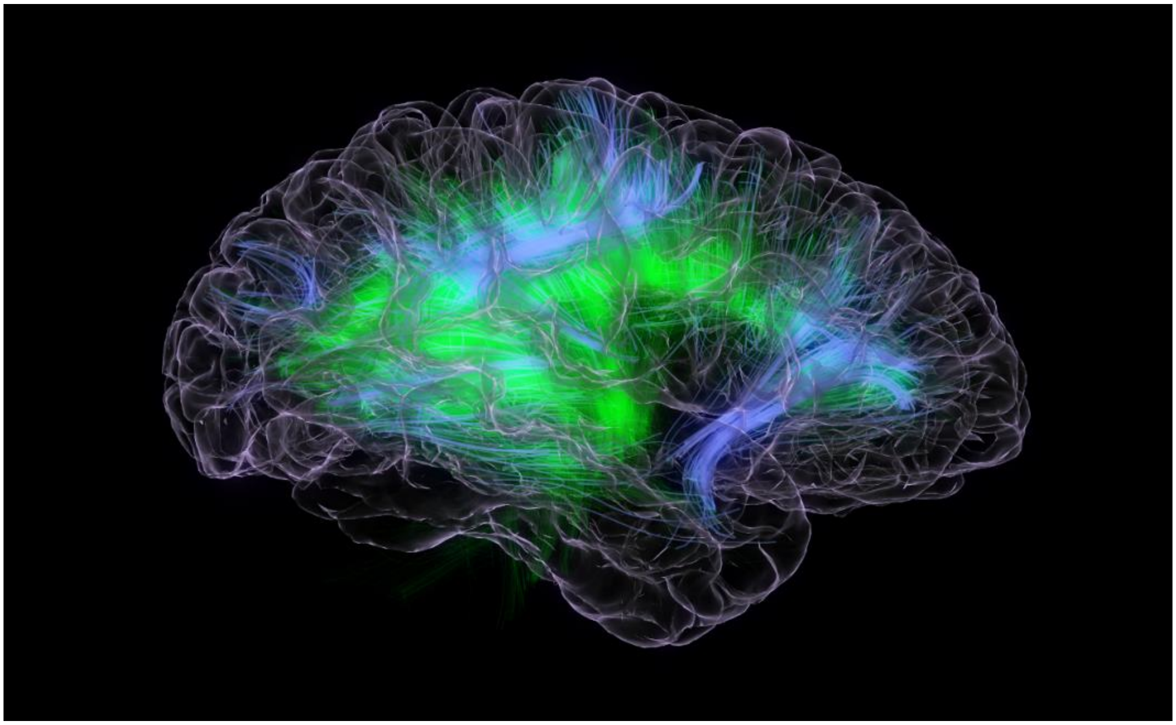

Figure 72 Visualization of activity inside a human brain. Composite image combining EEG, MRI and DTI data. Courtesy Roger Anguera, Neuroscape Lab, UCSF

2.3.1 Stimulus and Brainwaves: Definition of Stimulus

Among various definitions for stimulus the ones following are chosen, as more relevant to thesis' subject, to be mentioned. So stimulus is:

"Something that causes growth or activity. [72]

Something that causes part of the body to react (in Biology) [72]

Something that incites to action or exertion or quickens action, feeling, thought, etc. [73]

Something that stimulates or acts as an incentive [73]

An object or event that is apprehended by the senses [73]

Somethingthatcanelicitorevokeaphysiologicalresponseinacell,atissue,oranorganism.Astimuluscanbeinternalorexternal.Senseorgans,suchastheear,andsensoryreceptors,suchasthoseintheskin,aresensitivetoexternalstimulisuchassoundandtouch. [73]

Figure 73 Stimulus

Something that excites an organism or part to functional activity. (iN Physiology, Medicine/Medical) [73]

Somethingthathasanimpactoraneffectonanorganismsothatitsbehaviorismodifiedinadetectableway. (In Science Physiology) [73]

A thing or event that evokes a specific functional reaction in an organ or tissue": for instance "areas of the brain which respond to auditory stimuli" [74]

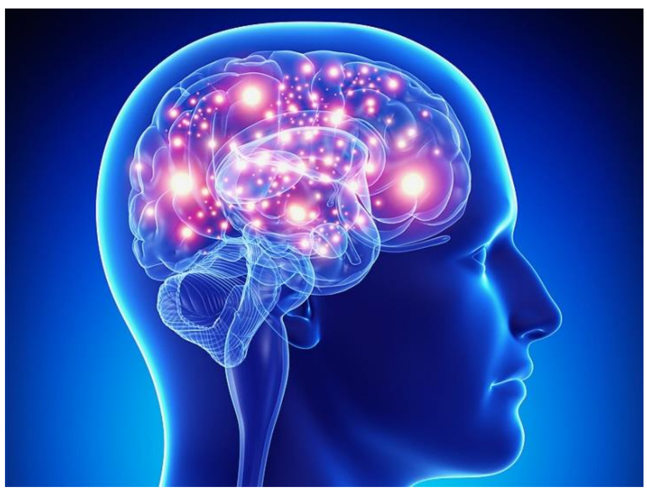

Figure 74 Brain Stimulation Techniques

When we choose to notice something or observe it or when something stimulates us, specific processes happen inside our brain. Different internal or external stimulus evokes neurons to react and produce different brainwaves. The brain's responses are detected using equipment of brainwave sensors' technology. When a condition or an event occurs, according to its kind, it is apprehended by human senses such as audition or vision. So these type of sensors are capable of brainwaves' differentiations' detection.

2.3.2 Homeostasis

Usually in nature there is harmony and everything tends to be in harmony. Same happens with human body, a part of nature also ourselves. Human body wants to have homeostasis, meaning maintain its inner balance. Homeostasis is the property of biological systems where things are controlled to keep constant and unchanged internal conditions. The body though maintains homeostasis in response to stimuli. These complex reactions quickly return the body to normal state. So since we are living beings and stimulation occurs constantly, it is helpful to know our own body's mechanism of reactions and surviving at the end.

2.3.3 Types of Stimulus

As it is referred in Wikipedia "In physiology, a stimulus (plural stimuli) is a detectable change in the internal or external environment. The ability of an organism or organ to respond to external stimuli is called sensitivity. When a stimulus is applied to a sensory receptor, it normally elicits or influences are flex via stimulus transduction. These sensory receptors can receive information from outside the body, as in touch receptors found in the skin or light receptors in the eye, as well as from inside the body, as in chemo receptors and mechanoreceptors. An internal stimulus is often the first component of a homeostatic control system." [75] "External stimuli are capable of producing systemic responses throughout the body, as in the fight-or-flight response."[76] "In order for a stimulus to be detected with high probability, its level must exceed the absolute threshold; if a signal does reach threshold, the information is transmitted to the central nervous system (CNS), where it is integrated and a decision on how to react is made. Although stimuli commonly cause the body to respond, it is the CNS that finally determines whether a signal causes a reaction or not." [77]

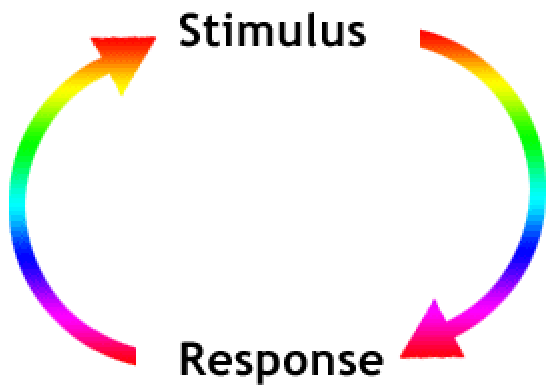

Figure 75 Stimulus - Response

2.3.2.1 Internal and External Stimulus

The body is affected by two types of stimuli: internal and external. Internal stimuli happen inside the body, when the inner conditions change. The body rapidly responds to situations as lacking water or food, when defiled food is eaten or when a virus is present in the body. Our body will make us feel hungry or thirsty if it is lacking food or water. In case of poisoned food our body might make us vomit to remove it. If a virus is in our body, the core temperature can be increased to assist in slowing the progress of the virus.

On the other hand, external stimuli are the ones or in general, information that happens outside our body. For instance if the conditions outside of the body change our senses detect them. For example, changes of external environment affecting human body could be light, temperature, and sources of danger. So human body respond relatively to the stimulus. The circadian rhythms of our bodies for instance, change when light is the external stimulus and to this effect we feel sleepy or awake.

2.3.2.2 Auditory and Visual stimulus

Depending on content and kind of external stimulus as well the type of human sense with which a stimulus is detected we distinguish among others the auditory and the visual stimuli.

Auditory stimulus as is referred in psychology dictionary is " any stimulus capable of eliciting auditory sensation. This usually refers to a distinct airborne sound, but can also include vibration produced by conduction or by internally generated events." [78] So an auditory stimulus could be: an Isolated Sound (eg sharp, strong), Beats or Melody or Music of Specific Frequencies.

Visual is related to seeing, and to things that you can see. It is also related to the sense of sight. So a visual stimulus could be something which can be seen such as a drawing, an image or photograph or even a film. Color is a common visual stimulus in the environment surrounding us.

Figure 76 NeuroSky: EEG Headset

2.3.4 Brainwave Entrainment

In order to stimulate the brain there is a method called Brainwave Entrainment. The method is about entering a particular situation, using a pulsed sound, light, or electromagnetic field. The vibrations cause the reaction of the brain "frequency following" encouraging brain waves to align with the frequency of a particular rate.

In other words Brainwave Entrainment is a common language for "neural entrainment" which is a term used to indicate the manner in which the total frequency of the oscillations produced by modern electrical activity in sets of neurons can be configured to synchronize with the periodic vibration of an external stimuli, such as a fixed audio frequency perceived as tar, a regularly repeating pattern of intermittent sounds, perceived as rhythm or a regular rhythmic intermittent flashing light.

Figure 77 Brainwave Entrainment

Brainwaves, or neural oscillations, share fundamental components with acoustic and optical waveforms, including frequency and amplitude. Consequently, still is a question whether or not the synchronous electrical activity of cortical neuronal ensembles not only could change in response to external auditory or visual stimuli, but also lure or synchronize its frequency them with that of a given stimulus. [79] [80] [81] [82]

Our brain does not function using one frequency each time a stimulus appear. Brain uses a variety of frequencies constantly. As we read in Brainworks' site a company among the first neurofeedback practices neurofeedback clinics in the UK: "The brain does not operate in just one single frequency; the full spectrum of brainwave frequencies are always running, all the time. The dominant frequency determines our mental state – and entrainment temporarily shifts our mental state by boosting one frequency to be louder than the others." [83]

Because half of the useful brainwave frequencies (0.3 to 40 Hz) is below the range of hearing of the human ear (20Hz-20,000Hz), many techniques have been developed to overcome this natural limitation. Brainwave entrainment techniques have developed using computers encoded: audio beats, strobe lights, low-energy electromagnetic fields.(e.g. NeuroSky [84], Brainworks [85], EOC Institute [86]).

A quick overview of the different existing techniques so far follows: Music Modulation, Monaural Beats, Binaural Beats, Isochronic Beats, Sound and Light Entrainment, EEG Active Entrainment, Electromagnetic (EM) Entrainment. [87]

Chapter 3 - THE CASE STUDY

3.1 Brainwave Sensors: The Mindwave EEG-monitoring Headset of NeuroSky

In the industry of Brainwaves Sensors Technology there are many available headsets nowadays. We refer just to some of them indicatively. So four available wearable headsets are 1. Muse: The Brain Sensing Headband, 2. NeuroSky Mindwave Headset, 3. Melon Headband and 4. Versus Headset [88]

One of them has been used in thesis' case study, the Mindwave Headset of NeuroSky.

NeuroSky, Inc. [89] is a manufacturer of Brain-Computer Interface (BCI) technologies for consumer product applications. The company adapts electroencephalography (EEG) [90] [91] [92] and electromyography (EMG) technology.[93][94] This way NeuroSky technology allows for low-cost EEG-linked research and products by using inexpensive dry sensors since older EEGs require the application of a conductive gel between the sensors and the head. NeuroSky Mindwave EEG device is an approximately $ 100 model. More information for NeuroSky at Appendix C.

Figure 78 The Mindwave EEG-monitoring Headset of NeuroSky

Mindwave Headset appertains to brainwave sensors' technology. It is a mental exercise equipment basically for children. The set contains hardware equipment, consisted of a brainwave sensor and a USB adapter accompanied with relevant software. The software basically is a collection of different kind of programs related with Math training, Smarter Brains, Mental Fitness and Intelligent Games.

Figure 79 The Mindwave EEG-monitoring Headset of NeuroSky

3.1.1 What Mindwave EEG-monitoring Headset does

The Mindwave measures brain's electrical activity and can detect the level of Focus (Attention against Mediation) and formally measuring brainwave patterns (beta, alpha, theta and delta). There are a number of games included, and a wide range of them to download from the AppStore. There is also relevant software developed such as Neurosky Brainwave Visualizer, a direct way to visualize or to record the data from the device.[95]

As it is mentioned on NeuroSky's equipment: “The human brain is made up of a vast network of neurons. Each neuron transmits information through electrochemical activity that creates tiny electric fields. When hundreds of thousands of neurons fire the same time, the resulting electric fields are big enough to measure outside the skull. This measurement is called electroencephalography (EEG) and the electric field brainwaves. Different mental states are characterized by different patterns of neural activity and they emit characteristic brainwaves. By measuring these characteristic brainwaves, NeuroSky devices can infer which mental state the user is in.” [96]

Following three steps on how NeuroSky senses state of mind with the Mindwave head set:

"Step 1: Neuron in the Brain produce tiny electrical signals when a person is in a specific mental state, neurons fire in brainwave patterns defined by neuroscientists.

Step 2: NeuroSky technology senses these brainwaves by lightly touching the scalp. The different types of brainwaves are interpreted to determine mental state.

Step 3: Mental state is shared with computer enabling NeuroSky powered applications to react to the person in real time." [96]

Figure 80 The Mindwave EEG-monitoring Headset of NeuroSky

3.1.2 Software used in Case Study

3.1.2.1 ThinkGear Connector

"The ThinkGear Connector (TGC) is responsible for directing headset data from the serial port to an open network socket and runs as a background process on your computer. It is available on both Windows and OS X. Any language or framework that contains a socket library should be able to communicate with it." [97]

3.1.2.2 Meditation Journal

It is an application of Mind Wave head set. "Meditation Journal enables you to keep track of your daily meditation and attention levels, and track them through a digital calendar. Meditation Journal keeps track of your meditation, attention, and brainwave recordings in a journal and presents them to you in a series of data charts and accomplishments." [98]

It is a way for people to quantify spiritual growth, transcend one's self through meditation and find enlightenment from within. Also allocates them a way to notice their focus.

Figure 81 Meditation Journal, an application of Mindwave head set

Meditation Journal provide measurements of Attention's and Meditation's levels to a scale from 1 -100 in amplitude and in sec for time. It's a representation of Attention/Meditation vs Time. It can be shown either only Attention vs Time or Meditation vs Time. It is possible to observe both values in one chart during time.

Figure 82 A Screenshot of Meditation Journal: Attention's and Meditation's Fluctuations

Meditation Journal enables perceiving state of Attention and Meditation while acting. Combination of these two provides the level of Concentration of a person.

3.1.2.3 Screen Recording Software

In order to capture the fluctuations of Attention and Meditation imprinted using Meditation Journal in case study, and mainly the different values and levels of them (through the scale 1-100) during time (msec) Screen Recording Software was used. Video files were created thus, for further data processing and analysis.

CamStudio, one of the two programs used, records all screen and audio activity. It is a free and open source video screen recorder, that manages, displays and records onscreen video and audio from any source and puts it in a video.

Snagit also is a powerful screen capture tool that allows you to grab an image or video of what you see on your computer screen.

3.1.3 Observations and Use

Figure 83 Practice with Mindwave EEG-monitoring Headset of NeuroSky

Using mindwave head set and become aware of yourself during mental changes or observing visually representations of your attention's and meditation's status can be very interesting. First measurements were daily with main purpose to notice how the way of thinking or using your brain can take a visual effect.

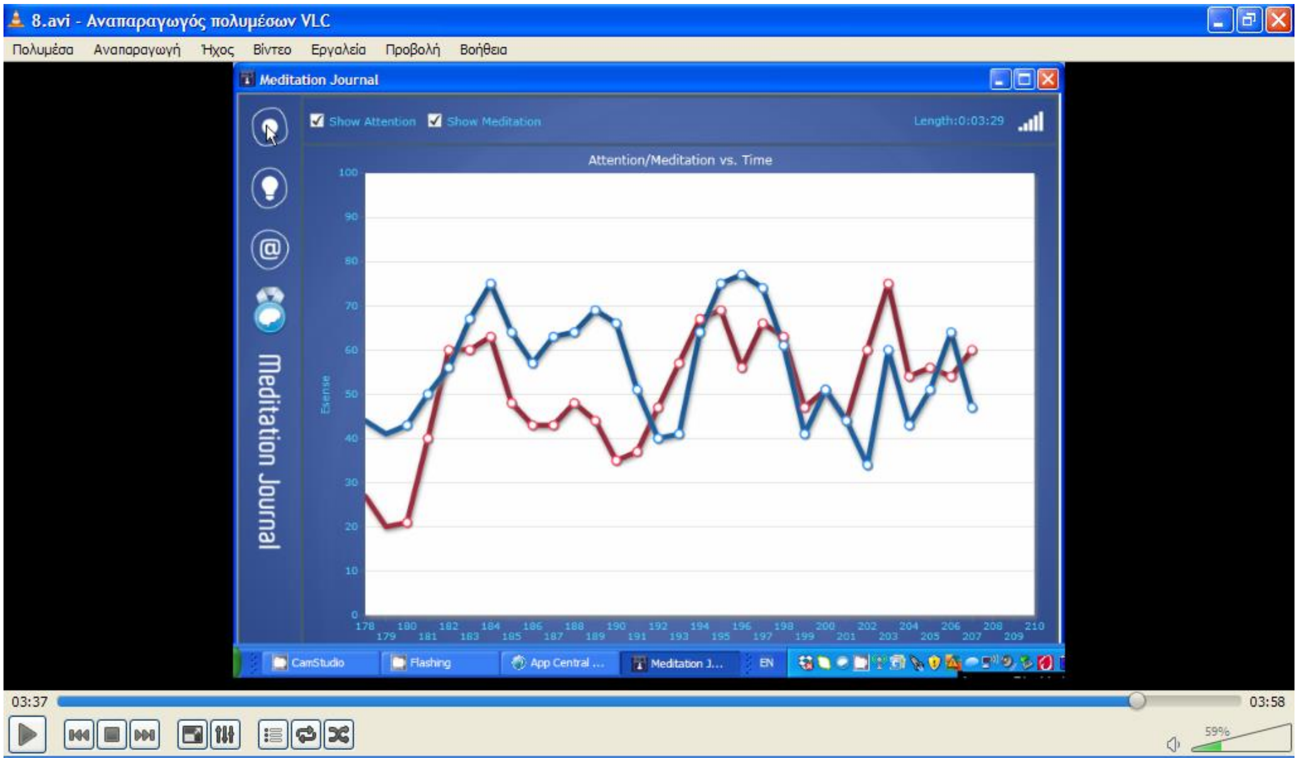

Figure 84 A Screenshot of Meditation Journal: Attention's and Meditation's Fluctuations

Observing the differentiations during time and day parts in order to find whether common characteristics in fluctuations of attention and meditation existed was a purpose of using mindwave in daily base. Also mood, thoughts and feelings were other factors looking for possible influence in measured brainwaves.

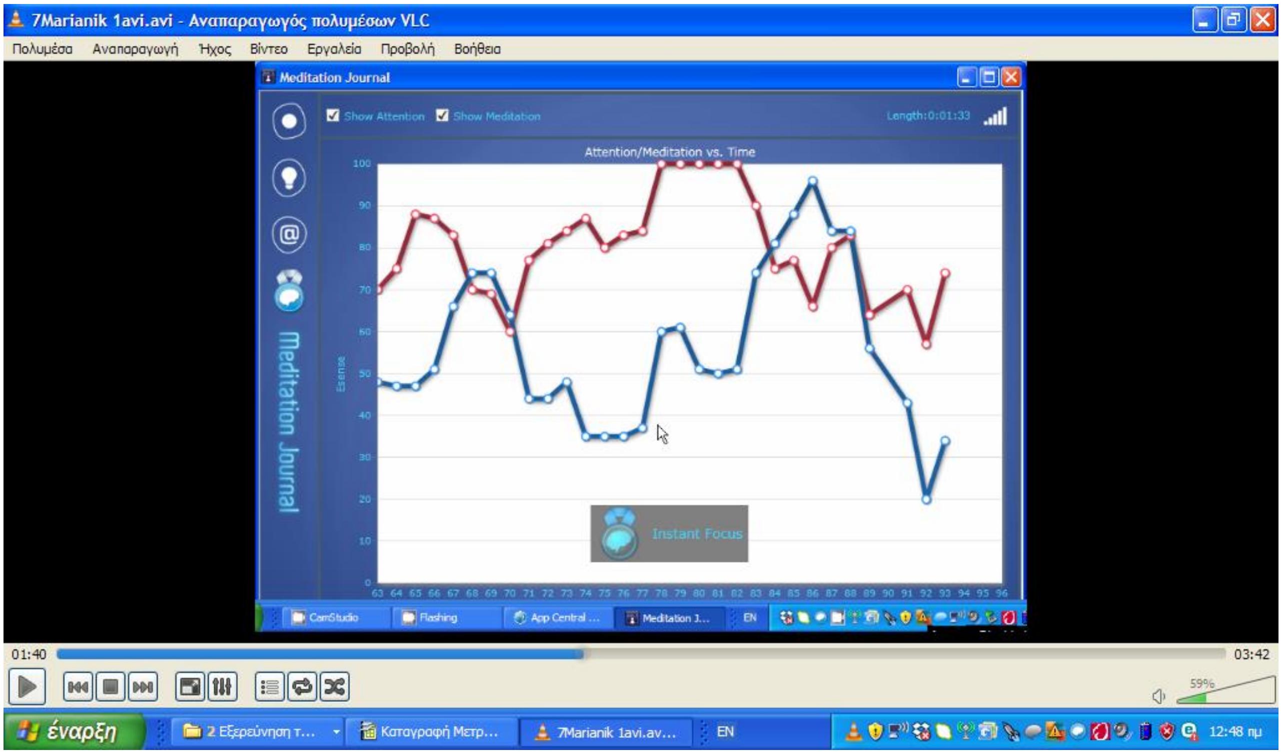

Figure 85 A Screenshot of Meditation Journal: Attention's and Meditation's Fluctuations

3.1.4 Auditory External Stimulus

At the end external stimuli were used in the preliminary research after investigation of related topic sites with existing applications developed for brain training & brainwaves. Auditory stimuli were chosen as external stimuli while utilizing the Mindawave head set.

Auditory Stimuli could be Sound as for instance 1. Binaural Beats or Monaural Beats, 2. Isochronic Tones, or Music, melodies combined with sounds. The ones which were used are EquiSync's Free Demo Audio Files for Brainwave Entrainment. Conclusions were that no particular differences observed in the levels (range 0-100) of Meditation and Attention with criterion: 1. time frame of the day, whether it was morning, afternoon or evening and 2. existence or not of Auditory Stimuli, e.g. Sounds.

Important note: no stereo headphones were used that would do scientifically more acceptable conclusions of observation.

For further information and research on the topic, sites in Appendix D - Information for Brainwave Entrainment could be investigated.

3.2 Visual External Stimulus

The research for possible external stimulus in order to be used in the thesis' case study was lead eventually to the choice of visual stimulus rather than auditory one, for which new stereo headphones and equipment was needed to be purchased. So color was the external stimulus for a person using the mindwave head set in order to observe the occurring brainwaves that change the levels of attention and meditation during time.

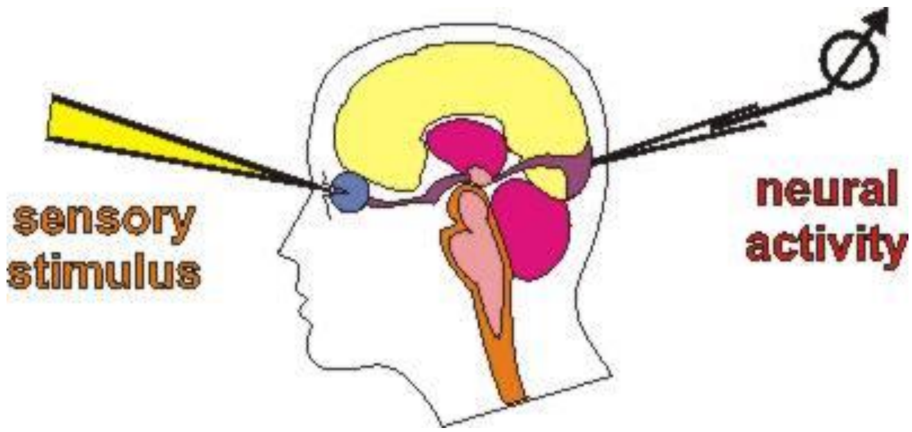

Figure 86 Sensory Stimulus and Neural Activity

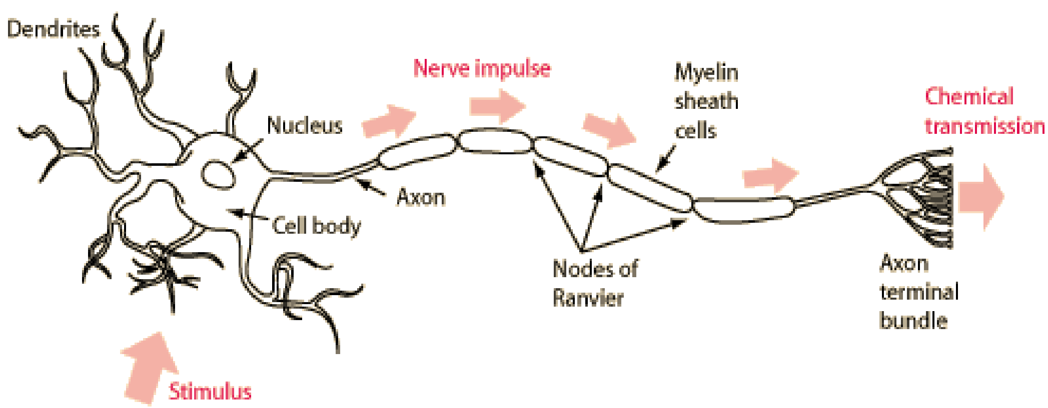

Figure 87 A Stimulus, Nerve Impulse and Chemical Transmission

Color perception is the ability of an organism or machine to distinguish objects based on the wavelengths (or frequencies) of light emitting reflect, or transmit. Colors can be measured and quantified in several ways; Indeed, the perception of an individual color is a subjective process by which the brain responds to stimuli produced when the incoming light is reacted with various kinds of cone cells in the eye. In fact, different people see the same object or illuminated light source in different ways.

When talking about colors or even apply them you can set a mood, attract attention, or make a statement. You can use color to energize, or to cool. Choosing the right color scheme, you can create an atmosphere of elegance, warmth or tranquility, or you can convey a playful youthfulness picture. The color can be more powerful element of a design, if learning to use it effectively.

Some basic elements of color theory are borrowed in order to approach understanding of possible color's ability affecting mental state of a person.

3.2.1 The Color Wheel

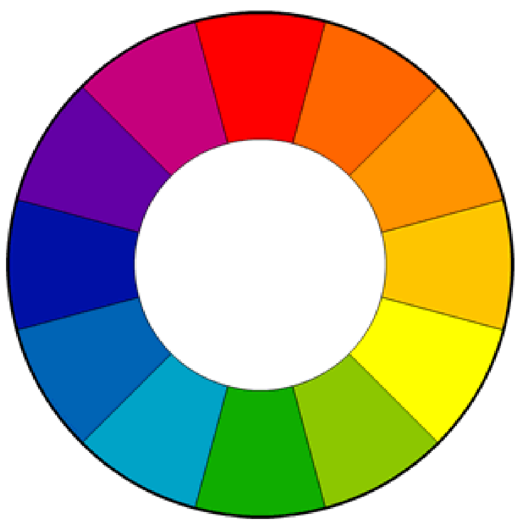

Figure 88 The Color Wheel

"The **color wheel** or **color circle** is the basic tool for combining colors. The first circular color diagram was designed by Sir Isaac Newton in 1666.

The color wheel is designed so that virtually any colors you pick from it will look good together. Over the years, many variations of the basic design have been made, but the most common version is a wheel of 12 colors based on the RYB (or artistic) color model.

Traditionally, there are a number of color combinations that are considered especially pleasing. These are called **color harmonies** or **color chords** and they consist of two or more colors with a fixed relation in the color wheel."[99]

3.2.2 Warm and Cool colors

The color circle can be divided into warm and cool colors. Warm colors are vivid and energetic, and tend to advance in space. Cool colors give an impression of calm, and create a soothing impression. White, black and gray are considered to be neutral. [99]

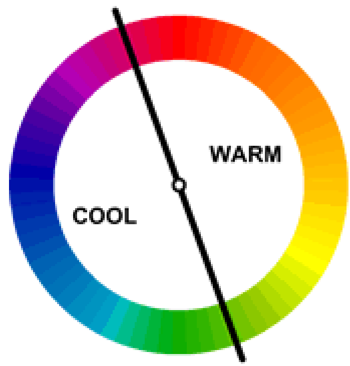

Figure 89 Cool and Warm Colors

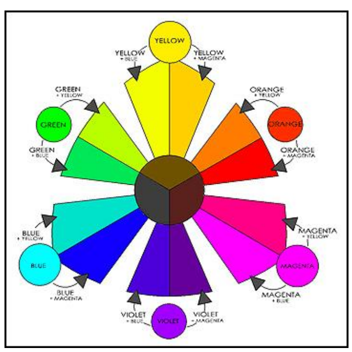

Figure 90 Colors, Basic Diagram

3.2.3 RGB Color model

"The RGB color model is an additive color model in which red, green, and blue light are added together in various ways to reproduce a broad array of colors. The name of the model comes from the initials of the three additive primary colors, red, green, and blue.

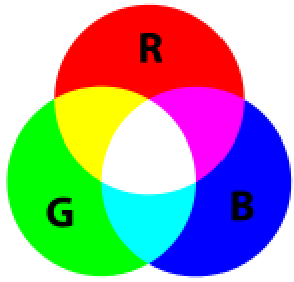

Figure 91 RGB Color Model

The main purpose of the RGB color model is for the sensing, representation, and display of images in electronic systems, such as televisions and computers, though it has also been used in conventional photography. Before the electronic age, the RGB color model already had a solid theory behind it, based in human perception of colors." [100]

3.2.4 Thesis Statement (Hypothesis)

Investigation for external stimulus, neurons' functioning and brain reactions lead to the formulation of the Initial thesis' Statement:

Does an external stimulus affect the level and rates of Human Brain’s Attention and Meditation?

That eventually lead to the following restatement:

If the external stimulus is a color then does a specific color stimulates more Human Brain than other colors?

Figure 92 Colored Pencils

3.2.5 RGB Color Palette

In order colors to be used as external stimuli following steps were done in the Case Study:

1. Needed Software: Java [101] [102] as programming language and NetBeans IDE 8.0.2 [103]

2. Program producing color panels was created

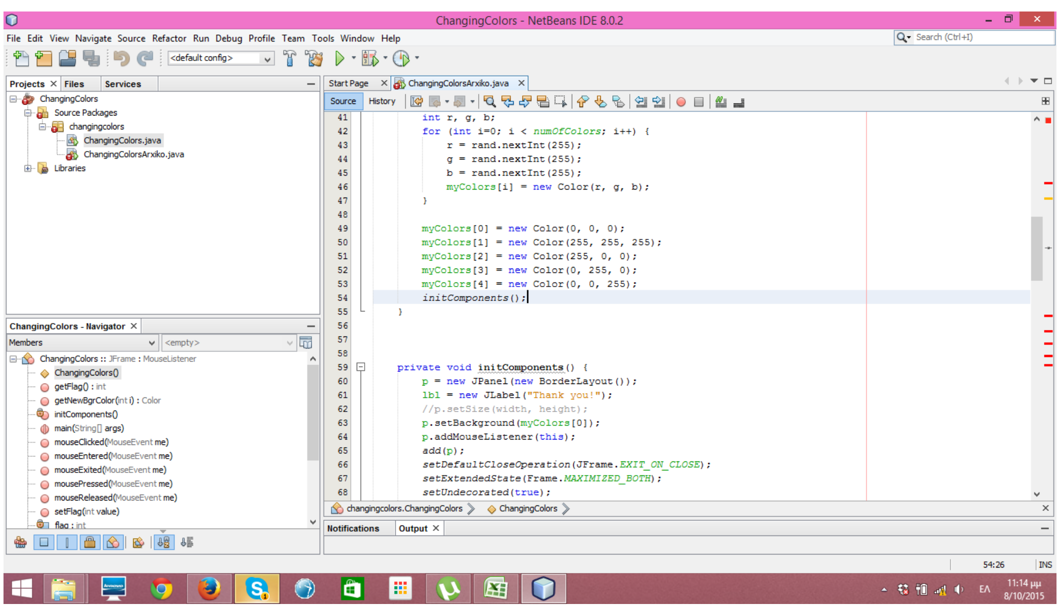

Figure 93 Software created for Color Panels

3. Initially program was tested by generating random colors

4. Finally 20 colors [table 3.1]were selected as continuous external stimuli

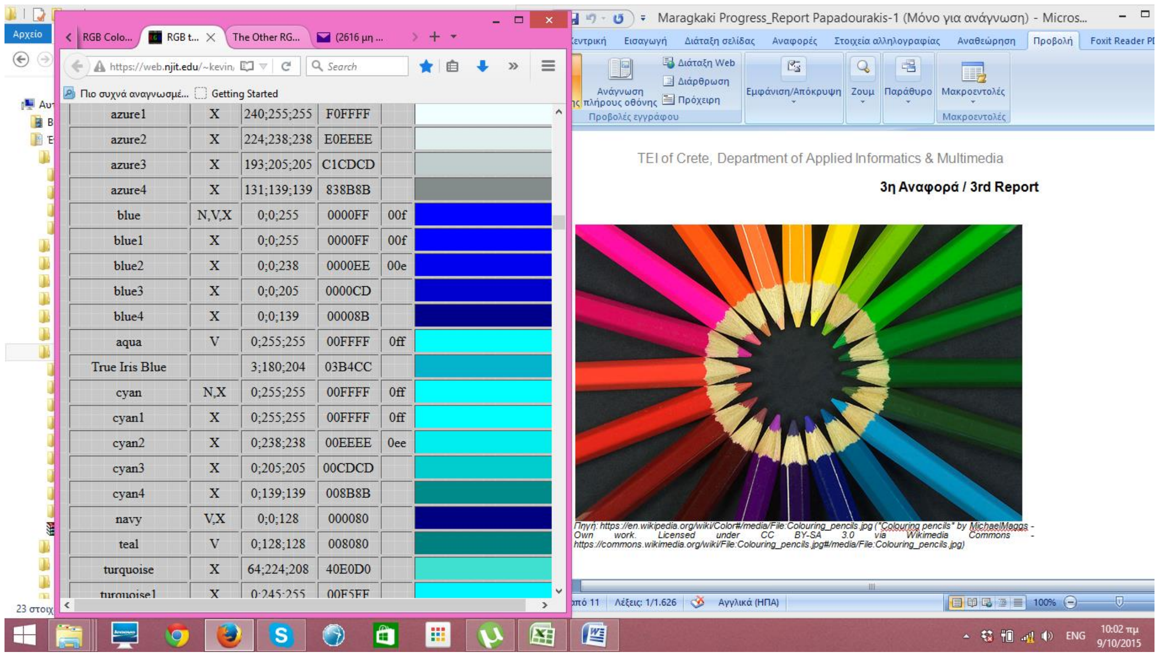

Figure 94 Picking Colors as External Stimuli

5. Colors were Primary colors and colors with Tonal variations of each one basic

6. Each color covers full screen

7. Duration of each color is 10msec

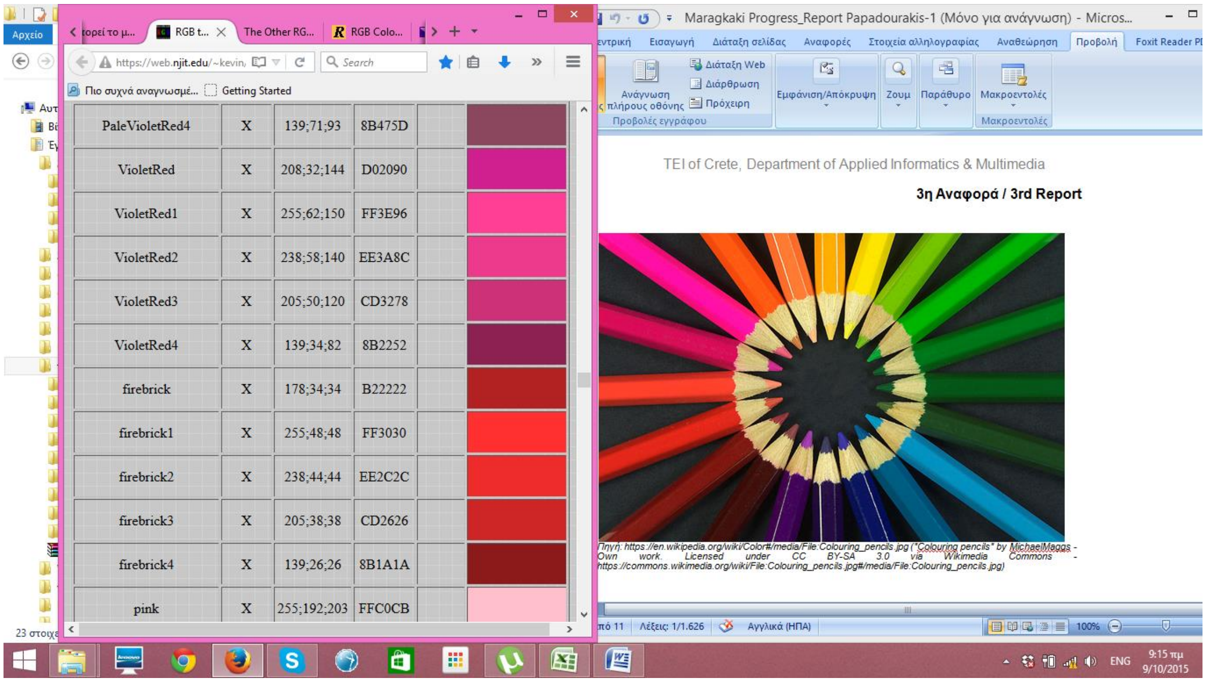

Figure 95 Picking Colors as External Stimuli

For picking the preferable colors research took place in sites with collection of RGB Colors.[104] [105] [106] [107] [108]

Colors among basic, secondary and combination of previous two categories were used. The finally chosen colors are mentioned at Table 3.1 with their RGB, Specific and General names.

3.3 Human Sample

60 People, Male and Female volunteered to participate to the Case Study. They cooperated and wore the mindwave head set. Their average age was 46, with secondary or higher education.

3.4 Conditions

Every person had to be accustomed with the mindwave set firstly.

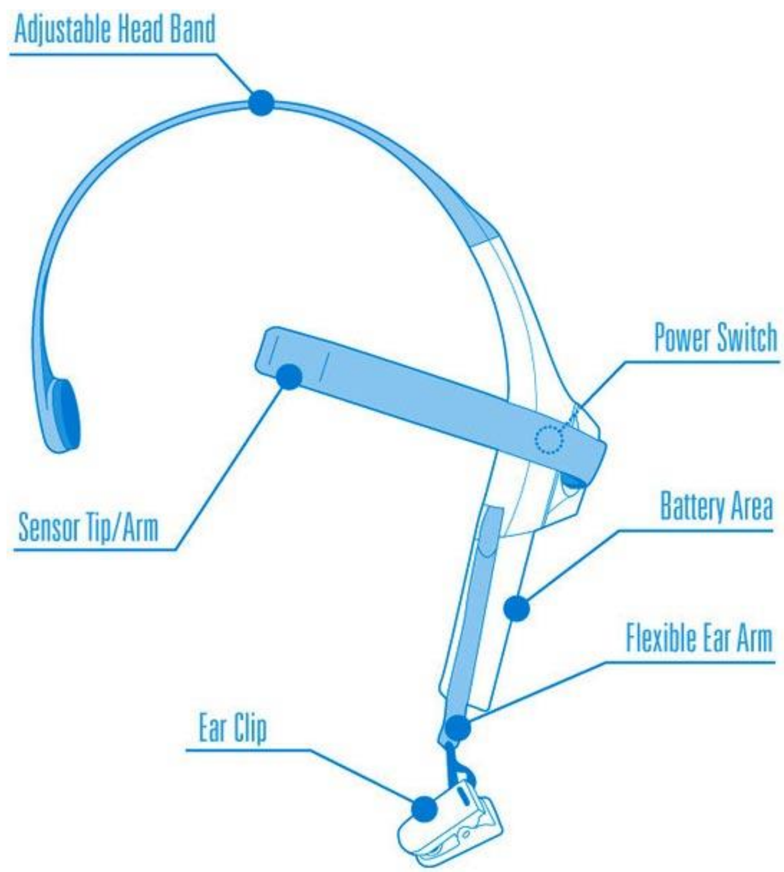

Figure 96 Parts of the Mindwave Head Set of NeuroSky

Head band to be adjusted, ear clip at proper position and sensor tip/arm to be in correct place touching the forehead.

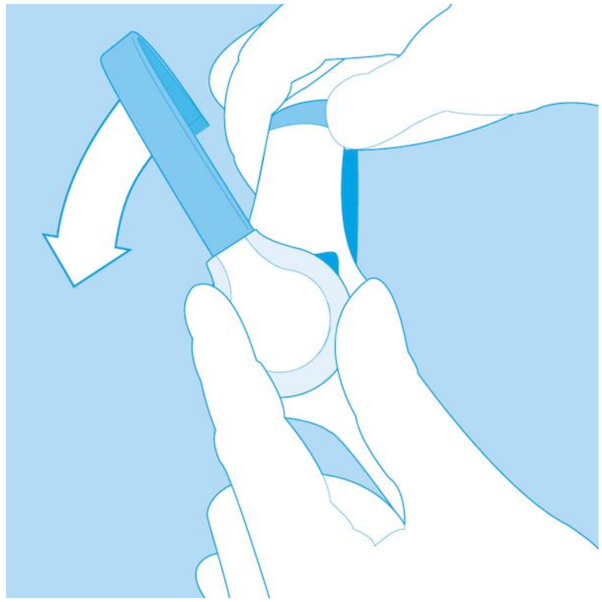

Figure 97 Adjusting Head Band

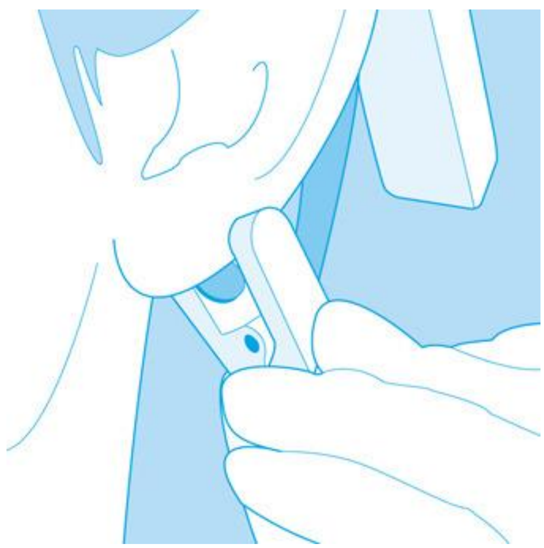

Figure 98 Putting on Ear Clip

They were told to relax first, keep their sight to colors' alternation, think nothing, just like emptying their mind in order to have each color only as stimulus.

A testing recording was taking place at beginning in order to ensure proper function of equipment in use and give time to participants to feel readily.

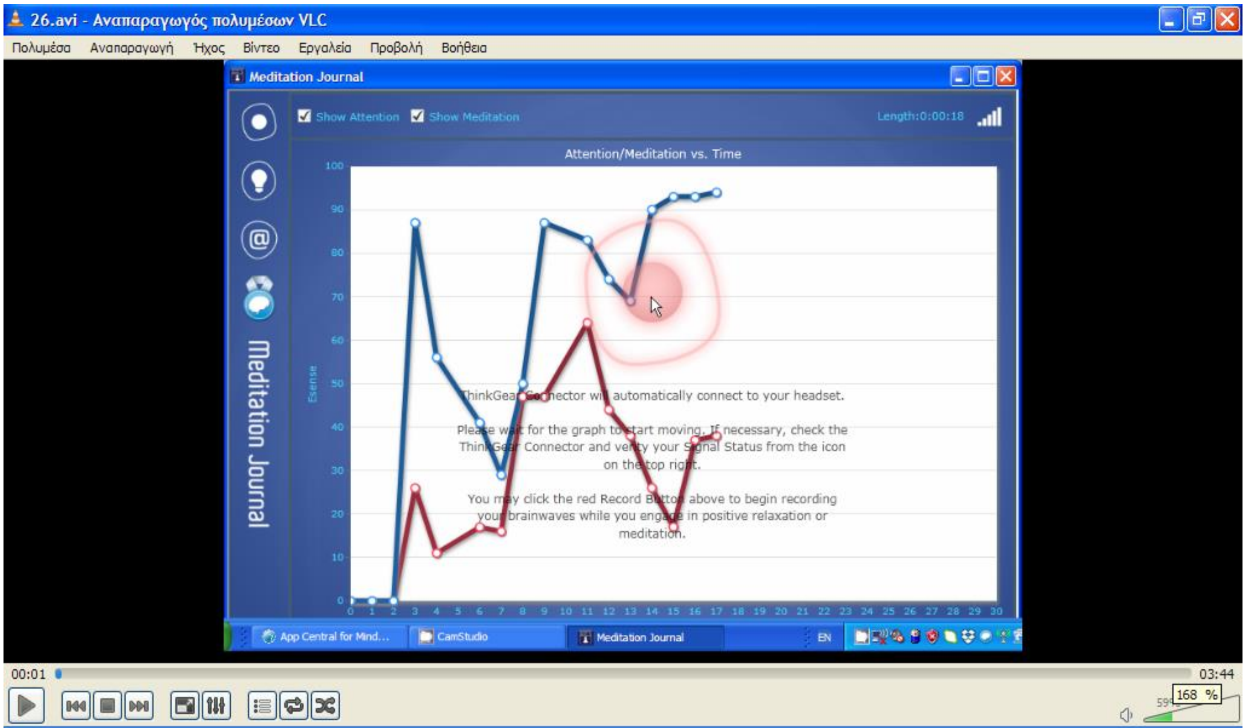

Figure 99 Meditation Journal Screenshot: Attention's and Meditation's Fluctuations

Great efforts took place in order to reduce or even eliminate all other external stimuli. So the conditions were total darkness and quietness with no other participants closely. Although some measurements were taken at midday, accordingly above conditions, most of them were done during evening and night (20:00 - 01:00)

The emitted brainwaves formed charts with fluctuations of their attention's and meditation's levels, which were monitoring in real time.

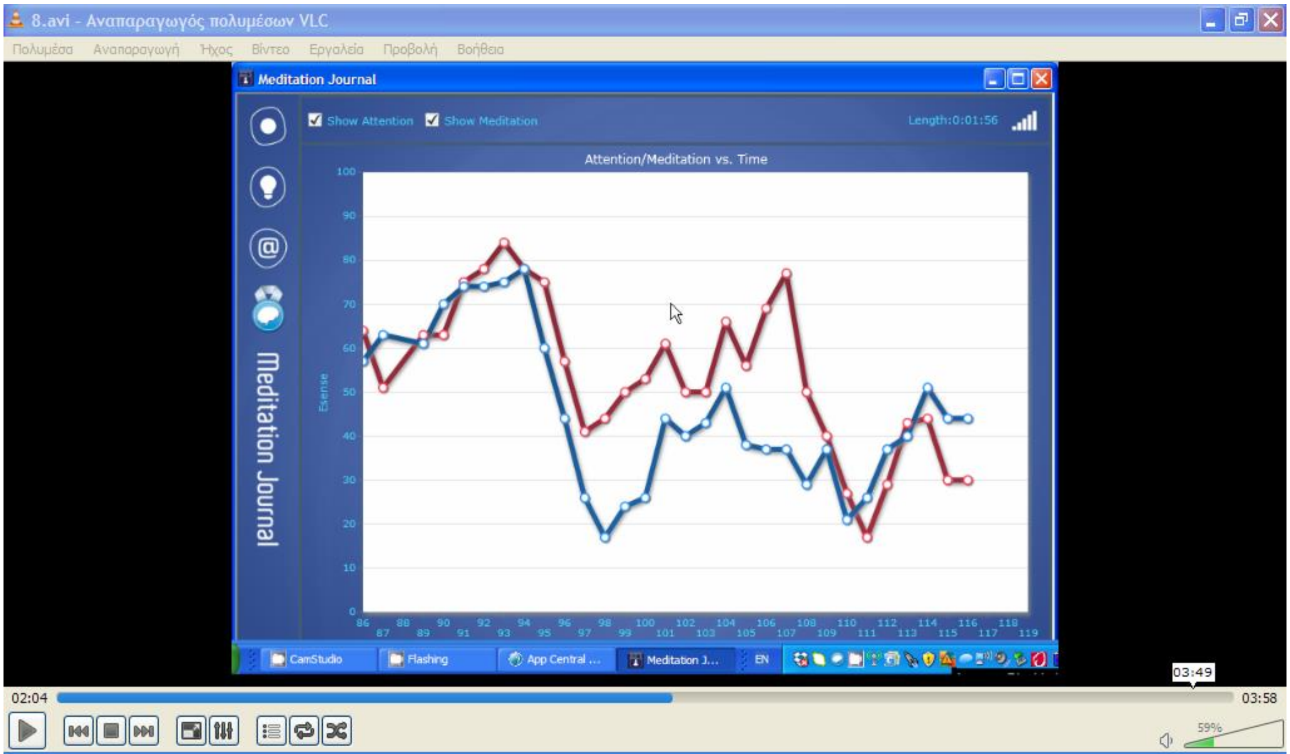

Figure 100 Meditation Journal Screenshot: Attention's and Meditation's Fluctuations

Measurements of the participants were put in work sheet for analysis and average rates were noticed as well as peaks at values per color as can be seen at Apendix B.

Table 3.1 First Table in Chapter 3 Chosen Colors for Thesis' Case Study

a/a	Color Specific Name	Color RGB Name	Color General Name
1	Cyan3	0, 205, 205	Blue
2	Blue1	0, 0, 255	Blue
3	Navy Blue	16, 78, 139	Blue - Violet
4	Dodger Blue4	0, 0, 128	Blue
5	Purple	128, 0, 128	Purple
6	Dark Purple	135, 31, 120	Purple
7	Medium Violet_Red	208, 32, 144	Violet - Red
8	Maroon	128, 0, 0	Red
9	Fres Speech Red	192, 0, 0	Red
10	Red	255, 0, 0	Red
11	Deep Pink	255, 20, 147	Red
12	Red_Orange	255, 69, 0	Red - Orange
13	Dark Orange	255, 140, 0	Orange
14	Orange	255, 165, 0	Orange
15	Gold	255, 215, 0	Yellow
16	Yellow	255, 255, 0	Yellow
17	Lawn Green	124, 252, 0	Green
18	Light Green/Lime	0, 255, 0	Green
19	Green	0, 128, 0	Green
20	Dark Green	0, 100, 0	Green

Chapter 4 - OUTCOMES

4.1 The Case Study

4.1.1 Analysis of Brainwaves' Measurements and Colors

During statistic analysis the averages of measurements for state of attention and meditation were extracted. Observing them separately, it occurred that some colors,demonstrating higher levels than others (>75),influence the majority of participants.

Some other colors also influence participants but in lower rates.

Also the stimulations that a specific color evokes may be either upwards or downwards or even having alternations during 10ms of color's duration.

No similarities also or proportions occurred between attention and meditation. They could change analogically during time (Figure 101) or totally differently and in opposite levels (Figure 102).

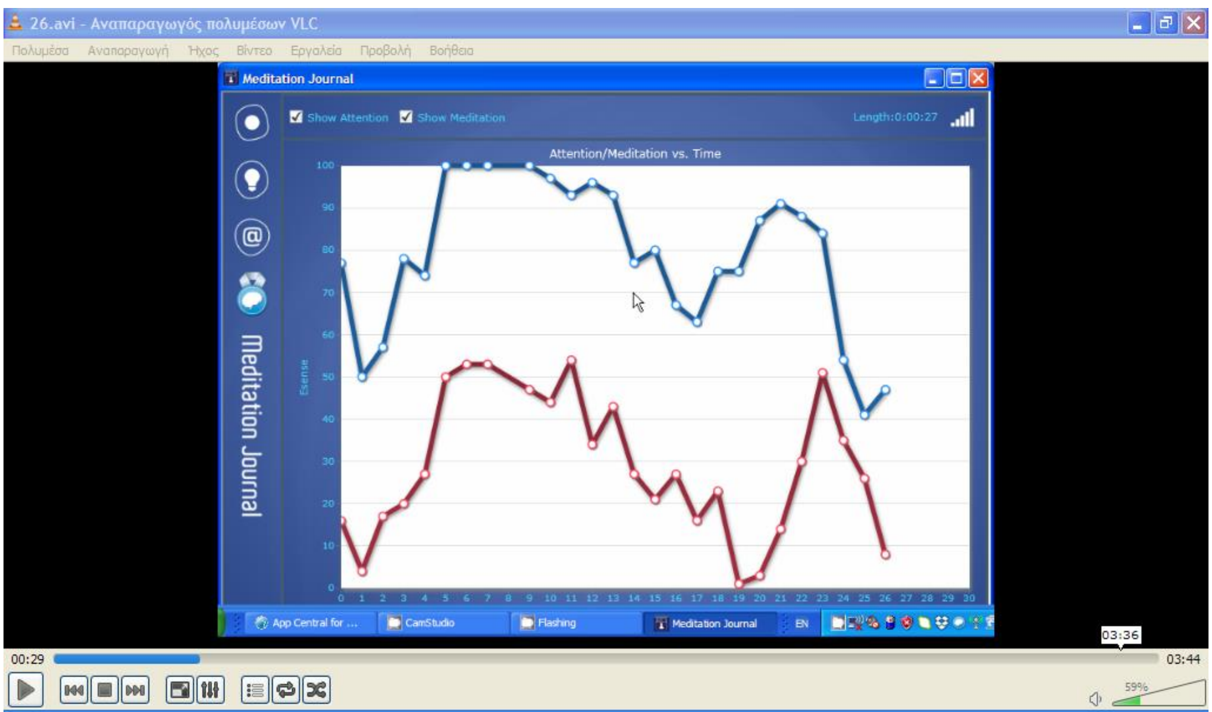

Figure 101 A Screenshot of Meditation Journal: Attention's and Meditation's Fluctuations

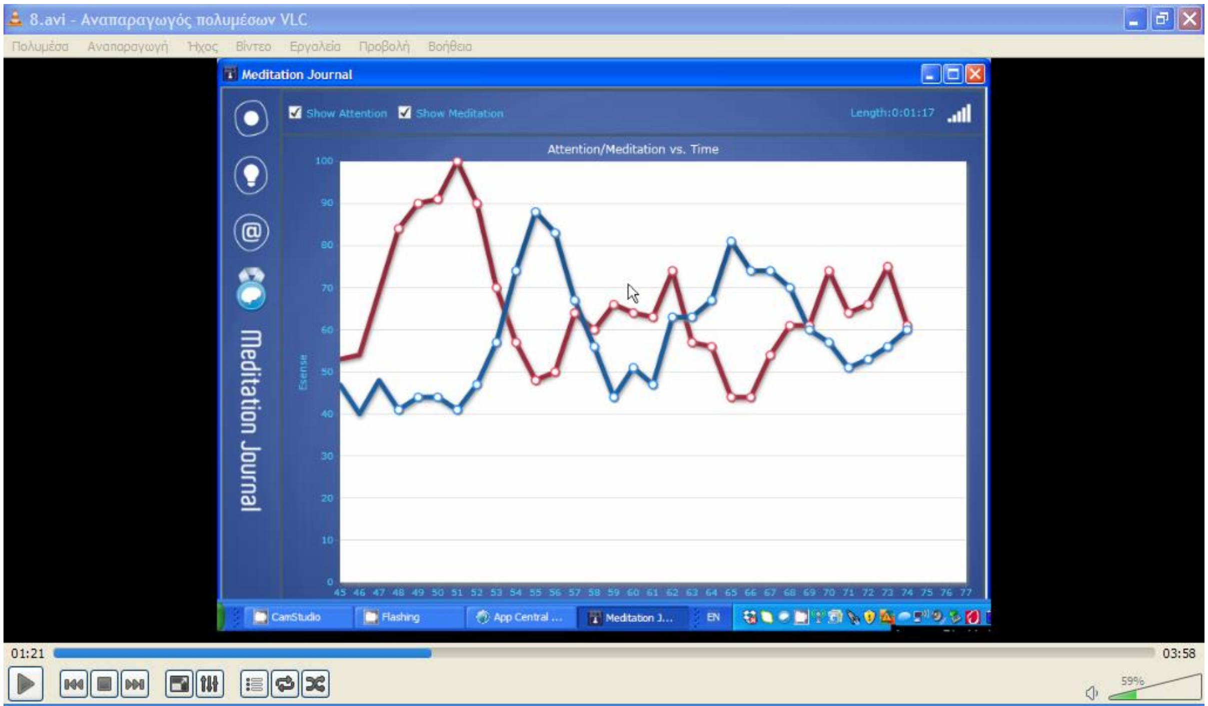

Figure 102 A Screenshot of Meditation Journal: Attention's and Meditation's Fluctuations

So the conclusions and findings at last were composite and layered.

Observing the different emitted brainwaves and the variety of their fluctuations lead to the outcome and thought that brainwaves' ranges are unique, something like a footprint, for each one and characterize him or her. The way they changes after a stimulation is unique also since everybody is affected differently.

4.1.2 Hypothesis

Initial thesis' Statement was "Does an external stimulus affect the level and rates of Human Brain’s Attention and Meditation?". The case study showed that the visual external stimulus, color evoked a variety of brainwaves' changes in the brain alternating values from almost 0 to 100 in the scale of Meditation Journal.

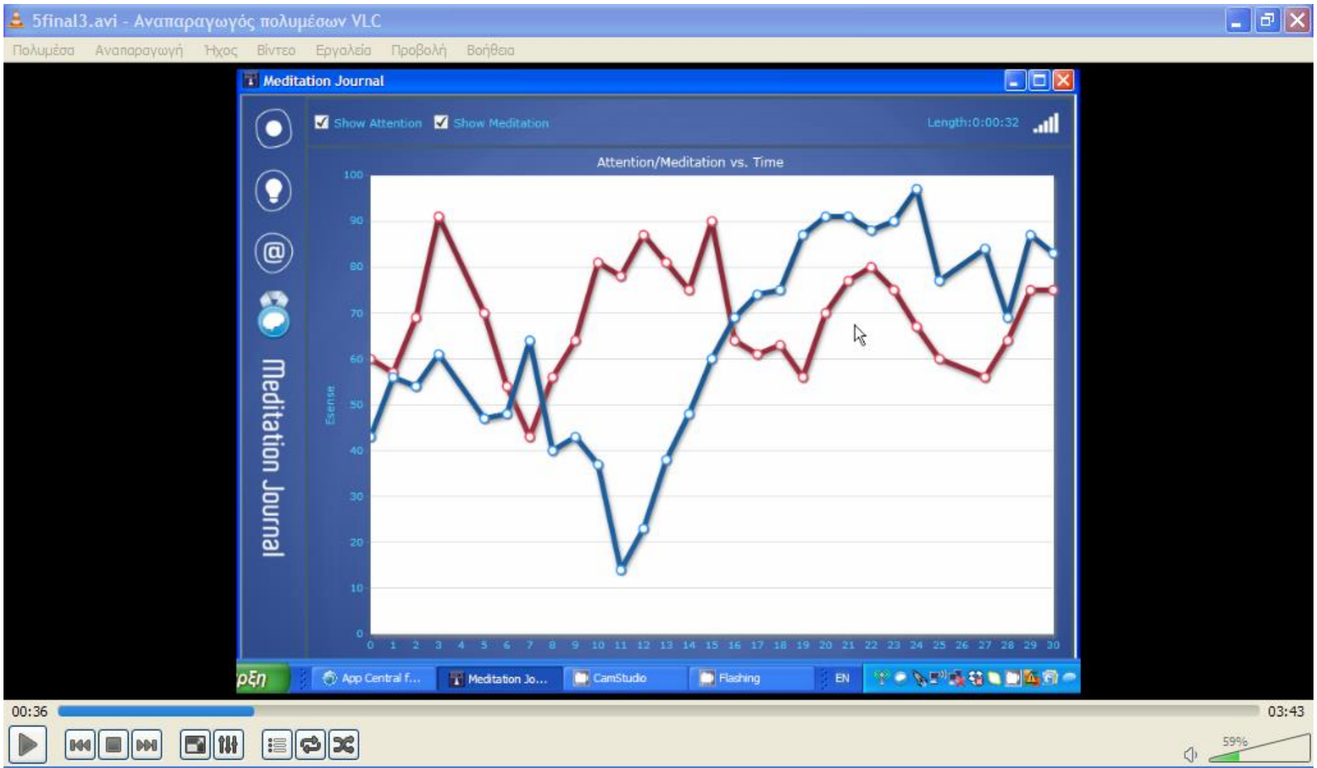

Figure 103 A Screenshot of Meditation Journal: Attention's and Meditation's Fluctuations

And the restatement was: "If the external stimulus is a color then does a specific color stimulates more Human Brain than other colors?"

With caution and thoughtfully could be written that yes some colors tend to provoke changes in brainwaves at higher values of scale (>75) than others.

Figure 104 Lawn Green Color

4.1.2.1 Attention

For the participants colors augmenting their Attention seem to be:

1) with criteria the highest average of measurements / color (10 values / 10ms):

Mostly Lawn Green, Blue 1 and Navy blue, also Gold, Yellow, Medium Violet-Red, and moderately Cyan3, Red-Orange, Red, Dark Orange.

2) with criteria the Peak / color (the highest value of ten values / one color in 10ms):

Mostly Lawn Green, Blue 1 and Navy blue, also Gold, Yellow, Medium Violet-Red, and moderately Cyan3, Red-Orange, Red, Dark Orange.

3) with criteria the Variance of two consecutively colors' averages (the thought is that if the first colour has an average A and the sequential color has a much higher average Bof measurements' values the augmentation at values (B - A) and consequently the influence of the second in order color to the participant is estimable):

Mostly Lawn Green, Blue 1, Gold and Red-Orange, also Dark Purple, Green, Red, Maroon, and moderately Dark Orange and Dodger Blue4.

4.1.2.2 Meditation

On the other hand Meditation's augmentation seem to favor Light Green/Lime.

With same previous three criteria we have:

1) Mostly Light Green/Lime and Medium Violet-Red, also Maroon, Dodger Blue4, Navy Blue and Purple, and moderately Yellow, Fres Speech Red, Lawn Green and Dark Purple.

2) Mostly Light Green/Lime and Fres Speech Red, also Medium Violet-Red, Dodger Blue4, and Maroon and moderately Purple, Navy Blue, Red, Yellow, and Lawn Green.

3) Mostly Dark Orange and Light Green/Lime, also Red, Navy Blue, Red-Orange and Medium Violet-Red, and moderately Blue1, Deep Pink, Yellow and Gold.

There were also colors a category alone since almost all participants had reactions and alternations to their levels of brainwaves and also in greater scale than other colors (a bigger peak). Usually both attention and meditation levels were changing either oppositely or relevantly. For sure these colors did not leave the participants indifferent. These colors seem to be Lawn Green and Deep Pink for changes usually upwards, Yellow and Navy Blue. Light Green/Lime, also but in lower degree. Maroon is a color like previous ones although usually levels were decreasing after it was shown.

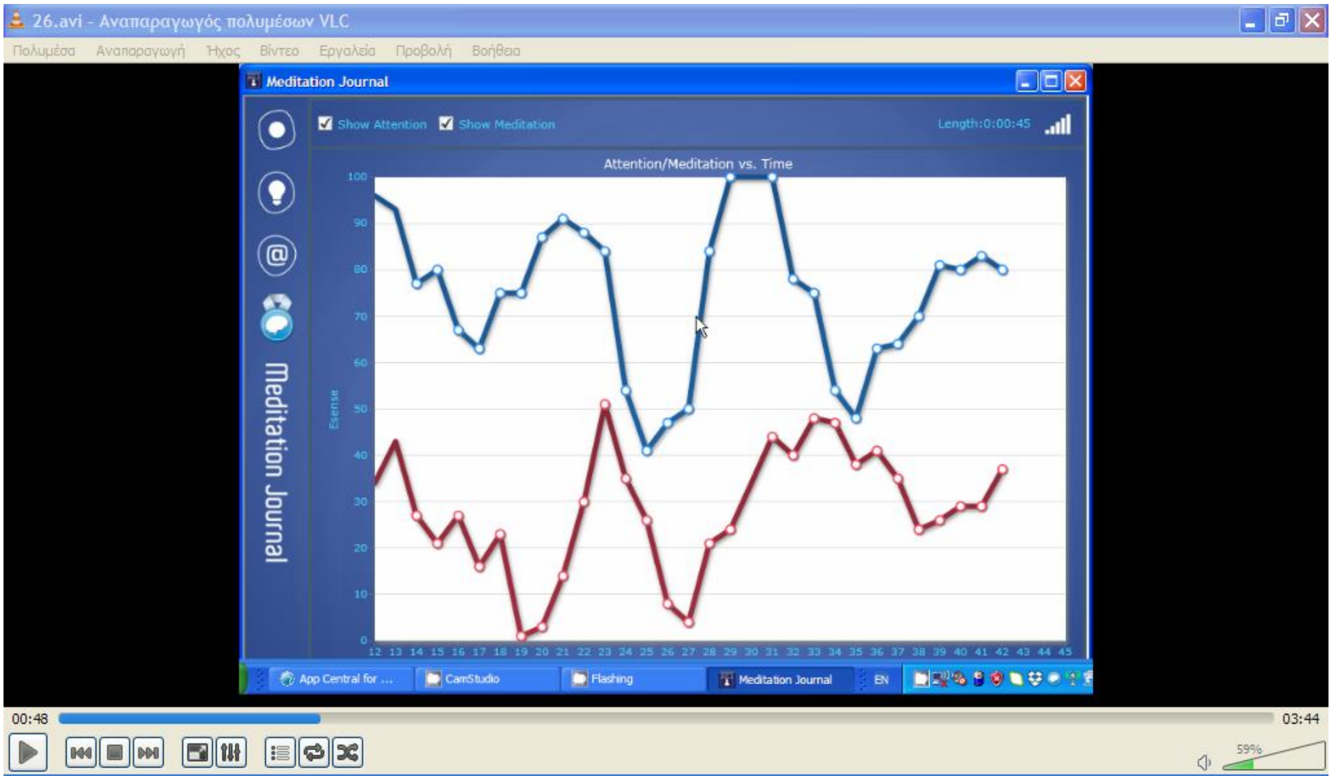

Figure 105 Fluctuations of Attention and Meditation in Time

4.2 Learning / Cognition, Potential Benefits for Education and Instruction

4.2.1 Enhancing Learning

Enhancing means to improve or augment, especially in effectiveness, value, or attractiveness [109] the learning.

Be effective in learning is having an intended or expected effect or producing a strong impression or response, [110] just like striking.

Arresting the attention and producing a vivid impression on the sight or the mind [111] in order to absorb knowledge. Previous sentence could not explain better the educational goal for all trainers, teachers in benefit of their students.

4.2.2 Auditory Stimuli

Training and teaching, having noticed the amazing support and increase in levels of good mental state that brainwaves can present, can be more efficient.

Some of the mental states that researchers work with when observing the emitted brainwaves using brainwaves sensors' technology (EEG, MRI, etc) follow. They are chosen as they influence focus and other learning elements. The areas of interest for cognition concerning bandwidth patterns in use are mentioned below.

Beta Brainwaves: concentration, alertness, analytical thinking, cognition

Alpha Brainwaves: relaxed focus, super learning, increased serotonin production. When serotonin augments joy is expanded, there is good mood, it affects the psychological status of the pupil which, in turn, affect the overall good feeling being 'breeding ground' for learning and general education.

Theta Brainwaves: increased retention of learned materia, increased production of catecholamines, which are vital for learning and memory increased creativity.

Gama Brainwaves: whole-brain activity, super-learning, sudden insight

As for Delta Brainwaves: since they refer to dreamless sleep, deep non-physical state, loss of body awareness they are rather best used for sleep disorders, accelerated physical healing and deep relaxation than for tutoring.

More about Brainwaves Patterns and related mental activity in relation to their use and benefits can be seen in Appendix C.

4.2.3 Visual Stimuli

Color is a stimulus daily encountered. If it assists augmenting cognition should be seriously considered as one of the factors of learning's amelioration.

As the researchers Mariam Adawiah Dzulkifli and Muhammad Faiz Mustafar in "The Influence of Colour on Memory Performance: A Review" advocate in the conclusion [42]: "An important aspect in successful and efficient cognitive functioning is the abilities to utilize the system to the fullest. Research on memory has provided a vast strategy that can be used to ensure successful retrieval. There appears to be a basis for associating colour and its significant effect on memory abilities. In other words, colour has the potential to increase chances of environmental stimuli to be encoded, stored, and retrieved successfully. The choice of colours and the manipulative aspects can, however, influence the extent to which colours can influence human memory performance.”

Memory has a great role in learning and attaining knowledge. Color seems to improve ability to remember since it helps brain to correlate a color with an object, an act or something new and useful to be assimilated. [42]

In education and training it may be useful being aware of the significance of colors in daily life and the boost of human ability to learn that they provoke. It seems that when learning objects are related to colors it could act as amenity or incentive to learning during entrainment and lessons.

In Education or also Relevant Ranges color may be used suitably either at Personal Computers' Displays as background or letters' color or forming Learning Objects [112] apropos to Colors.

When new things are learned the brain is stimulated and is being encouraged to rewire itself and change throughout life. By learning new activities brain can develop new neural connections [16], [17], [18] and thereby alter the physical structure of it throughout our life.

It turns out we can teach an old dog new tricks. And as Dr. Matthew Bambling of the University of Queensland, Australia, says: “The brain is a remarkably flexible and dynamic organ responding structurally to everything we do, the old adage ‘use it or lose it’ might never be more true than for the brain.” [113], [39]

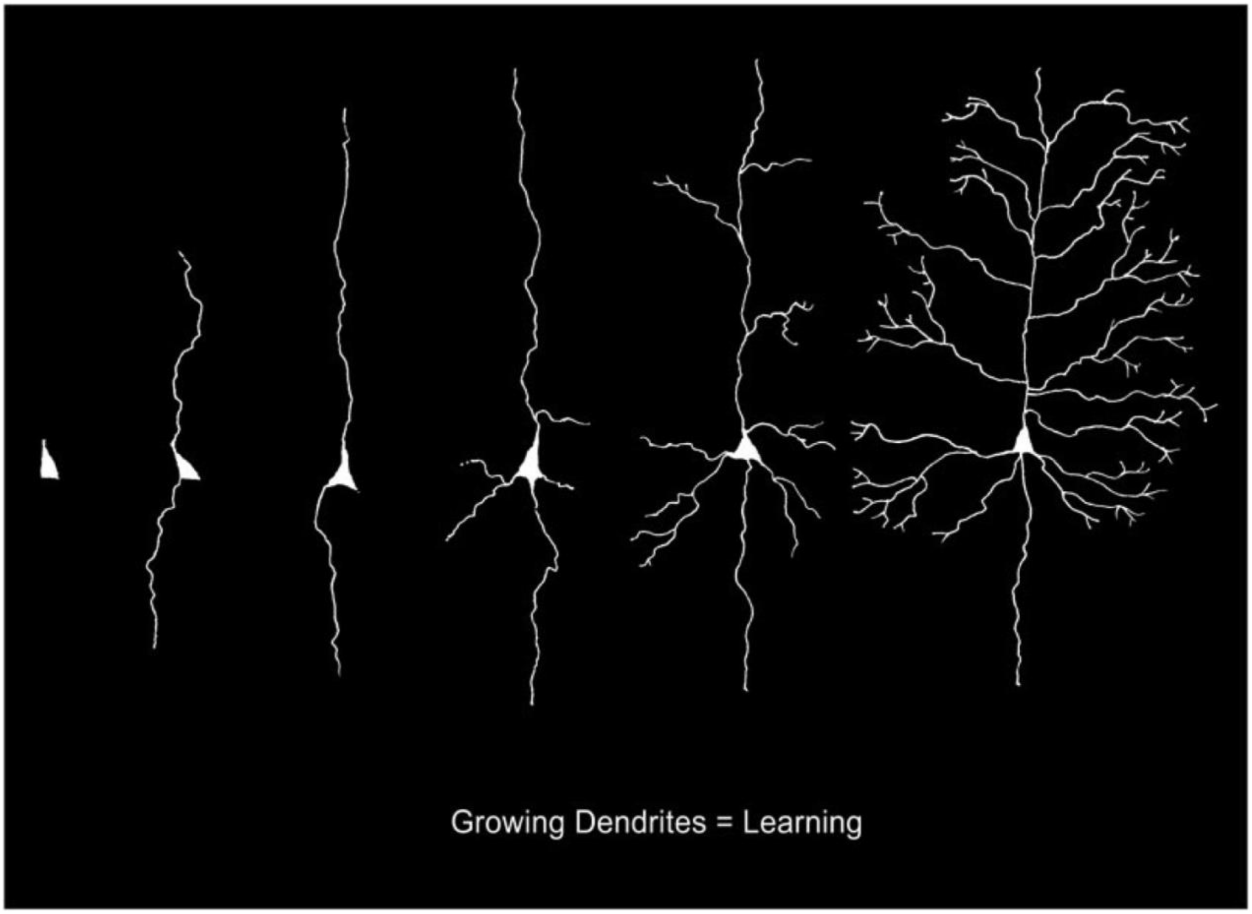

Figure 106 Growing Dendrites = Learning

After all people with higher cognitive reserve (training, education) tend to experience less cognitive decline.

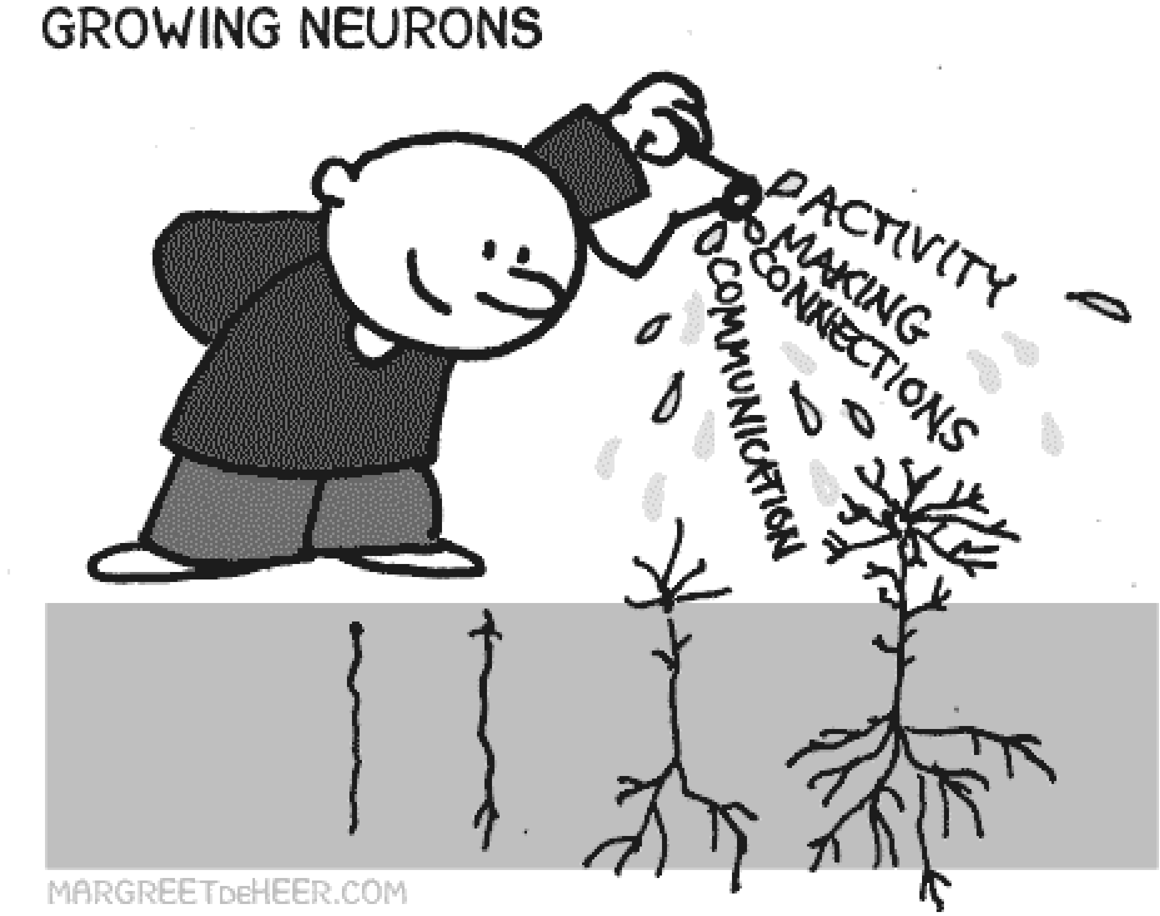

Figure 107 Growing Neurons: Activity, Making Connections, Communication

4.3 The Future ...today

A new age comes where wearable technology [114], [115], [116], [117], [118] and biofeedback [119], [120], [121] are going to continue to grow as new technology generates. Neurofeedback or electroencephalography (EEG) technology, which measures brain wave activity, has been around since the early 1900's. Though only now people can purchase their own devices or measure their brainwaves in order to adjust their lives more effectively and counteract against worries, bad mood, stress, or more severe health situations life could put them in. By using these technologies people can improve their focus as well augment learning in order to finally enhance themselves.

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APPENDIXES

Appendix A - Thesis' Abstract for Call for Papers to 9th International Conference: on New Horizons in Industry, Business and Education, Skiathos 2015, Topic of Interest : Science and Education

Enhancing Learning - A Case Study of Mind's Responses to External Stimuli interfacing with Brain Wave Sensors

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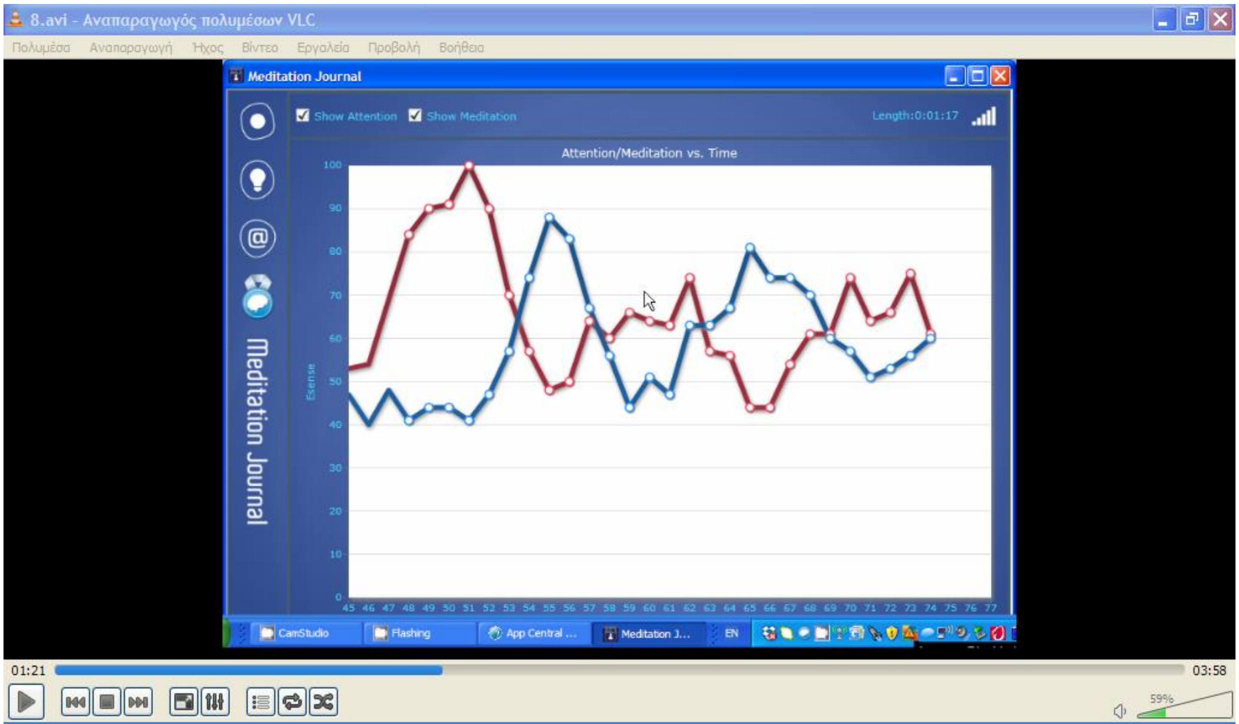
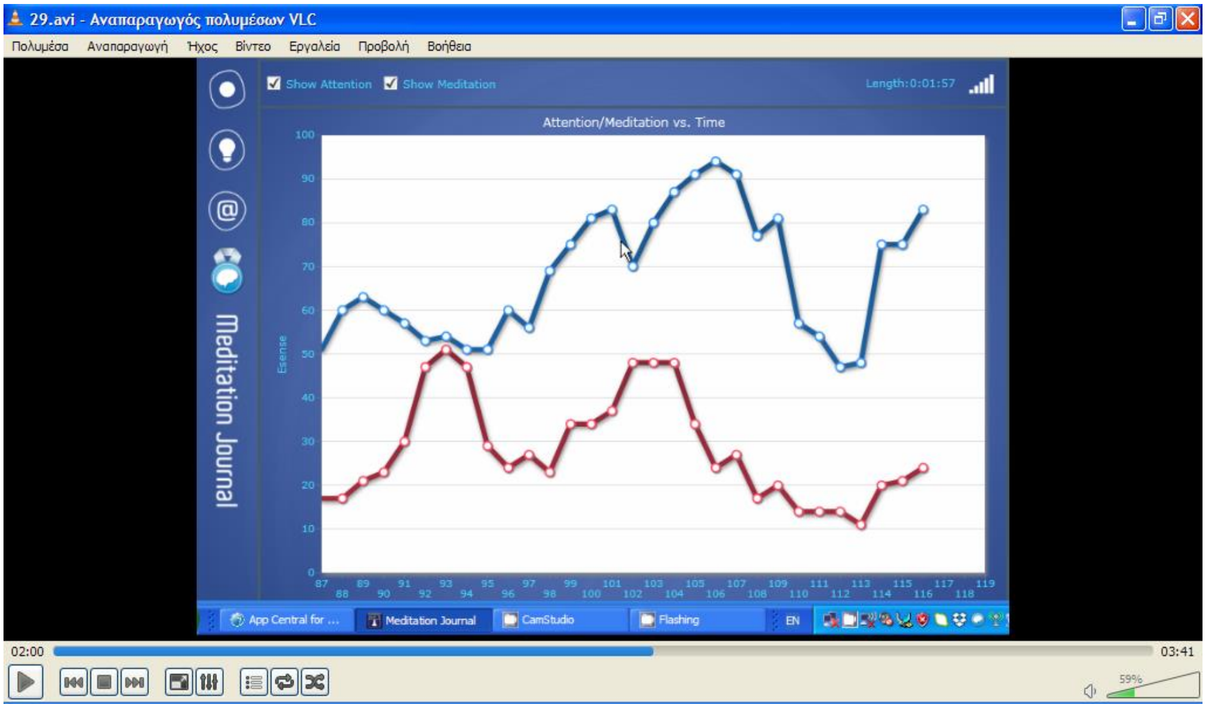
Abstract:

Improving learning, especially in effectiveness and value, arousing interest of learners and augmenting attention during training or a variety of procedures is an aspiration. Exploring brain's activity is not yet fully defined and remains a huge research area. This project attempts to approach and understand the diversifications of brain's responses while interfering with different situations. The aim is to observe and notice brain's reactions to an external stimulus. Neural activity is related with mental state while their differentiations emit characteristic brainwaves. The electrical impulses in the brain can be measured using Brain Wave Sensors. Colour or Sound can be used as External Stimulus. Attention's and Meditation's status are states of Human Mind being observed. Outcomes of this project may have a beneficial use in education or relevant ranges.

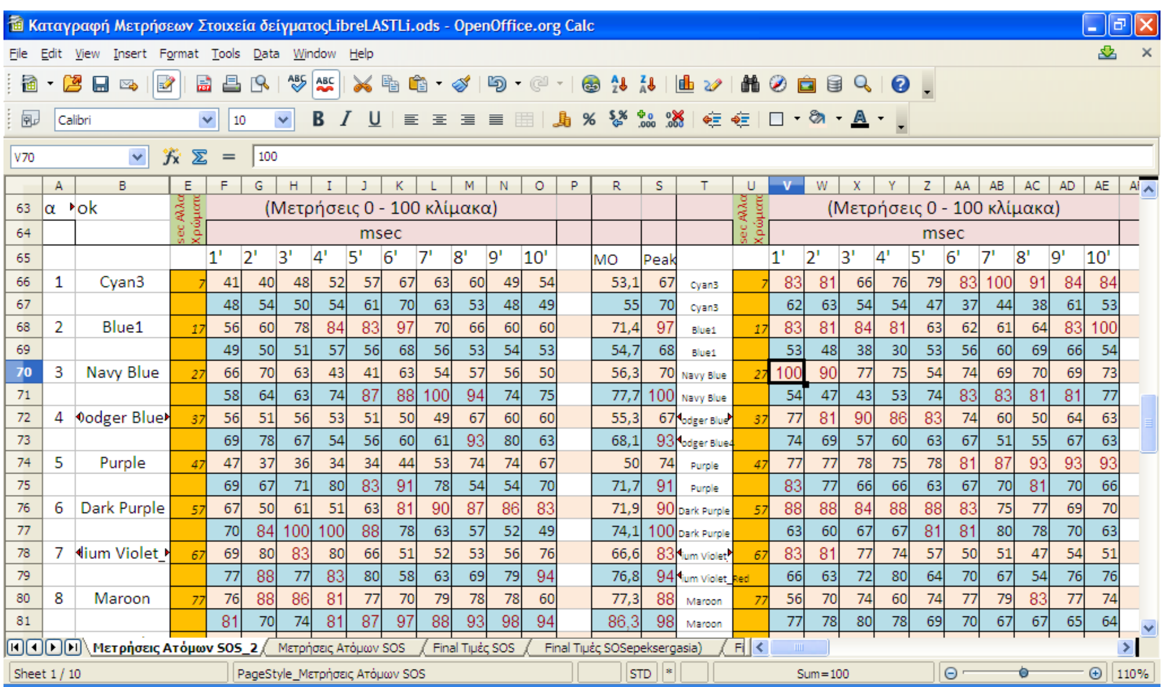
Appendix B - Case Study's Measurements and Analysis



Appendix 1 Fluctuations at values (0 - 100) of Attention (in red) and Meditation (in blue) during time (msec)

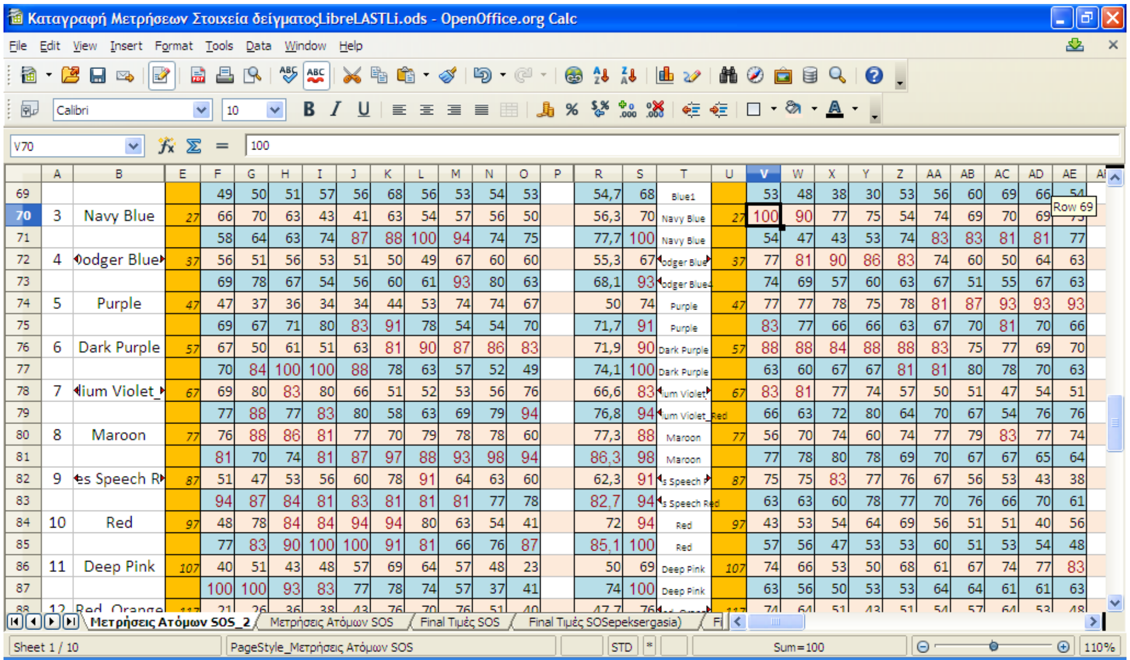


Appendix 2 Fluctuations at values (0 - 100) of Attention (in red) and Meditation (in blue) during time (msec)



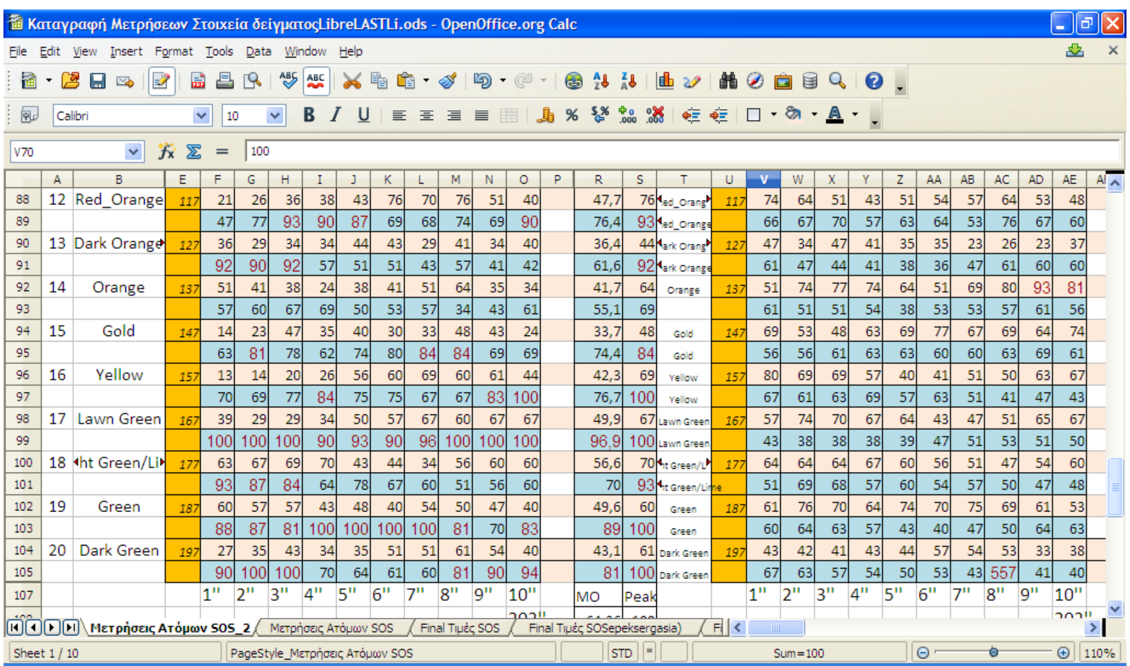
	A	B	E	F	G	H	I	J	K	L	M	N	O	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
63	α	ok	sec Άλλα Χρώματα	(Μετρήσεις 0 - 100 κλίμακα)													sec Άλλα Χρώματα	(Μετρήσεις 0 - 100 κλίμακα)									
64				msec														msec									
65				1'	2'	3'	4'	5'	6'	7'	8'	9'	10'	MO	Peak			1'	2'	3'	4'	5'	6'	7'	8'	9'	10'
66	1	Cyan3	7	41	40	48	52	57	67	63	60	49	54	53,1	67	Cyan3	7	83	81	66	76	79	83	100	91	84	84
67				48	54	50	54	61	70	63	53	48	49	55	70	Cyan3		62	63	54	54	47	37	44	38	61	53
68	2	Blue1	17	56	60	78	84	83	97	70	66	60	60	71,4	97	Blue1	17	83	81	84	81	63	62	61	64	83	100
69				49	50	51	57	56	68	56	53	54	53	54,7	68	Blue1		53	48	38	30	53	56	60	69	66	54
70	3	Navy Blue	27	66	70	63	43	41	63	54	57	56	50	56,3	70	Navy Blue	27	100	90	77	75	54	74	69	70	69	73
71				58	64	63	74	87	88	100	94	74	75	77,7	100	Navy Blue		54	47	43	53	74	83	83	81	81	77
72	4	odger Blue	37	56	51	56	53	51	50	49	67	60	60	55,3	67	odger Blue	37	77	81	90	86	83	74	60	50	64	63
73				69	78	67	54	56	60	61	93	80	63	68,1	93	odger Blue		74	69	57	60	63	67	51	55	67	63
74	5	Purple	47	47	37	36	34	34	44	53	74	74	67	50	74	Purple	47	77	77	78	75	78	81	87	93	93	93
75				69	67	71	80	83	91	78	54	54	70	71,7	91	Purple		83	77	66	66	63	67	70	81	70	66
76	6	Dark Purple	57	67	50	61	51	63	81	90	87	86	83	71,9	90	Dark Purple	57	88	88	84	88	88	83	75	77	69	70
77				70	84	100	100	88	78	63	57	52	49	74,1	100	Dark Purple		63	60	67	67	81	81	80	78	70	63
78	7	ium Violet_	67	69	80	83	80	66	51	52	53	56	76	66,6	83	um Violet	67	83	81	77	74	57	50	51	47	54	51
79				77	88	77	83	80	58	63	69	79	94	76,8	94	um Violet_Red		66	63	72	80	64	70	67	54	76	76
80	8	Maroon	77	76	88	86	81	77	70	79	78	78	60	77,3	88	Maroon	77	56	70	74	60	74	77	79	83	77	74
81				81	70	74	81	87	97	88	93	98	94	86,3	98	Maroon		77	78	80	78	69	70	67	67	65	64

Appendix 3 Values' Measurements and Analysis of Attention and Meditation



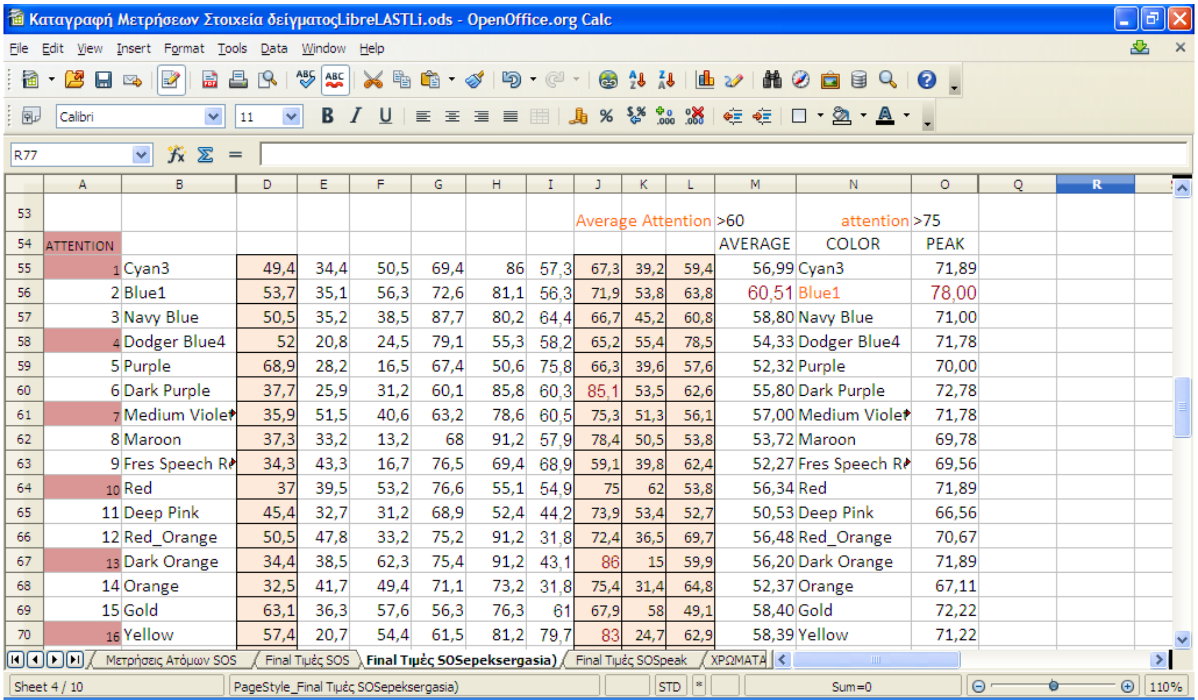
	A	B	E	F	G	H	I	J	K	L	M	N	O	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
69				49	50	51	57	56	68	56	53	54	53		54,7	68	Blue1		53	48	38	30	53	56	60	69	66	54
70	3	Navy Blue	27	66	70	63	43	41	63	54	57	56	50		56,3	70	Navy Blue	27	100	90	77	75	54	74	69	70	69	75
71				58	64	63	74	87	88	100	94	74	75		77,7	100	Navy Blue		54	47	43	53	74	83	83	81	81	77
72	4	odger Blue	37	56	51	56	53	51	50	49	67	60	60		55,3	67	odger Blue	37	77	81	90	86	83	74	60	50	64	63
73				69	78	67	54	56	60	61	93	80	63		68,1	93	odger Blue		74	69	57	60	63	67	51	55	67	63
74	5	Purple	47	47	37	36	34	34	44	53	74	74	67		50	74	Purple	47	77	77	78	75	78	81	87	93	93	93
75				69	67	71	80	83	91	78	54	54	70		71,7	91	Purple		83	77	66	66	63	67	70	81	70	66
76	6	Dark Purple	57	67	50	61	51	63	81	90	87	86	83		71,9	90	Dark Purple	57	88	88	84	88	88	83	75	77	69	70
77				70	84	100	100	88	78	63	57	52	49		74,1	100	Dark Purple		63	60	67	67	81	81	80	78	70	63
78	7	ium Violet_	67	69	80	83	80	66	51	52	53	56	76		66,6	83	um Violet	67	83	81	77	74	57	50	51	47	54	51
79				77	88	77	83	80	58	63	69	79	94		76,8	94	um Violet_Red		66	63	72	80	64	70	67	54	76	76
80	8	Maroon	77	76	88	86	81	77	70	79	78	78	60		77,3	88	Maroon	77	56	70	74	60	74	77	79	83	77	74
81				81	70	74	81	87	97	88	93	98	94		86,3	98	Maroon		77	78	80	78	69	70	67	67	65	64
82	9	es Speech R	87	51	47	53	56	60	78	91	64	63	60		62,3	91	s Speech	87	75	75	83	77	76	67	56	53	43	38
83				94	87	84	81	83	81	81	81	77	78		82,7	94	s Speech Red		63	63	60	78	77	70	76	66	70	61
84	10	Red	97	48	78	84	84	94	94	80	63	54	41		72	94	Red	97	43	53	54	64	69	56	51	51	40	56
85				77	83	90	100	100	91	81	66	76	87		85,1	100	Red		57	56	47	53	53	60	51	53	54	48
86	11	Deep Pink	107	40	51	43	48	57	69	64	57	48	23		50	69	Deep Pink	107	74	66	53	50	68	61	67	74	77	83
87				100	100	93	83	77	78	74	57	37	41		74	100	Deep Pink		63	56	50	53	53	64	64	61	61	63

Appendix 4 Values' Measurements and Analysis of Attention and Meditation



	A	B	E	F	G	H	I	J	K	L	M	N	O	P	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
88	12	Red_Orange	117	21	26	36	38	43	76	70	76	51	40		47,7	76	ed_Orang	117	74	64	51	43	51	54	57	64	53	48
89				47	77	93	90	87	69	68	74	69	90		76,4	93	ed_Orange		66	67	70	57	63	64	53	76	67	60
90	13	Dark Orange	127	36	29	34	34	44	43	29	41	34	40		36,4	44	ark Orang	127	47	34	47	41	35	35	23	26	23	37
91				92	90	92	57	51	51	43	57	41	42		61,6	92	ark Orange		61	47	44	41	38	36	47	61	60	60
92	14	Orange	137	51	41	38	24	38	41	51	64	35	34		41,7	64	Orange	137	51	74	77	74	64	51	69	80	93	81
93				57	60	67	69	50	53	57	34	43	61		55,1	69			61	51	51	54	38	53	53	57	61	56
94	15	Gold	147	14	23	47	35	40	30	33	48	43	24		33,7	48	Gold	147	69	53	48	63	69	77	67	69	64	74
95				63	81	78	62	74	80	84	84	69	69		74,4	84	Gold		56	56	61	63	63	60	60	63	69	61
96	16	Yellow	157	13	14	20	26	56	60	69	60	61	44		42,3	69	Yellow	157	80	69	69	57	40	41	51	50	63	67
97				70	69	77	84	75	75	67	67	83	100		76,7	100	Yellow		67	61	63	69	57	63	51	41	47	43
98	17	Lawn Green	167	39	29	29	34	50	57	67	60	67	67		49,9	67	Lawn Green	167	57	74	70	67	64	43	47	51	65	67
99				100	100	100	90	93	90	96	100	100	100		96,9	100	Lawn Green		43	38	38	38	39	47	51	53	51	50
100	18	ht Green/Li	177	63	67	69	70	43	44	34	56	60	60		56,6	70	t Green/L	177	64	64	64	67	60	56	51	47	54	60
101				93	87	84	64	78	67	60	51	56	60		70	93	t Green/Lime		51	69	68	57	60	54	57	50	47	48
102	19	Green	187	60	57	57	43	48	40	54	50	47	40		49,6	60	Green	187	61	76	70	64	74	70	75	69	61	53
103				88	87	81	100	100	100	100	81	70	83		89	100	Green		60	64	63	57	43	40	47	50	64	63
104	20	Dark Green	197	27	35	43	34	35	51	51	61	54	40		43,1	61	Dark Green	197	43	42	41	43	44	57	54	53	33	38
105				90	100	100	70	64	61	60	81	90	94		81	100	Dark Green		67	63	57	54	50	53	43	557	41	40
107				1''	2''	3''	4''	5''	6''	7''	8''	9''	10''		MO	Peak			1''	2''	3''	4''	5''	6''	7''	8''	9''	10''

Appendix 5 Values' Measurements and Analysis of Attention and Meditation



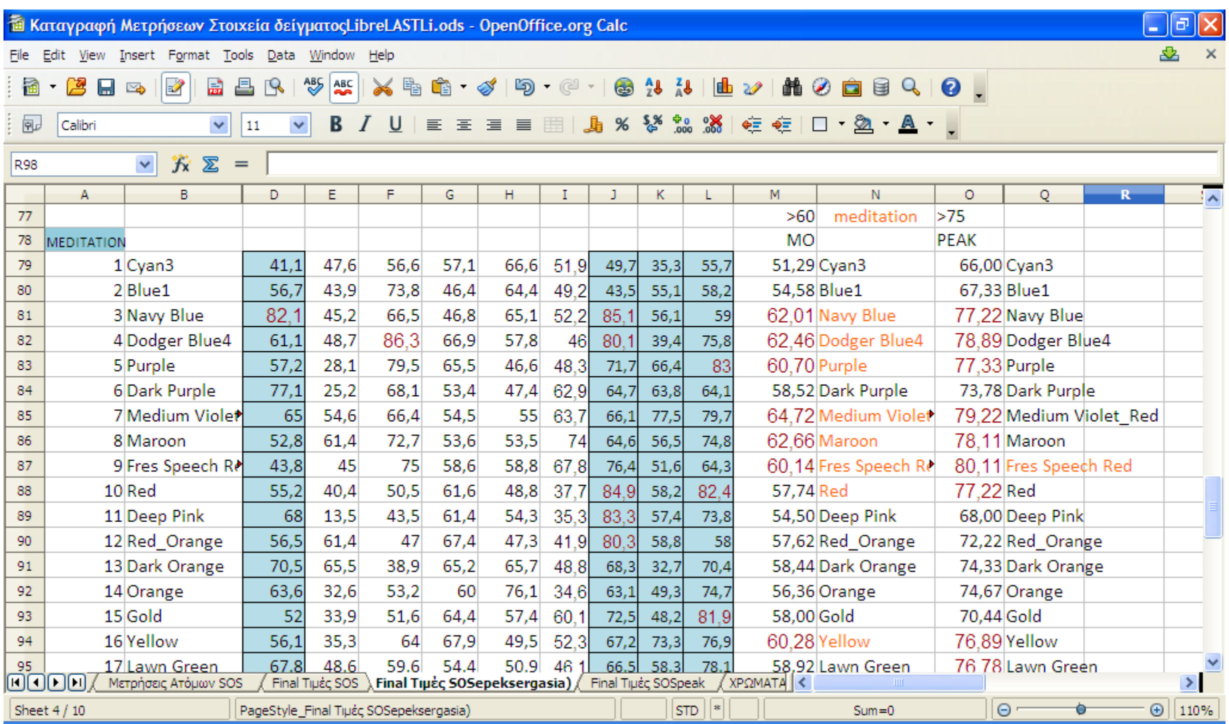
Καταγραφή Μετρήσεων Στοιχεία δείγματοςLibreLASTLi.ods - OpenOffice.org Calc

	A	B	D	E	F	G	H	I	J	K	L	M	N	O
53									Average Attention			>60	attention	>75
54	ATTENTION											AVERAGE	COLOR	PEAK
55	1	Cyan3	49,4	34,4	50,5	69,4	86	57,3	67,3	39,2	59,4	56,99	Cyan3	71,89
56	2	Blue1	53,7	35,1	56,3	72,6	81,1	56,3	71,9	53,8	63,8	60,51	Blue1	78,00
57	3	Navy Blue	50,5	35,2	38,5	87,7	80,2	64,4	66,7	45,2	60,8	58,80	Navy Blue	71,00
58	4	Dodger Blue4	52	20,8	24,5	79,1	55,3	58,2	65,2	55,4	78,5	54,33	Dodger Blue4	71,78
59	5	Purple	68,9	28,2	16,5	67,4	50,6	75,8	66,3	39,6	57,6	52,32	Purple	70,00
60	6	Dark Purple	37,7	25,9	31,2	60,1	85,8	60,3	85,1	53,5	62,6	55,80	Dark Purple	72,78
61	7	Medium Violet	35,9	51,5	40,6	63,2	78,6	60,5	75,3	51,3	56,1	57,00	Medium Violet	71,78
62	8	Maroon	37,3	33,2	13,2	68	91,2	57,9	78,4	50,5	53,8	53,72	Maroon	69,78
63	9	Fres Speech R	34,3	43,3	16,7	76,5	69,4	68,9	59,1	39,8	62,4	52,27	Fres Speech R	69,56
64	10	Red	37	39,5	53,2	76,6	55,1	54,9	75	62	53,8	56,34	Red	71,89
65	11	Deep Pink	45,4	32,7	31,2	68,9	52,4	44,2	73,9	53,4	52,7	50,53	Deep Pink	66,56
66	12	Red_Orange	50,5	47,8	33,2	75,2	91,2	31,8	72,4	36,5	69,7	56,48	Red_Orange	70,67
67	13	Dark Orange	34,4	38,5	62,3	75,4	91,2	43,1	86	15	59,9	56,20	Dark Orange	71,89
68	14	Orange	32,5	41,7	49,4	71,1	73,2	31,8	75,4	31,4	64,8	52,37	Orange	67,11
69	15	Gold	63,1	36,3	57,6	56,3	76,3	61	67,9	58	49,1	58,40	Gold	72,22
70	16	Yellow	57,4	20,7	54,4	61,5	81,2	79,7	83	24,7	62,9	58,39	Yellow	71,22

Μετρήσεις Ατόμων SOS / Final Τιμές SOS / Final Τιμές SOSepeksergasia) / Final Τιμές SOSpeak / ΧΡΩΜΑΤΑ

Sheet 4 / 10 PageStyle_Final Τιμές SOSepeksergasia) STD Sum=0 110%

Appendix 6 Values' Measurements and Analysis of Attention and Meditation



Καταγραφή Μετρήσεων Στοιχεία δείγματοςLibreLASTLi.ods - OpenOffice.org Calc

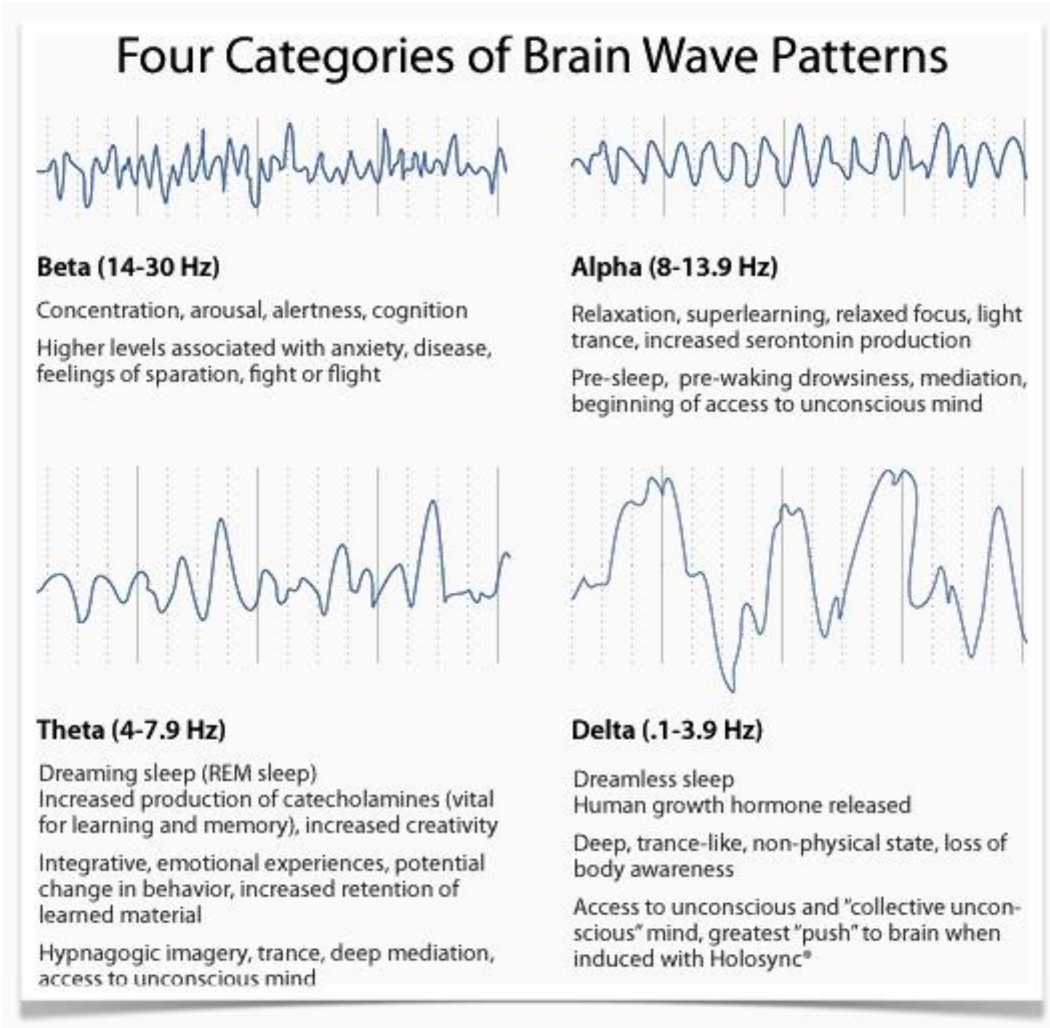
	A	B	D	E	F	G	H	I	J	K	L	M	N	O	Q
77												>60	meditation	>75	
78	MEDITATION											MO		PEAK	
79	1	Cyan3	41,1	47,6	56,6	57,1	66,6	51,9	49,7	35,3	55,7	51,29	Cyan3	66,00	Cyan3
80	2	Blue1	56,7	43,9	73,8	46,4	64,4	49,2	43,5	55,1	58,2	54,58	Blue1	67,33	Blue1
81	3	Navy Blue	82,1	45,2	66,5	46,8	65,1	52,2	85,1	56,1	59	62,01	Navy Blue	77,22	Navy Blue
82	4	Dodger Blue4	61,1	48,7	86,3	66,9	57,8	46	80,1	39,4	75,8	62,46	Dodger Blue4	78,89	Dodger Blue4
83	5	Purple	57,2	28,1	79,5	65,5	46,6	48,3	71,7	66,4	83	60,70	Purple	77,33	Purple
84	6	Dark Purple	77,1	25,2	68,1	53,4	47,4	62,9	64,7	63,8	64,1	58,52	Dark Purple	73,78	Dark Purple
85	7	Medium Violet	65	54,6	66,4	54,5	55	63,7	66,1	77,5	79,7	64,72	Medium Violet	79,22	Medium Violet_Red
86	8	Maroon	52,8	61,4	72,7	53,6	53,5	74	64,6	56,5	74,8	62,66	Maroon	78,11	Maroon
87	9	Fres Speech R	43,8	45	75	58,6	58,8	67,8	76,4	51,6	64,3	60,14	Fres Speech R	80,11	Fres Speech Red
88	10	Red	55,2	40,4	50,5	61,6	48,8	37,7	84,9	58,2	82,4	57,74	Red	77,22	Red
89	11	Deep Pink	68	13,5	43,5	61,4	54,3	35,3	83,3	57,4	73,8	54,50	Deep Pink	68,00	Deep Pink
90	12	Red_Orange	56,5	61,4	47	67,4	47,3	41,9	80,3	58,8	58	57,62	Red_Orange	72,22	Red_Orange
91	13	Dark Orange	70,5	65,5	38,9	65,2	65,7	48,8	68,3	32,7	70,4	58,44	Dark Orange	74,33	Dark Orange
92	14	Orange	63,6	32,6	53,2	60	76,1	34,6	63,1	49,3	74,7	56,36	Orange	74,67	Orange
93	15	Gold	52	33,9	51,6	64,4	57,4	60,1	72,5	48,2	81,9	58,00	Gold	70,44	Gold
94	16	Yellow	56,1	35,3	64	67,9	49,5	52,3	67,2	73,3	76,9	60,28	Yellow	76,89	Yellow
95	17	Lawn Green	67,8	48,6	59,6	54,4	50,9	46,1	66,5	58,3	78,1	58,92	Lawn Green	76,78	Lawn Green

Μετρήσεις Ατόμων SOS / Final Τιμές SOS / Final Τιμές SOSepeksergasia) / Final Τιμές SOSpeak / ΧΡΩΜΑΤΑ

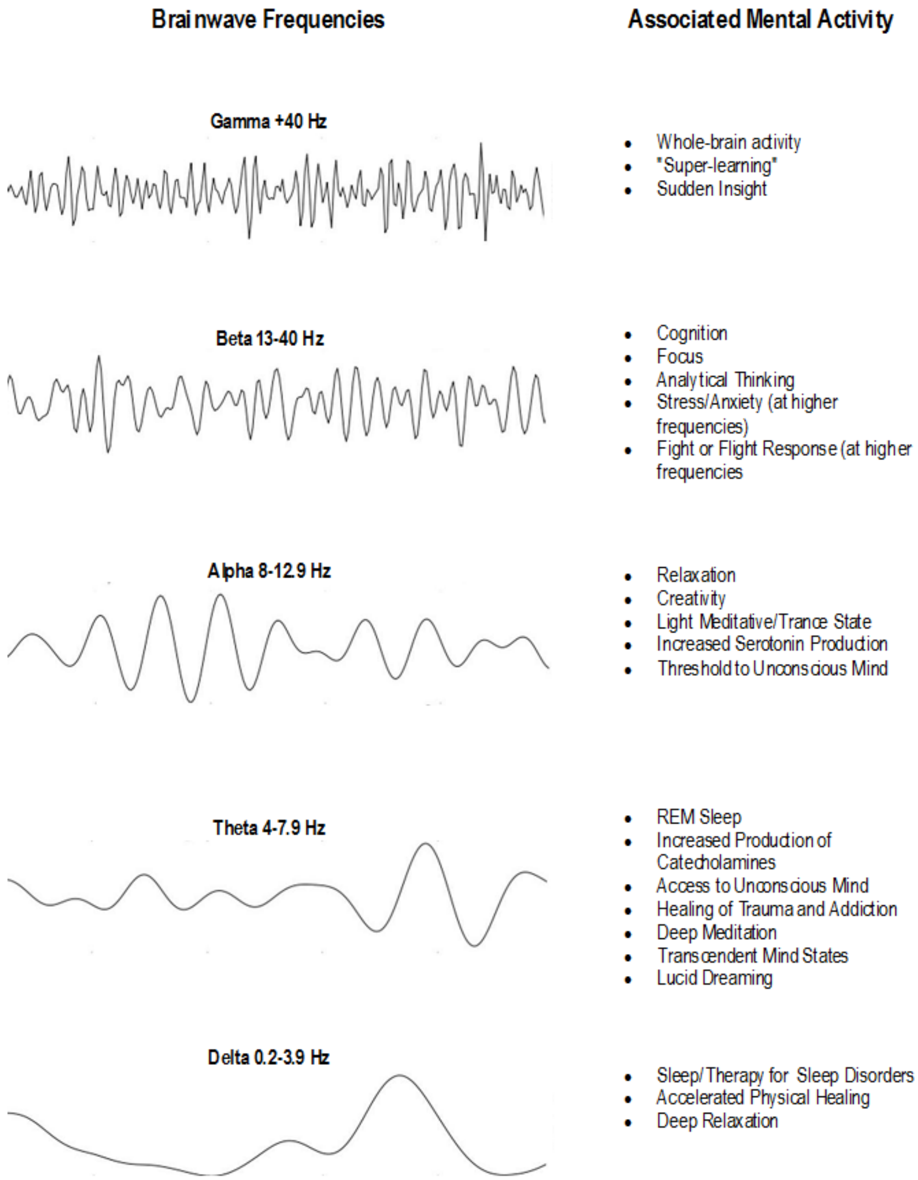
Sheet 4 / 10 PageStyle_Final Τιμές SOSepeksergasia) STD Sum=0 110%

Appendix 7 Values' Measurements and Analysis of Attention and Meditation

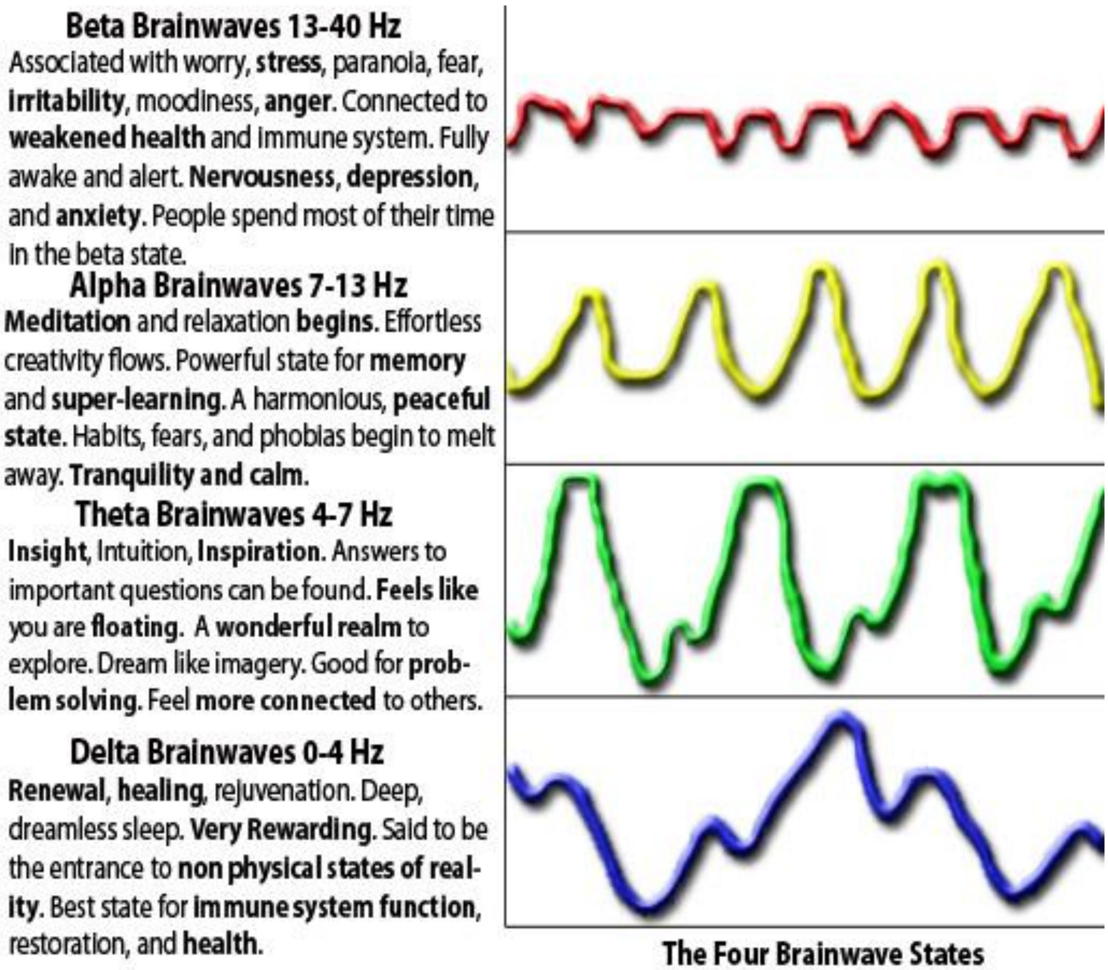
Appendix C - Brainwaves and related Mental Activity



Appendix 8 Four Categories of Brain Wave Patterns



Appendix 9 Brainwave Frequencies and Associated Mental Activity



Appendix 10 The Four Brainwave States

From: store.eocinstitute.org

Appendix D - Information for Brainwave Entrainment

Information for NeuroSky [1]

NeuroSky, Inc. is a manufacturer of Brain-Computer Interface (BCI) technologies [2] for consumer product applications, which was founded in 2004 in Silicon Valley, California.[3] [4] [5] [6] The company adapts electroencephalography (EEG) [7] and electromyography (EMG) [8] technology to fit a consumer market within a number of fields such as entertainment (toys and games), education, automotive, and health.[9][10]

NeuroSky technology allows for low-cost EEG-linked research and products by using inexpensive dry sensors; older EEGs require the application of a conductive gel between the sensors and the head. The systems also include built-in electrical “noise” reduction software/hardware, and utilize embedded (chip level) solutions for signal processing and output. [11]

Exploration of Consciousness Research Institute / EOC Institute [12]

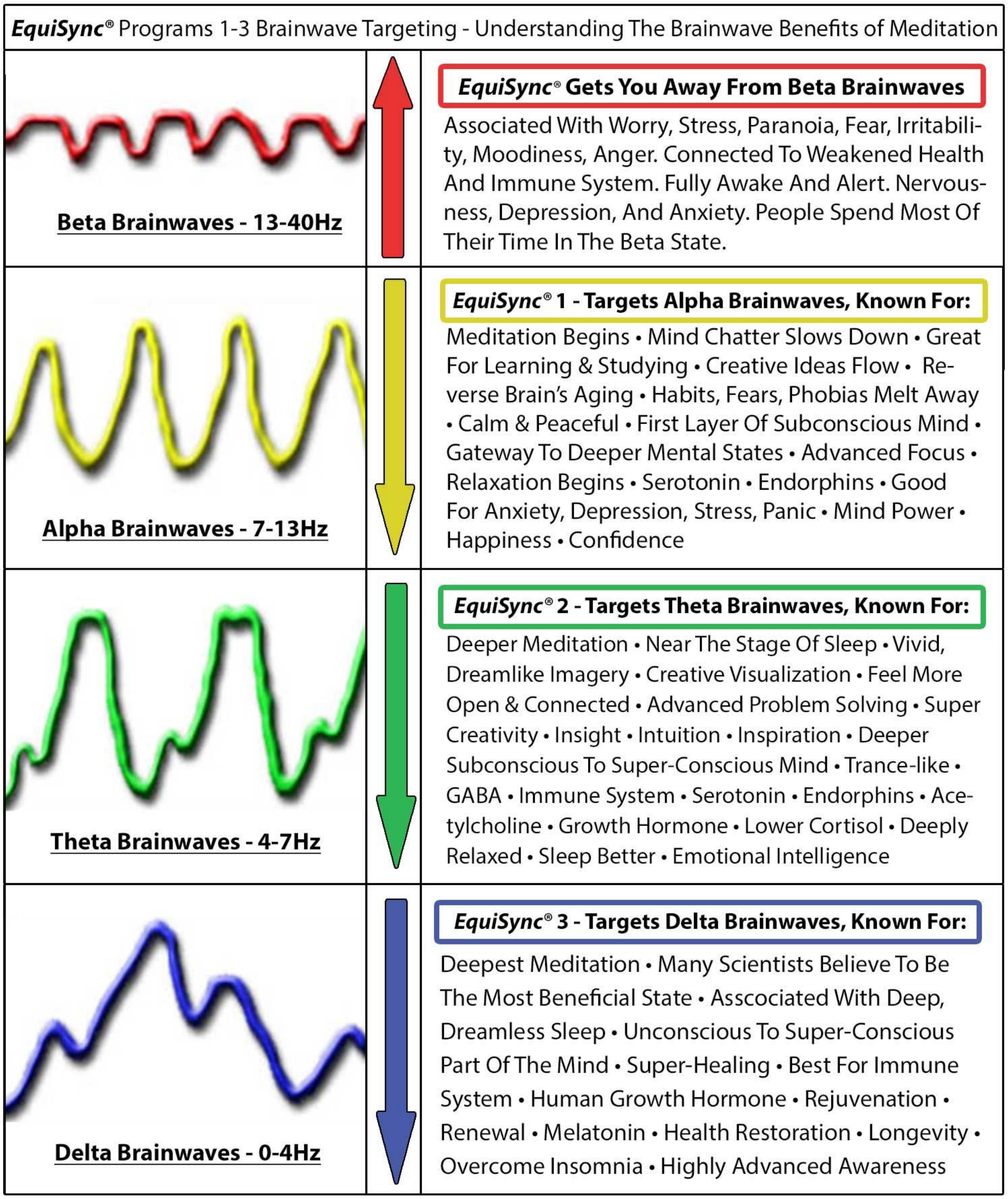
EquiSync - BinauralBeats

"EquiSync’s design is based on the 100’s of studies performed on the effectiveness of brainwave entrainment technology, and 1000’s of studies on the powerful benefits of meditation. If you are interested in better understanding the power of this technology and rapidly expanding field of research, then here is a very abbreviated bibliography, a very small sample of the studies out there:" [13]

"How Brainwave Entrainment With EquiSync Can Transform Your Life

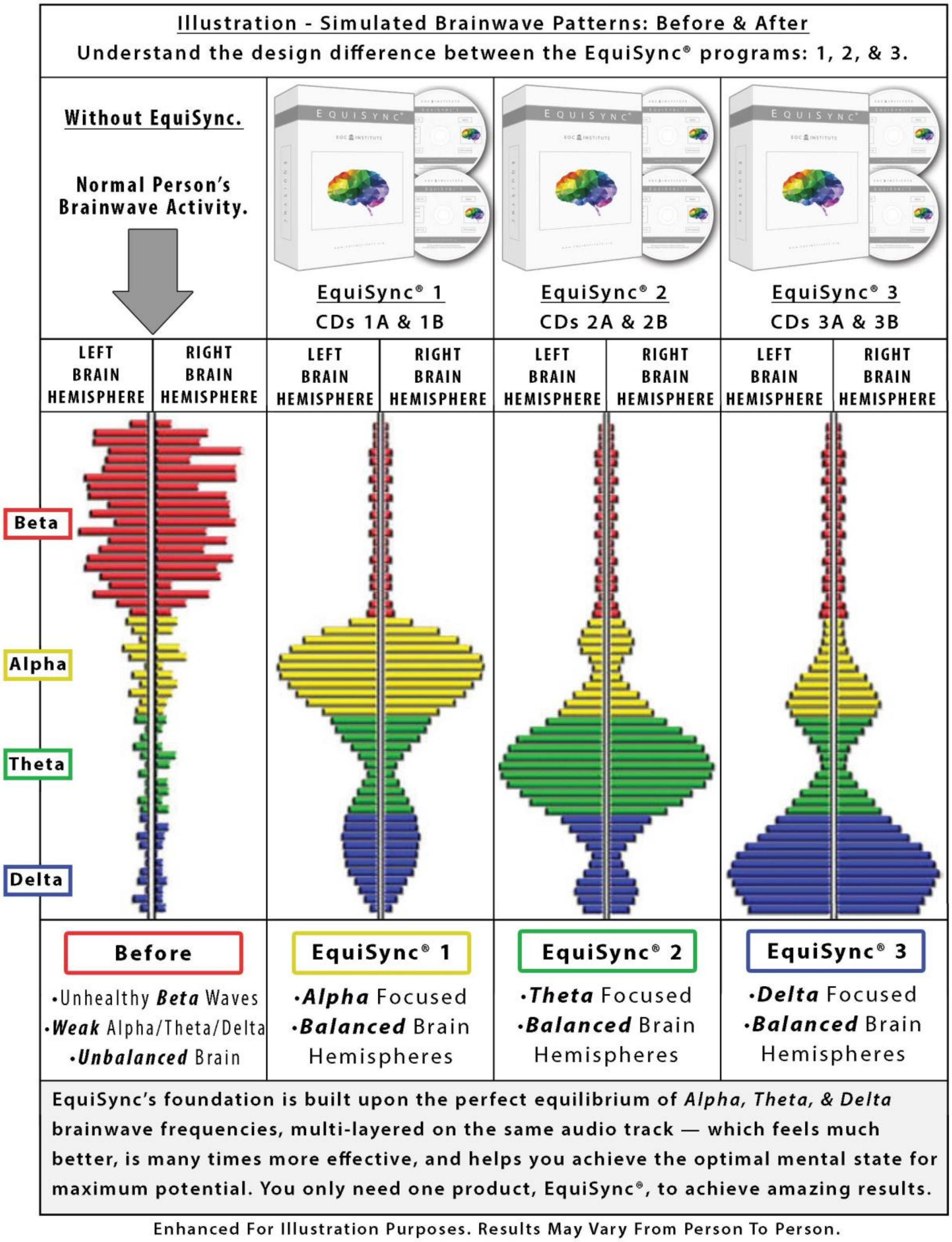
Your brain has nerve cells that fire electrical signals and oscillate in distinctive arrangements called brainwave patterns. These patterns are closely connected to your thoughts, emotions, moods, biological chemistry, everything you do, and really, everything you are. Because EquiSync sound technology guides you into different mind states (and various states of meditation) via brainwave entrainment, it is helpful to understand the different frequencies and how they contribute to your state of consciousness. Since most of us spend our days in the beta state, Equisync excludes the beta brainwave frequencies, and entrains only those responsible for the most beneficial brainwave states, physically and metaphysically: alpha, theta, and delta."

How Brainwave Entrainment With EquiSync® Can Transform Your Life [14]



This chart illustrates the potential benefits of each brainwave state. Results may vary from person to person.

Appendix 11 Brainwave Targeting - Understanding the Brainwave Benefits of Meditation



Appendix 12 Illustration - Simulated Brainwave Patterns: Before & After

Appendix 13 Free Demo Audio File

References for Appendix D

[1] http://neurosky.com/

[2] https://en.wikipedia.org/wiki/Brain%E2%80%93computer_interface

[3] *Takahashi, Dean.* "NeuroSky raises $11.8M for brainwave-controlled games (exclusive)". *VentureBeat.com. VentureBeat*. Retrieved 2010-07-31.

[4] "Brain Control Technology - A New Olympic Sport?". *EON.com. Enhanced Online News. 2010-02-23*. Retrieved 2010-07-31.

[5] "Uncle Milton and NeuroSky Announce Exclusive Partnership for Science Toys.". *Journal of Technology. 2009-07-28*. Retrieved 2010-07-31.

[6] *Li, Shan (2010-08-08).* "Mind reading is on the market". *LATimes.com (Los Angeles Times)*. Retrieved 2010-08-31

[7] https://en.wikipedia.org/wiki/Electroencephalography

[8] https://en.wikipedia.org/wiki/Electromyography

[9] *Eller, Evan (2007-12-13).* "NeuroSky ThinkGear Mind-Controlled Toys With Sega". *gamrFeed.com*. Retrieved 2010-08-31.

[10] *Monica, Sierra (2008-02-16).* "NeuroSky to Present Project Millennia". *Techpin.com. Tech Pin*. Retrieved 2010-07-31.

[11] https://en.wikipedia.org/wiki/NeuroSky(accessed 9/2/2016)

[12] http://eocinstitute.org/meditation/

[13] http://eocinstitute.org/meditation/Scientific_Studies_and_Research/?front-9-1-14

[14] http://eocinstitute.org/meditation/brainwave_charts_brainwave_patterns/?EQ

Beta Brainwaves: 13-40 Hz

The beta brainwave is the predominant frequency when we are **fully awake** and **alert**.

Active awareness directed to the outer world.

Beta brainwaves are present during **stress, paranoia, worry, fear, and anxiety**.

They are also present during **hunger, depression, irritability, and moodiness**.

Insomnia is the result of producing excessive beta brainwaves..

Associated with excessive **mental chatter** and self-destructive impulses.

Too much time in the beta state **weakens the immune system**.

Beta brainwaves make up much of our conscious mind.

Alpha Brainwave Entrainment Benefits: 7-13 Hz

The alpha state is where meditation and relaxation begins.

We start to encounter the wealth of effortless creativity flowing just beneath our conscious state.

Awake but deeply relaxed.

Studies have shown the alpha state has been associated with "**peak performance**." Elite athletes produce alpha brainwaves prior to concentrated performance (shooting a free throw, hitting an important golf shot). Amateur athletes produce more of the anxious beta brainwaves.

In the alpha state we learn, process, memorize and recollect **large sums of information** fast and with peak effectiveness.

Highly creative people have been shown to have "**bursts" of alpha brainwaves** when they have good ideas

Alpha brainwaves are thought to make the brain "act young" again.

In the alpha state fears, habits, and **phobias** begin to **melt away**.

Alpha brainwaves bring an effortless sense of **comfort, peace, and harmony**.

Best for "super learning".

The alpha state is the first layer of our subconscious mind.

A gateway to deeper states of awareness.

Theta Brainwave Entrainment Benefits: 4-7 Hz

Theta brainwaves become prominent when we go deeper into meditation and relaxation - "almost trance-like".

Here, brain activity decelerates to the **threshold of the sleep stage**.

One of the more **indescribable** and **wonderful realms we can explore**.

The theta state produces flashes of creative visualization through vivid imagery.

In this state we feel much **more open** and **connected to other people.**

People often report a feeling of **floating** while producing theta brainwaves.

Theta brainwaves are thought to bring out a person's dormant extrasensory perception (ESP) skills.

The theta state **heightens problem-solving skills**.

Having dominant theta brainwaves are correlated with **insight and intuition**.

Theta brainwaves bring **inspired thought and increased motivation**.

Sometimes long-forgotten memories come to the surface.

Children have strong theta brainwaves, which helps to explain their **superior ability** to learn.

Theta is briefly experienced as we climb out of the depths of delta upon waking, or when falling asleep.

The theta state is the deeper sub-conscious to super- conscious part of the mind.

Delta Brainwave Entrainment Benefits: 0-4 Hz

The deepest level of meditation.

The delta state is associated with "no thinking" during **deep, dreamless sleep**.

Delta brainwaves are **very rewarding**.

Delta is said to be the entrance to **non-physical states of reality.**

A crucial state for renewal, healing, and rejuvenation.

The **immune system strengthens** in the delta state.

The delta state is the unconscious/super-conscious part of our mind.

Many scientists believe this state to be the most beneficial.

Collection and Information for proposed Brainwave Entrainment with Auditory Stimuli

The Brain Garage

http://thebraingarage.com/beta-brain-wave-music-mp3-library/

http://thebraingarage.com/alpha-brain-wave-music-mp3-library/

http://thebraingarage.com/theta-brain-wave-music-mp3-library/

The Monroe Institute

https://www.youtube.com/watch?v=87kBTrJbMB4

https://www.monroeinstitute.org/

http://en.wikipedia.org/wiki/The_Monroe_Institute https://www.monroeinstitute.org/catalog/audio-downloads

http://www.last.fm/music/The+Monroe+Institute

http://www.hemi-sync.com/

EquiSync

http://eocinstitute.org/meditation/scientific_studies_and_research/?front-9-1-14

http://eocinstitute.org/meditation/brainwave_charts_brainwave_patterns/?8-2-14

http://eocinstitute.org/meditation/signup/

Beta Frequencies

- Binaural Beats

https://www.youtube.com/watch?v=87kBTrJbMB4

- Binaural Isochronic Tone

https://www.youtube.com/watch?v=S5UyebpFcV0

- Alpha Brain Waves

http://www.brainwavesblog.com/tag/super-learning/

Apendix E - "The Influence of Colour on Memory Performance: A Review"

Mariam Adawiah Dzulkifli and Muhammad Faiz Mustafar [44]

Malays J Med Sci. 2013 Mar; 20(2): 3–9. PMCID: PMC3743993

Abstract

Human cognition involves many mental processes that are highly interrelated, such as perception, attention, memory, and thinking. An important and core cognitive process is memory, which is commonly associated with the storing and remembering of environmental information. An interesting issue in memory research is on ways to enhance memory performance, and thus, remembering of information. Can colour result in improved memory abilities? The present paper highlights the relationship between colours, attention, and memory performance. The significance of colour in different settings is presented first, followed by a description on the nature of human memory. The role of attention and emotional arousal on memory performance is discussed next. The review of several studies on colours and memory are meant to explain some empirical works done in the area and related issues that arise from such studies.

Keywords: *attention*, *colour*, *long term*, *mental recall*, *short term*

Introduction

Memory refers to the mental process of encoding, retaining, and retrieving environmental information (1). How the human cognitive system deals with the memorization process remains the centre of research among cognitive psychologists. One of the most interesting and challenging questions in contemporary memory research is on ways to enhance human memory performance. Many variables have been proposed to contribute to the retrieval operations and one of the variables is colour, which will be discussed thoroughly in the present paper.

Colour is believed to be the most important visual experience to human beings (2). It functions as a powerful information channel to the human cognitive system and has been found to play a significant role in enhancing memory performance (3). Colour can be very effective in learning and educational setting, marketing, communication, or even sport. For instance, a marketing study has found that colour can increase brand recognition by up to 80% (4). Most advertisements use colour as one of the important element in influencing people's attention, attitude towards the product, and pressuring decision making (5). According to White (6), coloured advertisements can attract people to read the advertisement up to 42% more often than the non-coloured advertisement. This shows the importance of colour in making the information or message more attractive to the public.

In the educational setting, higher demand is put on excellent academic achievement. The extent to which students utilize their cognitive abilities is also important and may contribute to better academic achievement (7). The cognitive abilities of the students refer to the way the students perceive, pay attention, remember, think, and understand the lessons. There need to be strategies to facilitate the learning process and colours can play a role in motivating students to learn and profit from their educational experiences. [42]

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A plethora of studies have been conducted to understand the role of colour in enhancing memory performance. Back in 1976, Farley and Grant conducted experiments on the influence of colour on attention and found that coloured multimedia presentations resulted in better attention and memory performance (13). More experimental works exploring the influence of colour on the human cognitive processes were conducted since then (14–16).

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