Brain Computer Interface : A Review

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***Abstract*—Many years ago there was a revolutionary question that illuminated the path for advancement of brain science, i.e., "Can the brain understand the brain? Can it understand the mind?"[1]. From that simple question to the present technological scenario numerous neurobiologists, psychologists and physiologists have come a long way. In this report we discuss the discernments from such pioneers in the brain science field and how it enabled the integration of our brain with the computer and bringing about the innovative brain-computer interface, and the results which come along with such technological in the field of rehabilitation and therapy.**

Keywords—Brain-Computer Interface; Rehabilitation; Theraphy; Brain Science

I. INTRODUCTION

Before the advancement of brain science there was a great debate between two sects of people the Cephalo-centric (who believed that the brain was the origin of all major and minor effects in our body) and the Cardio-Centric (who believed that the heart caused all the changes pertaining to the body. Cephalo-centric were led by 'Hippocrates' said as such regarding the brain "Men ought to know that from the brain and the brain only, arise our pleasure, joy, laughter and jests, as well as our sorrow, pains, grief and tears. Through it in particular, we think, see and hear, and distinguish the ugly from the beautiful, the bad from the good, and the pleasant from the unpleasant."[2][1]

And the Cardio-centric who was led by Aristotle opposed it by saying, "Thoughts, sensations, and behavior originated in heart, and that the brain was there to make the heart and boiling in the heart well blent and tempered."[3][1]

We aim to bypass the nervous system to expand our consciousness into the surrounding environment, and an alternative communication system for the disabled. But nowadays we are able to produce different senses to the human body.

The current age of information, integrated technology with biological systems is what may be seen as a natural progression and obtaining a 'silicon nervous system' [1] is what may be seen as a natural evolution.

A. Motive

It was initially driven by the motivation to develop communication devices for the disabled mainly physical (where motor output was nearly zero). And the progress in the Brain computer interface has led to successfully implement a device to assist people with Amyotrophic Lateral Sclerosis (which is a degradation of motor neurons and leading to paralysis) and device for people with 'Locked-in syndrome' to express themselves. And making these devices more efficient and user friendly is what drives people in this field.

II. WHAT ARE BRAINWAVES?

"The brain is a tissue. It is a complicated, intricately woven tissue, like nothing else we know of in the universe, but it is composed of cells, as any tissue is. They are, to be sure, highly specialized cells, but they function according to the laws that govern any other cells. Their Electrical and chemical signals can be detected, recorded and interpreted and their chemicals can be identified; the connections that constitute the brain's woven framework can be mapped. In short, the brain can be studied, just as the kidney can."[4]

The Brain exhibits electric activity that is studied by a device called 'electroencephalograph (EEG)' which was invented by 'Hans Berger', these signals that the EEG machine measures are called the brainwaves. There are five types of brain signal each depicting a special function of the brain:[5]. *Fig. 1* shows the various brain waves.

1. Gamma Waves (38-42 Hz) - Insight, Expanded consciousness.
2. Beta Waves (13-22 Hz) - Concentration and Learning.
3. Alpha Waves (8-12 Hz) - Relaxation and Reflection.
4. Theta Waves (5-7 Hz) - Dreaming and Flow state.
5. Delta Waves (1-4 Hz) - Deep Healing sleep.

Figure 1: Brainwaves during EEG

The EEG signal that is received from the brain (over the scalp) has two power interfaces analysis:

1. ERD (Event Related De-synchronization) - It pertains to the decrease in the power of the signal related to the EEG output to the event.
2. ERS (Event Related Synchronization) - It pertains to the increase. in the power of the signal related to the EEG output due to the event.

We majorly utilize 'time related characteristics or the frequency related characteristics to process the EEG signals'[1]. EEG signals are the base on which the whole brain computer interface and with different approaches we can presume different uses.

The most commonly used signal of the EEG to study the brain and provide reliable communication is the 'Visual Evoked Potential' that are conditional on basic neural pathways and only particular stimulus evoke particular electric signal.

The various experiments that enable us to study these 'VEPs' are[6]:

1. Oddball Paradigm
1.1. Standard Oddball Paradigm
1.2. Spatially Varying Paradigm

2. Rapid Serial Visual Paradigm (Fig 2 shows the experimentation based on RSVP.)

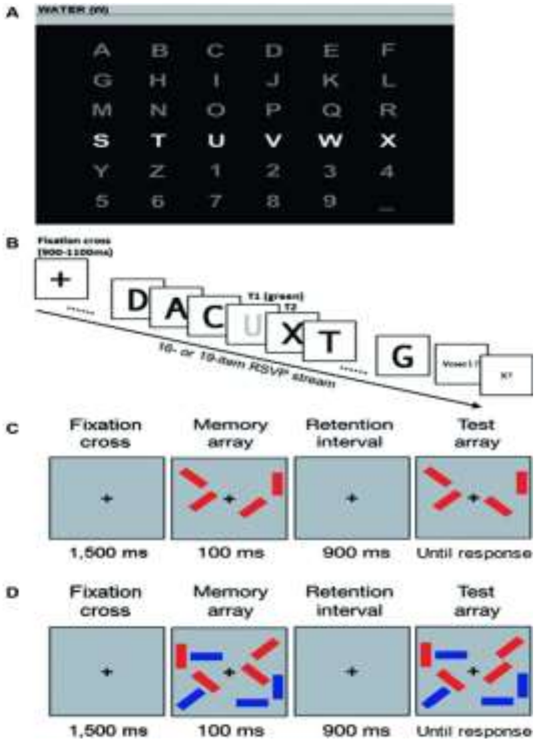

Figure 2: Rapid Serial Visual Paradigm

But VEP signals have various drawbacks, i.e., the subject undergoing the experiment is not allowed to change his gaze direction which will cause the experiment to fail, and the communication rates and accuracy are major issues[1], And the signal delivered are very complex.

Neil Birbaumer at the University of Tubigen in Germany has successfully built a 'Mind Reader' that is able to detect the brainwaves of the patient suffering from ALS (Amyotrophic Lateral Sclerosis) to express themselves by forming words for them to communicate.[7]

III. Invasive Methods

Brain Computer interface constitutes various ways in which brain signals can be obtained and there are can significantly classified into three. Fig 3 shows the classification of Brain computer Interface:

1. Non Invasive BCI
2. Invasive BCI
3. Partially Invasive BCI (Not significant, as research is still in progress to make it more efficient.)

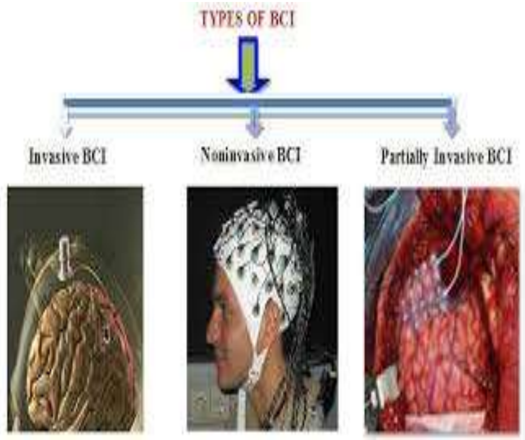

Figure 3: Types of Brain Computer Interface

EEG signals that are obtained from over the skull are very complex and are nearly attenuated due to the thick skull. So to avoid such inefficient forms of communication with the brain we use invasive technology.

A team based in Atlanta and led by Philip Kennedy, CEO of Neural Signal Inc., [9] developed new implant technology that was implanted into the somatic cortico motor cortex of the brain. [9] The implanted cone like electrode intercepted the signal whenever the neuron fired leading to an event related peak.

It provides more reliable and accurate signals of the brain. The trophic factor of the neuron helps the embedded electrode to stay connected with the neuron. These implants were used to control the cursor of a computer with great precision. Further a monkey's brain was implanted with nearly hundred electrodes to control a robotic arm at the other end of the room using Internet of Things technology by Duke University Medical Center, MIT, and the State University of New York Health Science Center.[9]

In future it might even be possible to connect number of electrodes to various parts of the brain that would allow precise movement of prosthetic limbs and possibly restore muscle movement to disabled and paralyzed patient.

IV. NEUROSTIMULATION BY COMPUTER

"If we can detect electric signals from the brain and understand them, might it also be possible to input appropriate artificially produced signals to the brain?"[1]

Eduard Hitzig, a German military doctor conducted experiments on deceased soldiers by passing electric current to the motor cortex of the brain and observed rapid movement of the eye, he then crudely controlled the movement of dogs. Later Wilder Penfield US neurosurgeon mapped the motor cortex of the brain and by sending controlled electric current observed movement in the human body. And also while undergoing the treatment the patients on excitation could briefly regain memories long forgotten, which was due to the temporal lobe activity which is caused by the electric current.

These conclusions led to the active treatment of Epilepsy by a device called 'Pacemaker for the Brain'[10] which sends appropriate signals to the neuron which is abnormally (involuntarily) fired. This pacemaker was successfully able to prevent seizure in the brain. It was used to send nullifying signals to the vagus nerve.

State University of New York,[11] was able to successfully hijack the brain of the rat by implanting three electrodes, two in the somatosensory cortex and one in the medial forebrain bundle. This allowed them to control the directional and vectored motion of the rat. These rats were used for the purpose of surveillance in places inaccessible to humans.

University of California [12] was able to restore vision to the blind by connecting a computer to the brain which received signals from the spectacle which consisted of various sensors. The input to the brain from the computer was connected to the 'Thalamus' with one in each hemisphere. The implants were sixty-eight platinum electrodes on the surface of the visual cortex.[1]

V. MAGNETIC EFFECTS

Jacques-Arse`ne D'Arsonval[13] showed that when the human body was exposed to time varying magnetic fields the subject saw flashes of light. This was concluded to be due to the magnetic excitation on the human nervous system. This led to the present extensively used TMS (Trans-cranial Magnetic Stimulation).[1]

These technologies enable the examination of the excitations in the cortex and observe the pathways. It was also efficient in detecting the hidden effects of drugs (both pharmaceutical and non-pharmaceutical) and alcohol. While the treatment (or) examination was being conducted we could observe that the subject could temporarily experience bliss, i.e., due to the 'prefrontal cortex' excitation. Fig 4 shows a MRI machine that utilizes magnetic field to study brain activity.

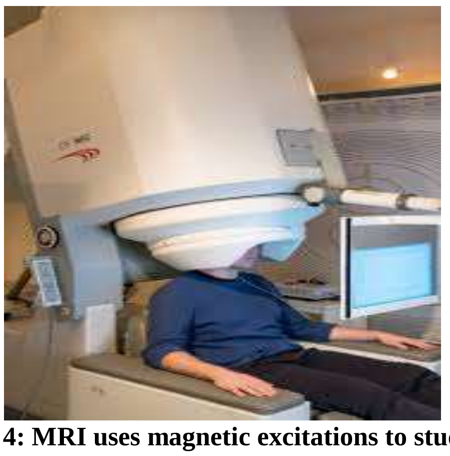
Figure 4: MRI uses magnetic excitations to study brain activity.

VI. Future Of Brain Computer Interface

The researchers believe that humans and computers will be integrated (become one), and certainly the technology is in the near future. There are rising questions regarding the ethics of ‘Brain-Computer interface’, “Where does one draw the line as to what is superfluous? In the future might insert electronic implants for new and different senses become as common as plastic surgery is now?”[1]

Kevin Warwick Professor of Cybernetics at University of Reading claims himself as the first human cyborg. He believes that human enhancement is possible through BCI, and this is the only way forward for humans to evolve.[1]

Some people like Stephan Hawking believed that, “If humans don’t watch out, computers will take over the earth.”[13]. But some debate it by saying, “However it is humans who create and program the computers and give its learning ability and we can also control their learning.”[1]. So Brain computer communication can perhaps deliver the best of the two worlds: learning is a two way process, and adaptability must come from both sides of the interface [1].

Hippocrates wrote: “I hold the brain is the most powerful organ of the human body….eyes, ears, tongue, hands and feet act in accordance the discernment of the brain.”[2]

So, the integration of such an organ to the greatest invention made by humans, may lead to breaking the shackles imposed by our body and perhaps be viewed as one step towards human evolution.

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