BCI based games and Psychiatric disorders

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Abstract

As modern computers technology developed to understand human brain signals, it's great to use a computer system as an output of brain signals. This developed technology is brain-computer interface (BCI).A brain-computer interface, sometimes called a brain-machine interface or a direct neural interface, is a hardware and software communications system that allows disabled people a direct communication pathway between a brain and an external device system rather than the normal output through muscles. After experimentation, three types of BCI have been developed which are Invasive BCIs, semi-invasive BCIs, and Non-invasive BCIs that differ in their implementation place of the brain. BCI is used in different applications such as gaming applications that provide these disabled people with entertainment depending on their brain signals as well as its use in the medical field and the bioengineering one. In addition, its usage as neurofeedback therapy contributing to the treatment of psychiatric conditions such as ADHD and anxiety.

I. Introduction

Attention deficit hyperactivity disorder (ADHD) is a neurobiological disorder, characterized by symptoms of inattention, overactivity, and impulsivity [2]. ADHD is estimated to affect 5 % of children worldwide [5]. While many Psychiatric disorders like ADHD have no cure, advancement in gaming technologies in particular, has had a long-lasting effect in treating patients with these symptoms [5]. The idea of incorporating gameplay as a new treatment has shown great promise for patients with psychiatric and cognitive disorders.

Brain-computer interfaces (BCIs) have been integrated in digital games since the beginning of BCI development [6]. Researchers have been exploring the potential of gameplay elements as a means of enhancing cognitive functions. By providing the patients with an entertaining environment, researchers hope to create more efficient therapy for patients with psychiatric disorders, BCI game therapy [5]. Recently, BCI games have become increasingly popular among many BCI research studies, with a large increase in the number of studies within the last decade (Fig. 1) [6].

BCIs enable users to interact with a device through brain activity only, this activity is measured and processed by the system's several hardware technologies, among which Electro Encephalo Graphy (EEG), Magneto Encephalo Graphy (MEG) functional Magnetic Resonance Imaging (fMRI), functional Near InfraRed Spectroscopy (fNIRS), Electro Cortico Graphy (ECoG) and Subcortical Electrode Arrays (SEA) have all been used for BCI research [3]. Integrating these technologies into a gaming environment will allow doctors to measure brain activity and neural signals during therapy.

BCI games have become progressively more advanced in recent years, and have come to include 3-D environments, multiple user objectives, and hybrid control systems combining both conventional input devices and BCI systems [6]. These advancements have opened the possibility to test multiple paradigms during therapy. Neurofeedback (NF) therapy (T), In particular uses BCI to enhance attention and other cognitive abilities. The most commonly employed NFT is based on surface EEG, as it is cost effective, practical, and transportable [3]. EEG-NFT (fig. 2) involves measuring neural signals and guiding patients towards improved neural function: patients observe a suitable graphical representation of their actual brain activity, usually processed through a computer, and learn to self-regulate this activity in order to bring it to a desired state. Tasks involved in NFT are repetitive and standardized. When the task is finished, the system responds to the patient indicating they have reached

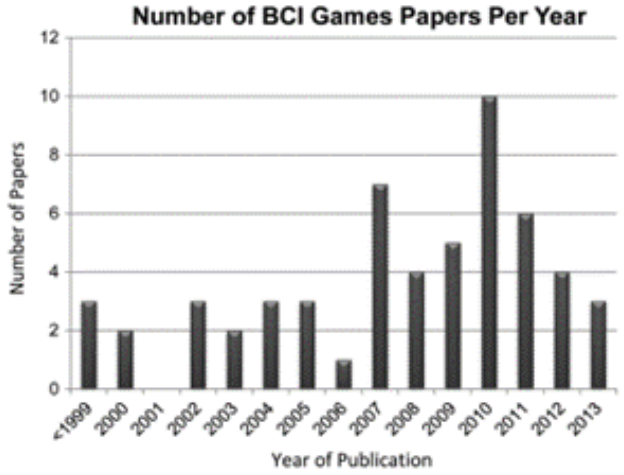

Figure 1: Number of BCI Games Papers Per Year.

the required brainwave pattern. Several conditions including attention deficit hyperactivity disorder (ADHD), anxiety, epilepsy, and addictive disorders have been treated using EEG-NFT, which shows the ability of BCI to treat both neurological and psychological disorders [3].

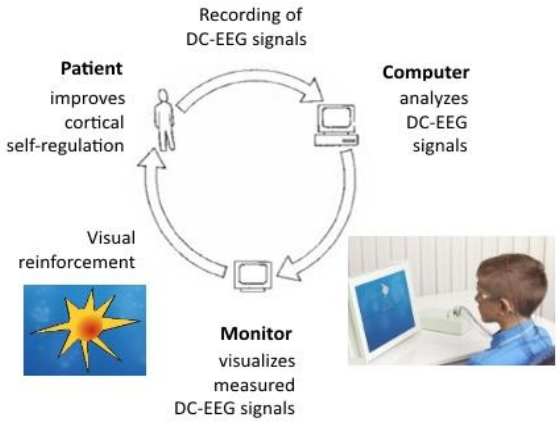

Figure 2: Recording EEG signals

II. An overview of BCI

As modern technology advances and our understanding of the human brain deepens, we are getting closer to making some of science fiction's marvels a reality.

Imagine having a real device that sends signals directly to the brain to make a person see, or feel something as soon as the person thinks about implementing this command.

The development of a brain-computer interface (BCI) may be the most important invention that has occurred in decades for people with severe disabilities.

The "BCI" is called a brain-machine interface or a direct neural interface. It works by transforming thought into reality without requiring any physical effort. It is a communication or association pathway between the human brain and an external device.

BCIs had been the recent development of HCI, but still, many realms have to be explored. Following extensive testing, three types of BCIs were developed: invasive BCIs, partial-invasive BCIs, and non-invasive BCIs.

Furthermore, BCIs have been used in a variety of extremely useful applications.

For example, it has been used in bioengineering applications, where brain-computer interfaces have the potential to allow patients with severe neurological disabilities to interact and communicate with society again, supporting them to break free from isolation as well as move around and enjoy the scenic views.

It also enabled quadriplegics or disabled people to play computer games without exerting any effort; all they had to do was think, and the BCI translated their thoughts into actions in the game [8].

Moreover, It used other fields like human subject monitoring, neuroscience research, man-machine interaction, military applications, and counterterrorism [9].

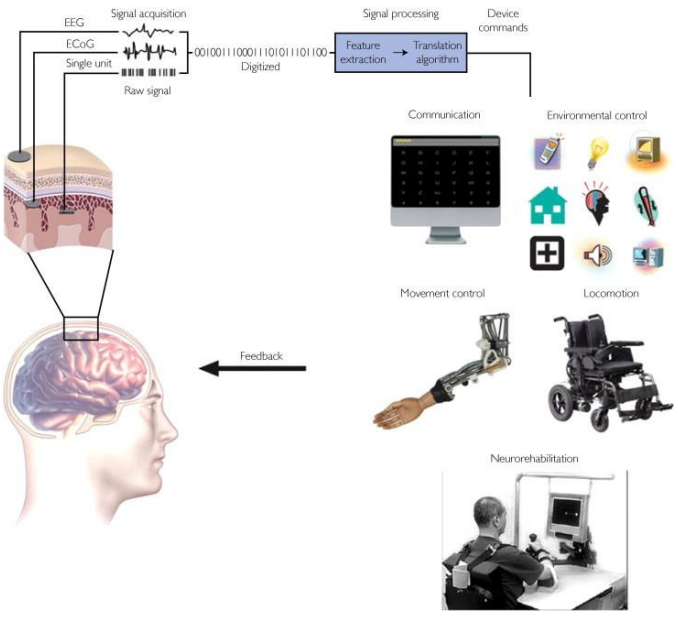

Figure 3: BCI loop and applications in different fields.

III. Loop and components

BCI is comprised of five elements that form a closed loop on its framework, as shown in Figure (4).

These are “Control paradigm”, “Measurement”, “Processing”, “Prediction”, and “Application” [10].

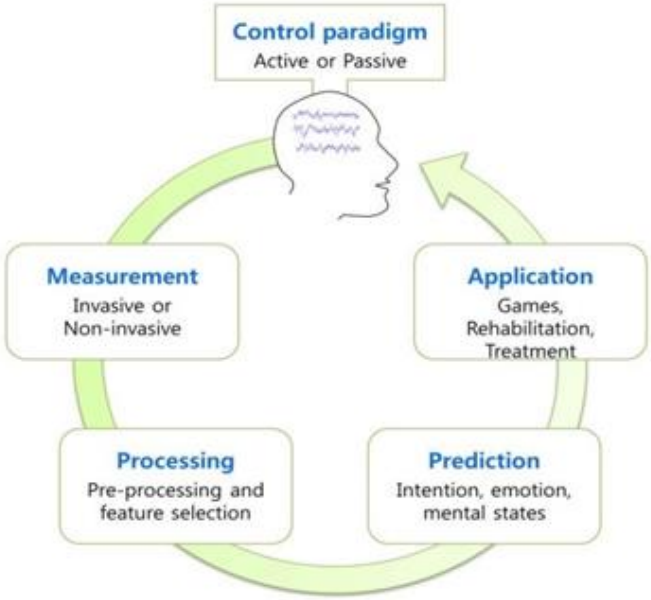

Figure 4: the closed loop of BCI.

The BCI interprets a user's intention or mental state using these five steps and uses the information to run the application. This closed loop between the user and the application is repeated until the system is terminated, with the four modules forming an interface between them.

The following are the specifics of the BCI elements:

Control paradigm:

At this stage, the user can transfer data to the system by pressing a button with the appropriate function, or by moving the mouse in traditional interfaces. However, BCI necessitates the development of a "control model" for which the user can be held accountable. For example, the user may imagine moving a part of the body or focusing on a specific object to generate brain signals that include the user's intent.

Some BCI systems may not require intended user efforts; instead, the system detects the user's mental or emotional states automatically. They are classified as active, reactive, or passive approaches in terms of interaction.

Measurement:

Brain signals can be measured in two ways: invasively and non-invasively. Invasive methods, such as electrocorticogram (ECoG), single micro-electrode (ME), or micro-electrode arrays (MEA), detect signals on or inside the brain, ensuring relatively good signal quality.

However, these procedures necessitate surgery and carry numerous risks; thus, invasive methods are clearly not appropriate for healthy people. As a result, significant BCI research has been conducted using non-invasive methods such as EEG, magnetoencephalography (MEG), functional magnetic resonance imaging (fMRI), and Near-Infrared Spectroscopy (NIRS), among others. EEG is the most widely used of these techniques.

EEG is inexpensive and portable when compared to other measuring devices; additionally, wireless EEG devices are now available on the market at reasonable prices. As a result, EEG is the most preferred and promising measurement method for use in BCI games.

Processing:

The measured brain signals are processed to maximize the signal-to-noise ratio and select target features. Various algorithms, such as spectral and spatial filtering, are used in this step to reduce artifacts and extract informative features. The target features that have been chosen are used as inputs for classification or regression modules.

Prediction:

This step makes a decision about the user's intention or quantifies the user's emotional and mental states. Classifiers such as threshold, linear discriminant analysis, support vector machine, and artificial neural network are commonly used for prediction.

Application:

After determining the user's intent in the prediction step, the output is used to change the application environment, such as games, rehabilitation, or treatment regimens for attention deficit hyperactivity disorder. Finally, the user is given the predicted change in the application as a response.

IV. BCI Applications

There are numerous applications that use Brain-Computer Interface (BCI). Bioengineering, human subject monitoring, neuroscience research, man-machine interaction, military, gaming, and counter-terrorism applications are a few examples. We'll go over a quick rundown of some of these applications.

i. Bioengineering

Brain-computer interfaces have the potential to enable patients with severe neurological disabilities to re-enter society through communication and prosthetic devices that control the environment as well as the ability to move within that environment as shown in figure (5) [11].

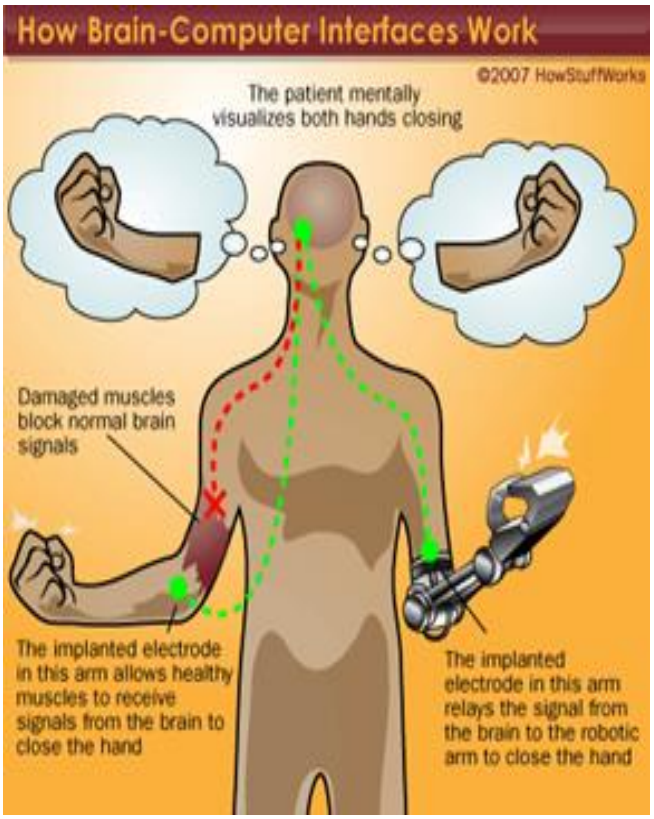

Figure 5: example of Bioengineering applications.

ii. Gaming

In that hectic life, the most important interest is work and maybe family which increases boredom. So,

what thoughts about disabled people without even work or entertainment?

Some researchers have focused recently on the application of BCI to games for use by healthy people. Studies have demonstrated examples of BCI applications in such well-known games like "Pacman" , "Tetris", and "World of Warcraft", as well as new customized games, such as "MindBalance" , "Bacteria Hunt" , and others [10].

Disabled people through amputated limbs or even paralysis live most of their life in a boredom feeling; so many research are done to provide them with entertainment factors through BCI sensors that enable a direct control between brain signals and an external device as computer or robot. Hence the use of BCI in gaming began.

Gaming BCI is a very interesting development of BCI usage where it allowed these people to get entertained through games depending on their brain signals without such a big effort. In addition, the gaming section increases from user ability to acquire new skills of controlling BCI through the entertainment engagement and the extra communication modalities through the interesting compete play also through gaming enthusiasm that allows getting from level to a higher one to get more ranking in the completion through more and more efforts and attempts. So, that increases people's ability to control and become more adaptable to BCI systems, and then the accuracy of the resulted signals increases [12].

Besides the general gaming benefits in stress relieving, brain function improvement, and the energetic (fresh feeling).

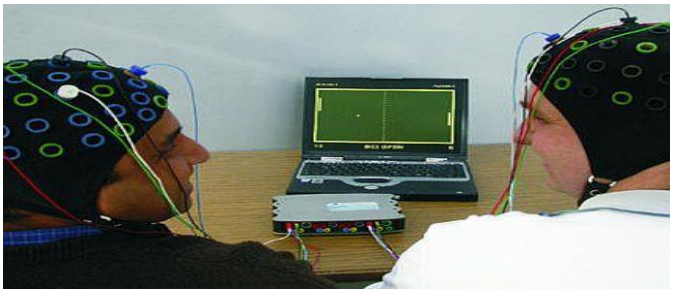

Figure 6: People playing Ping Pong Using BCI

iii. Medical

The spectrum use of BCI for control is very wide and includes different applications such as neural prostheses, wheelchairs, home environments, humanoid robots and much more. Another exciting clinical application of BCIs focuses on facilitating the recovery of motor function after a stroke or spinal cord injury.

iv. Neuroscience research

Neuro-technology and Neurosciences have been continuously advancing, as a result society, individuals, and healthcare professors had to deal with this advancement, BCI seems to be an emerging technology in Neurosciences. Also it is known that BCI technology is providing such a direct relation between our brains and the external devices by passing the neuromuscular pathways [13].

This amazing technology had a great impact in making a disabled person communicate with his/her environment [14].

BCI has changed the way provided by Professors to the neurosurgical services it also helped to achieve the neurosciences laboratory advances [15].

One of the main challenges facing neuroscientists is to understand how our brains networks work together. One method was actually used was to deliver brief pulses of an electrical current inside a patient's brain and at the same time, the resulting voltage in the other regions of the brain is measured and monitored.

Recently, a new sub-field of Neuroscience has been matured as an effect of BCI, It was mainly around the systematic measurement and stimulation through the implanted arrays of our brain surfaces, deeply-penetrating electrodes which are typically called "Coritco-Cortical Evoked Potentials" (CCEPs), and in special cases the short pulses that happen regularly after each other by several seconds only, "Single Pulse Electrical Stimulation" (SPES) [16].

However, this new field generated a great complex, time-intensive, and difficult to measure tasks for

humans, but a well-suited tasks for AI machines, So the researchers created a new type of AI algorithm for this purpose.

V. Psychiatric disorders

Mental illness or psychiatric disorders are mainly a wide range of health conditions or neurological disorders that can affect your mood, thinking, and even your behavior. It doesn't mean that people having mental health concerns from time to time have a mental disorder, but a mental health concern is said to be a mental disorder in case of ongoing symptoms that affect the person's ability to function. A variety of environmental and genetic factors are the main cause of Psychiatric disorders, this includes:

i. The brain chemistry

This happens when the neural networks involving the brain chemicals (that carry signals to different parts of the body and brain) are impaired, the function of nerve systems and receptors changes causing depression and other mental issues.

ii. Inherited traits

Many genes are capable of increasing the risk of developing mental disorders.

iii. Environmental exposures before birth

Exposure to some conditions, toxins, drugs, or Alcohol can sometimes be linked to Psychiatric disorders. Examples of Psychiatric disorders include ADHD, Autism, addictive behaviors, eating disorders, schizophrenia, anxiety disorders, and depression.

All these examples of Psychiatric disorders cause many common symptoms including feelings of guilt, fear, and worry, confused thinking, inability to concentrate, continuous feeling down and ongoing sadness, extreme tiredness, inability to handle stress, drug, and alcohol-abusing, excessive violence, in addition to trouble understanding of some situations and people.

A psychiatric disorder can also lead to many physical symptoms including stomach pain, headache, and back pain.

Due to all of these symptoms, a treatment way must be followed, the treatment way mainly depends on the symptoms the person have, ways of treatment include:

i. Medication

Although medications don't cure, they just improve symptoms

ii. Psychotherapy

Also, they are called talk therapy, involves talking with a therapist about mental issues and conditions. Psychotherapy in most cases is completed successfully in just a few months, but in many cases, life-long treatment is needed.

iii. Brain-stimulation treatments

They are usually used for treating depression, they include electroconvulsive therapy, vague nerve stimulation, repetitive transracial, deep brain stimulation, and magnetic stimulation.

As we are currently at the age of technology, scientists invented a new way to treat Psychiatric disorders using Brain-Computer Interface (BCI).

BCI has been used in the treatment of attention deficit hyperactivity disorder (ADHD) which is a neurological condition that causes many symptoms including hyperactivity, impulsivity, loss of attention, and cognitive task difficulty. It also can be responsible for the negative academic skills and semiprofessional outcomes. Scientists have found that the interactive multi-player games are the same as a therapeutic and long-term usage due to the

higher social motivation and cooperation among children with ADHD [17].

VI. ADHD treatment using BCI based games

To treat ADHD using BCI based games, an experiment was conducted in 2015 to study a BCI system that mainly uses steady state potentials, such that their main target is to improve the attention levels of people suffering from ADHD [18].

This system was in the form of a game composed of two sub-rooms, the first one is a 3D classroom including 2D games on the blackboard. This game's main purpose is to measure patients' attention levels by changing the game environment from the 2D classroom to the 3D one.

Results have shown that when the game environment changes from the 2D environment to the 3D one, in addition to adding some distractions to the screen, patients' attention levels drop and they get distracted. Also, Results have shown that when attention levels advances, accuracy levels decrease during playing, and time taken to pass a level increases [19].

So, the higher the level of the game, the harder and more difficult it becomes to concentrate.

More recently, a new game was held named FOCUS, its main purpose is to detect and determine the focus & attention of patients suffering from ADHD. The game utilizes the EEG BCI device in order for the player or the patient to control the game's avatar movement by concentrating, by this way the attention level of patients with ADHD is amplified and thus ADHD is treated [20].

VII. BCI game therapy

Neurofeedback or electroencephalography (EEG) according to its medical term is a kind of biofeedback, process to learn how to change physiological activity for the purposes of performance and improving health, that measures brain waves and body temperature in a non-invasive way where it changes and normalizes the speed of specific brain waves in specific brain areas to treat different psychiatric disturbances like ADHD and anxiety.

So, it teaches self-control of brain functions by measuring the brain waves then giving feedback represented in audio or video. The produced feedback depends on the susceptibility and desire for the brain activities where it's positive or negative of the brain activities are desirable or undesirable, respectively.

Neurofeedback is adjuvant therapy for psychiatric conditions such as attention deficit hyperactivity disorder (ADHD), Generalized anxiety disorder (GAD), and phobic disorder

The treatment starts by mapping out the brain through quantitative EEG to identify what areas of the brain are out of alignment. Then EEG sensors are placed on the targeted areas of your head where brain waves are recorded, amplified, and sent to a computer system to process the produced signals and give the proper feedback. Then that brain current state is compared to what it should be doing [21].

Given the fact that intrinsic motivation is found in gaming and that it provides positive influences on concentration and motivation, it's recommended to focus on gaming when creating neurofeedback training software. Imagine neurofeedback which is applied as a treatment is being perceived as fun and enjoyable action which is found in games. In this case a shift from 'treatment' to 'play' could be both desirable and achievable [22]. So, serious games proved their worth and have been found effective training tools in mental health care, for example, for improving cognitive abilities in older adults, improving cognitive functioning in patients with alcohol abuse, enhancing emotional regulation in individuals with eating disorders, band improving executive functioning in children with attention deficit hyperactivity disorder (ADHD) [23].

In addition, Games are developed to be appealing to psychiatric patients that increase their motivation for treatment through neurofeedback therapy. Furthermore, these games represent effective training tools in mental health care where they improve cognitive abilities in adults

VIII. Conclusion

The Neurofeedback (NFB) therapy technique provides the user with real-time feedback on brainwave activity. That activity is measured by sensors in the form of a video display and sound. Brain-Computer Interfaces (BCI) framework consists of five stages that form a closed loop.

BCI helps patients with neurological disabilities to re-communicate by prosthetic devices. BCI also provides disabled people through amputated organs with the entertainment they need; as they mostly feel bored. Gaming BCI allowed these people to get entertained through games that don't need effort, only brain signals.

Psychiatric disorders are mental health issues that can affect your mood and actions. A variety of things are capable of causing these disorders. Inherited traits & environmental exposures can be reasons for psychiatric disorders. Psychotherapy is one of the ways to get rid of mental health issues. In most cases, psychotherapy is completed successfully in a few months, but in many cases, a life-long treatment is needed.

Brain-stimulation treatment can be used to get rid of depression, but as it is the age of technology, BCI is now capable of getting rid of those disorders. Depression, substance abuse, anxiety, and mood instability; all these are disorders that NFB has shown effectiveness in. There is proof that supports the idea that NFB decreases seizures. Some proof also supports the effectiveness of NFB for ADHD.

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