A review of Brain Computer Interface: Applications and potential

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ABSTRACT
Brain-Computer Interface (BCI) is a popular branch of science that combines our knowledge of neuroscience and computer science, providing us with ways to interact with computers and other devices by thought.

BCI can be implemented to produce a wide range of applications from the medical/rehabilitation sectors to video games. This potential comes from the BCI's unique property of letting a mere thought without any extra physical inputs to control computers. However, like all technology there are obstacles to be overcome before it can be practically used to aid our lives.

In this review we will look into three popular areas of BCI for their obstacles and potential. In the first section we will look at the potential of implementing this technology into video games. In the second section we will look at how BCI can artificially restore some of the lost abilities of the severely disabled. In the third and final section we will look at how EEG-based emotion recognition could improve daily human-computer interactions with emotional data abstraction.

Author Keywords
Brain-Computer Interface (BCI), Electroencephalography (EEG), Electrocorticography (ECoG)

INTRODUCTION
Brain computer interaction is a field that has been around since the 1970s [1] when scientists wanted to harness and study the billions of electrical signals emitted by our brain's activity.

The most popular, affordable and available method of reading brain signals is using the non-invasive EEG. It requires electrodes to be attached to the scalp and works best when there are fewer obstacles between the brain and the sensors (for this reason researchers and developers to seek bald volunteers when testing with EEGs). To get higher resolution signals, one must use the invasive method of implanting electrodes directly into the grey matter of the brain. Such extreme measures require proper surgery, and are only undertaken when it is completely necessary to attach the electrodes on a specific patch of brain surface to read the exact type of signals.

Video Game Applications
One of the most sought-after areas of BCI is the use in video games. The video game industry and passionate gamers are always looking for ways to add more modalities to enhance the gaming experience. Such desire has led to the now popular Xbox Kinect (which detects the user's body movements), the Nintendo Wii and the PlayStation Move (which detect the orientation and aim of the controller held in the hands), and BCI with the use of EEGs is the new topic of discussion in this competitive and high-revenue market. However, as stated in Fabien Lotte's '*Brain-Computer Interfaces for 3D Games: Hype or Hope?*' [2] the nature of EEGs limit a significant amount of desirable functions the developers want.

Probably the first thing that comes up in our minds when we think about the uses of BCI in video games would be the ability to fully control the game, such as freely moving a character to interact with the environment, without the need of conventional hand-held controllers (see figure 1). This concept would provide the users with the most intuitive ways to interact with the game since their pure thought is being translated directly into commands instead of having to go through an extra physical, learnt method of using a controller. One would also imagine it to be more responsive and accurate than controllers, especially when needing to react quickly in the game. Sadly, the current BCI technology not only fail to provide fast and accurate feedback of the user's commands, but merely setting up the commands can be a cumbersome endeavor.

Figure 1. BCI based navigation in a virtual environment [2]

Firstly, the EEG detects the minute electric signals produced by the brain, but it is impossible to accurately read the thought which is generated by the billions of neurons, so rather than actually reading and interpreting what the user is thinking it reads patterns of brain activity in different parts of the brain and assigns those patterns to the command that is being calibrated. This already makes the game less intuitive that how we have imagined, for the user will have to recall, focus and hold that specific thought pattern until the computer recognizes it correctly. This method also requires the user to spend several minutes calibrating each and every command prior to their use [2].

One possible solution to reduce the inconvenience of pre-game-play calibration is by implementing clever ways to capture the user's brain signals. For example, instead of asking the player to think about "jump" for the jump command during the game, ask during the loading screens which all gamers must endure. During this loading phase (which can last from seconds to minutes) the user can calibrate one or even more commands and choose to continue on with the game after the calibration is complete.

Secondly, players will be frustrated with the lack of accuracy and quick response. Small movements or even blinking can pollute the readings and slow down the recognition process or even produce incorrect outcomes. On top of this, the players will need to recall the exact mental state they collaborated the commands with, which is an unrealistic request when the majority of games people enjoy today are fast paced and require multitasking.

The only pragmatic way BCI can add value to the recent fast-paced games is by observing the players' emotional status throughout a phase and adjust the behaviours of the game to that. A practical example would be to lower the difficulty of the game or provide hints if a player is experiencing too much frustration trying to complete the game.

Interactions for the disabled

Providing a method of physical and digital interaction for the severely disabled people is the most popular and researched area of BCI. This is because it is a technology that allows the completely paralyzed people to have control over the machines they otherwise cannot. The theories have already been tested [3][4],

However, researchers and doctors are compelled to use the invasive electrocorticography (ECoG)-based BCI system due to the lack of signal precision deliverable by non-invasive systems. Doctors have attached custom ECoG grids directly to brains in specific regions to capture the brain activity that corresponds to the actions patients are to perform [3]. Through these endeavours they have successfully and repeatedly equipped the participating patients with the ability to perform tasks like moving a cursor on a computer screen and freely commanding a robotic arm. Figure 2 shows one of the participants enjoying a sip of coffee which was brought close to her by the use of a robotic arm, which she moved using BCI. Such research has given hope to thousands of physically disabled people around the world.

When combined with other technologies such as the steady-state visual-evoked potential, which are natural response signals generated by the brain when visually stimulated at specific frequencies [8], it is possible for these patients to drive a vehicle [9].

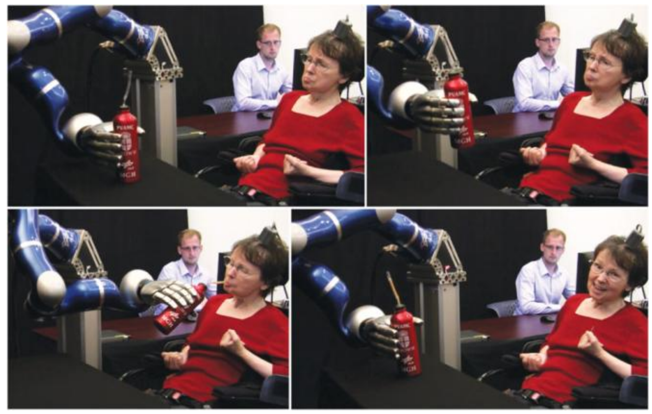

Figure 2. Participant with an ECoG device connected directly to her brain is drinking from a bottle using the DLR robotic arm. [4]

Emotion and emotional brain activity abstraction

Detecting brain signals to perform virtual or real actions is not the only use for BCI. Using EEG we are able to monitor and log the brain activity of the user when he or she performs specific tasks. This can be exceptionally useful when researchers want to study the mental effect of certain tasks, such as comparing the motor activity on spatial cognition when navigating inside a Virtual Reality (VR) [5]. In that specific study, researchers were able to monitor the how the brain recalls spatial knowledge when using different levels of virtual interfaces.

Similarly, video game or software developers can use the headsets to measure different emotions during game-play or user interface testing to examine and review their system. EEG is also capable of detecting our mood and emotional changes when calibrated, so it is possible to log the changes in our mood as we complete any given tasks [2][6]. With this, software developers will be able to accurately detect the flaws in their design, adding more certainty and value to their usability tests. This could also lead to live customization and adaptation of digital information presented [10].

Doctors could also use EEG to measure the stability of their patients when they are outside the hospital. The logged data about the changes in different sections of the patient's brain could be graphed, even in real time.

CONCLUSION

This review looked at the three useful areas of BCI. It looked at the advantages and disadvantages of the two major types of BCI systems available (EEG and ECoG) and their applications. From this it was clear that BCI is a technology that is definitely maturing to provide benefits for mankind, but continuous improvements must be made in order to reduce the costs and risks of usage and increase accessibility and accuracy. One can confidently predict that once the non-invasive methods catch up to the standards of the invasive methods, the use of BCI will thrive in all the previously mentioned areas; especially in the gaming industry.

FUTURE POTENTIAL

In the future we can expect to see EEG devices seamlessly being merged in our daily lives. They will evolve to become smaller, more affordable and more powerful (accurate) just like the mobile phone, and will contribute to our interaction with the digital devices by providing meaningful data like our mood, desires, thought-process and panic signals. Our digital environment will become more aware of our emotions, reacting and adjusting to suit our needs. It will find us the near-by restaurants when we think about hunger and food, play the music suited to our mood, and initiate emergency protocols when triggered by panic and sense of danger.

Video games will become more intelligent; adapting to the emotional feedback received from the user during the game-play. It can easily be implemented into role-playing games that log and measure the user's moral choices throughout the game (e.g. Fable, Mass Effect), recording the level of satisfaction or distress felt when making decisions. However, in order to see it being used has the primary modality of control, we must find a more effective way of measuring the brain signals without losing the accessibility of the technology.

One other area which may gain popularity once the EEG method becomes more refined is the controlling of robots in dangerous environments. For instance, once EEG becomes precise and responsive enough to provide perfect gaming controls it would be matured enough to apply on construction or military machines. Cranes could be operated from the ground when needed. Tanks and planes could become unmanned like the Predator drones, minimizing the risks of losing lives at war.

The power of ECoG allows us to open our minds to the possibility of achieving yet another science-fiction miracle; Cyborg (cybernetic organism) technology - the implantation of our brain into a robotic body. This concept of humans having robotic body parts to significantly aid our natural physical capabilities has only appeared in science-fiction, but the accuracy and speed ECoG can offer clearly indicates that we are one step closer to making it a reality. It would not be farfetched to say that one day we will be able to greatly increase our life expectancy by transplanting our brains into a more durable, mechanical body.

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