Brain-Computer Interface for Cyberpsychology: Components, Methods, and Applications

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ABSTRACT

As a new way of implementing human-computer interface, brain-computer interfaces (BCI) dramatically change the user experiences and have broad applications in cyber behavior research. This methodological review attempts to provide an overall picture of the BCI science and its role in cyberpsychology. After an introduction of BCI and the literature search methods used in this review, we offer an overview of terms, history, components, methods and signals used in BCI. Different applications of BCI on both the clinical population and the healthy population are summarized in detail, with a conclusion of the future directions of BCI.

Keywords: *Brain-Computer Interface, Cyber Behavior, Cyberpsychology, Human-Computer Interaction, User Experiences*

1. INTRODUCTION

A 49-year-old patient who has been paralyzed for more than a decade since 1993 because of a degenerative disease participated in studies of a German lab. He could only communicate with others by blinking his eyes until a device was introduced into his life. This spelling device, a BCI-based machine, was developed by Kübler and her colleagues (Birbaumer et al., 1999), which could even "speak" for the patient. The "magical" device worked as follows. First, it extracted the signals produced by patients when they were watching screen. The signals were later translated into commands by a machine with signal processing algorithms which take brain signals as input and deduce humans' intention. With the help of a protocol that determines the onset, offset, and timing of operation, the devices were controlled by brain signals. Thus the patient could drive a cursor on a video screen, select letters from the alphabet, or even steer his motorized wheelchair, to name just a few (Brownlee, 2005).

What we have described above is one of the thousands of the real stories, showing us an early use of brain-computer interfaces. This technology was applied to devices such as the wheelchair and the cursor mentioned above to link human beings' brains with outside world

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directly and to change the way we live. It brings opportunities for paralyzed people to live a more convenient life while for healthy people more joyous.

Since the discovery of electroencephalography (EEG) dating back to the year of 1924, numerous research papers have been published to advance the brain-computer interface (BCI) technology. There is also a considerable amount of reviews on BCI. For example, Wolpaw, McFarland, and Vaughan (2000) provided a comprehensive summary of the BCI technology prior to the first international meeting on BCI research and development; Lotte, Congedo, Lécuyer, Lamarche, and Arnaldi (2007) compared classification algorithms for EEG-based BCIs; Zander, Kothe, Jatzev, and Gaertner (2010) reviewed how to enhance HCI with input from BCIs, and. For the use of BCIs in the field of assistant technology (AT), please refer to a recent review by Moghimi, Kushki, Marie Guerguerian, and Chau (2013) for details. Please refer to Kaplan, Shishkin, Ganin, Basyul, and Zhigalov (2013) for a review of existing games and trends in this field. These reviews have effectively synthesized the existing literature and inspired a specific review focusing on what, how, and why BCI can be used for cyber behavior research, an important and emerged field of research. To meet this need, the present review intended to summarize research papers devoted to the application of BCIs in the field of cyber behaviors, such as e-learning, neuro-gaming, and neuro-surfing. We introduce the literature search methods. Then we provide the concept, history, components, methods, and signals used in BCI. Finally, we present different aspects of applications of BCI, including the use of BCI in the clinical and healthy population.

2. METHOD

2.1. Literature Search Strategies

To provide an overall picture of the application of Brain-Computer Interfaces (BCI) in the field of cyber behavior and learning, existing literatures were searched extensively from multiple bibliographic databases, namely Google Scholar, PubMed, Web of Knowledge, and ScienceDirect. Because BCI is also known as Brain-Machine Interface or Mind-Machine Interface, all of these aliases were covered in the keyword list. Moreover, we included names of some consumer BCI devices, e.g. NeruoSky and Emotiv, to explicitly search for ever-expanding applications using these low-cost systems. Cyber behavior involves research on how the use of new technologies affects human behavior, and in particular, the emerging computer-based activities such as e-learning, online social communication, and online games. In order to explore the applications of BCIs to various subfields of cyber behavior, we searched the databases by combining BCI with other related keywords, including e-learning, online gaming, online communication, etc.

2.2. Exclusion and Inclusion Criteria

Several inclusion/exclusion criteria were later applied to the search results in order to guarantee appropriateness. First, we included publications involving human BCIs, largely EEG-based non-invasive BCIs. While most of the BCI-related works were based on the electroencephalography (EEG), magnetic methods, e.g. functional magnetic resonance imaging (fMRI) and transcranial magnetic stimulation (TMS), also served as minor techniques for recording or manipulating human and animal brain signals. However, animal BCI research and articles dealing with invasive BCIs for human beings were excluded as they can hardly be applied to the field of cyber behavior.

Second, we especially included publications concerning Human-Computer Interaction (HCI). Cyber behavior encompasses all the emerging behaviors associated with new technologies, and it is mainly based on how users interact with new technologies (Brandtzæg, 2012). BCI systems capture brain activities as input flow, providing a new, direct way for human beings to interact with computers. BCI systems give users the ability to control comput-