Chapter 13
Cybersecurity Risks Associated With Brain-Computer Interface Classifications

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ABSTRACT

Brain-computer interfaces (BCIs) have experienced a considerable evolution in the last decade, expanding from clinical scenarios to sectors such as entertainment or video games. Nevertheless, this popularization makes them a target for cyberattacks like malware. Current literature lacks comprehensive works focusing on cybersecurity applied to BCIs and, mainly, publications performing a rigorous analysis of the risks and weaknesses that these interfaces present. If not studied properly, these potential vulnerabilities could dramatically impact users' data, service availability, and, most importantly, users' safety. Because of that, this work introduces an evaluation of the risk that each BCI classification already defined in the literature presents to raise awareness between the readers of this chapter about the potential threat that BCIs can generate in the next years if comprehensive measures, based on standard mechanisms, are not adopted. Moreover, it seeks to alert academic and industrial stakeholders about the impact these risks could have on future BCI hardware and software.

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INTRODUCTION

Application Scenarios

Brain-Computer Interfaces (BCIs) are bidirectional devices that allow communication between the brain and external systems, such as computers. On the one hand, BCI systems permit the acquisition of neuronal data, study the status of the brain, and control external devices such as wheelchairs or prosthetic devices (Lebedev et al., 2017). On the other hand, they are used for neurostimulation procedures to stimulate targeted regions of the brain (Edwards et al., 2017). These separate approaches can be unified under the concept of bidirectional BCIs, which can alternate recording and stimulation actions to verify that the stimulation actions have the desired effect within the brain or offer feedback to BCI users through stimulation (Rao, 2019).

BCI technologies are mainly used in medical scenarios for the diagnosis and treatment of neurological diseases. Focusing on the acquisition perspective, BCIs are extensively used to detect various conditions, such as epilepsy, which allow the detection of anomalous neural activity (Sowndhararajan et al., 2018). They have also been used as mental speech systems, where the BCI can analyze the user's neural activity to determine each spelled letter (Guan et al., 2004). Additionally, technologies such as fMRI based on magnetic fields allow the visualization of the whole brain to detect damaged tissue, extensively used nowadays in most hospitals worldwide. Regarding neural stimulation, a wide variety of technologies is currently accepted by health agencies such as the American FDA to treat different illnesses. For example, Deep Brain Stimulation (DBS) is a BCI technology used to treat several conditions, such as Parkinson's Disease, essential tremor, or obsessive-compulsive disorders (Edwards et al., 2017).

Although BCIs are commonly used for medical purposes, these systems have gained popularity in other economic sectors. One of the most relevant is the military scenario, where the application of BCIs is studied in multiple scenarios (Binnendijk et al., 2020). One of these application scenarios is systems able to monitor soldiers' mental state, assessing the cognitive and emotional response against complex situations. They are also being researched to augment soldiers' mental capabilities in physical, cognitive, and emotional dimensions. Additionally, they could serve as systems to mentally transmit commands between individuals, improving the telecommunication systems on the battlefield. Finally, these devices are interesting for controlling exoskeletons, aiming to restore lost motor functionality or even improve natural human strength.

Another emerging application sector for BCIs is the entertainment and video game industries, where BCI systems have been used for controlling the avatar of the game with the mind (Ahn et al., 2014). The application of BCI technologies could generate a revolution in this field, similar to introducing virtual reality technologies in recent years. Despite these recreational purposes, the application of BCIs in video games also positively benefits neurorehabilitation therapies, where these systems can improve lost motor abilities (McMahon et al., 2018).

Moreover, new technologies and application scenarios have emerged in recent years, presenting considerable engineering challenges. First, invasive BCIs are moving to the miniaturization of their electrodes, aiming to reduce the damage caused by surgical procedures, and a better resolution and coverage of the brain (Musk, 2019). Furthermore, BCIs are incipiently used to allow users to access the Internet with their minds (Saboor et al., 2018) or even allow direct mental communication between subjects (Pais-Vieira et al., 2013).