Special Issue

Clinical Applications of Brain-Computer Interface Technology

Editorial: Eric W. Sellers, Guest Editor

Brain-computer interface (BCI), or brain-machine interface (BMI), research has shown great promise to provide alternative and augmentative communication options for people with severe neuromuscular disabilities. Despite BCI's promise, there is a relative paucity of published work supporting translation from basic research to reliable and valid communication options for users. In other words, a large void still exists between what BCI technology can *potentially* provide and what the technology *currently* provides. Hundreds of BCI papers have been published since 1999, when Birbaumer et al.[1] demonstrated that a BCI could be used for communication in a locked-in person's home environment; nonetheless, 11 years passed before a second paper documented long-term home use of the technology for the purpose of independent communication and environmental control.[2] Several concomitant technical and logistic issues are responsible for hindering researchers' ability to move the technology from bench-to-bedside.[3] The overarching goal of this Special Issue is to highlight novel research and theory that aims to overcome obstacles currently hindering practical BCI use.

A variety of tasks that vary from simple to complex can be performed with a BCI. For example, a user can move cursors, emulate keyboards, operate assistive robotic devices or environmental controls, and even move independent robotic devices. Thus, BCI technology can be especially important for people with severe neuromuscular disabilities who are unable to use the brain's normal output pathways (i.e., peripheral nerves and muscles) for communication and/or environmental control.

BCIs use electrodes that are placed directly into cortex, under or on top of the dura mater, or on the scalp to actuate control. Although the required components of BCI may differ in their particulars, all include certain essential components: signal acquisition, digitization, signal translation into commands, and closed-loop control feedback to the user. This special issue focuses primarily on scalp recorded BCIs, as these systems are most commonly employed in clinical populations. Two types of brain activity are typically used for scalp recorded device control. Frequency domain signals – sensorimotor rhythms (SMRs) or event-related synchronization and desynchronization – are generally used for continuous control. Event-related potentials (ERPs) are used to make discrete selections. SMR and ERP-based systems are both presented in the papers contained within this volume.

The Special Issue call for papers yielded 24 submissions from research groups around the world. All of the submitted papers were directly relevant to the topic. Space limitations precluded the acceptance of all submissions and dictated that the peer review process occur with the utmost sensitivity for the potential practical impact of the research reported. Nine of the papers have been published, indicating the quality of the manuscripts. The papers represent several distinct areas of research, all of which focus on moving toward practical implementation of BCI for the end-user. All of the research reported is innovative in nature, either by using disabled people as subjects or by demonstrating unmistakable relevance for disabled individuals.

The first two papers examine P300-based BCI control. Fazel-Rezai et al.[4] demonstrate that a region-based P300 BCI can lead to faster and more accurate performance than the standard row/column presentation or a single item presentation. This work is highly complementary to novel presentation paradigms recently introduced from other research labs.[5,6] In the next paper Ortner et al.[7] test 15 people with a variety of motor impairments and show that 11 of the subjects effectively operated a P300 BCI after only five minutes of calibration. In addition, they demonstrate that manipulating classification parameters can improve performance for subjects who are unable to perform well with standard electrode placement or a limited amount of calibration data.

The next two papers describe innovative asynchronous paradigms. First, Aloise et al.[8] show that elderly subjects with movement disorders are significantly more accurate traversing a virtual environment using asynchronous control than using synchronous control. This study has important ramifications for BCI in practical settings where asynchronous control is necessary for the user to engage and disengage the communication device. In the second paper, Tsui et al.[9] present a motor imagery based asynchronous robotic wheelchair that only requires 2-class control. In this study, Tsui et al. demonstrate the efficacy of the self-paced, EEG-driven wheelchair, which may substantially benefit locked-in people when it becomes available. In addition to mobility, the wheelchair can provide access to environmental control, volition, and will presumably improve quality of life.

The integration of BCI control with assistive devices and assistive technology (AT) is addressed in the subsequent two papers. Thompson and Huggins[10] introduce a "plug and play" multi-purpose output device (MPOD). The MPOD provides a user-friendly platform that allows easy integration into the context of the real-world environment. Zickler et al.[11] then present the integration of BCI and an AT product (QualiWORLD). Initial tests with end-users and AT experts evaluated factors such as effectiveness, efficiency, and user satisfaction. The results showed that disabled subjects achieved highly accurate performance in spelling, electronic mail correspondence, and general Internet use. The main drawbacks of the system were relatively slow speed and the requirements of the electrode cap and electrolyte gel. Nonetheless, the system may provide a final option for people having little or no alternative means of effective communication.

The next two papers report on the bourgeoning area of BCI for the purpose of stroke rehabilitation. Silvoni et al.[12] review BCI in stroke applications, present a pilot study introducing a novel rehabilitation paradigm, and discuss the challenges of moving toward large-scale BCI-based stroke rehabilitation. Ang et al.[13] then present the results of a clinical study including 54 stroke patients as subjects. Motor imagery and finger tapping were discriminated from a rest condition equally well for stroke- and control-subjects. The majority of the stroke subjects were able to achieve high levels of control accuracy. Collectively, these two papers are encouraging in that they provide some of the first empirical evidence of BCI's role in the future of stroke rehabilitation.

In the final paper Thongpang et al.[14] describe a micro-electrocorticography (ECoG) array and show that it can record stable signals for up to eight weeks in a rhesus macaque model. Although more non-human primate testing is required before the array can be chronically tested in humans, it is possible that existing ECoG arrays may eventually be replaced by micro-arrays. Micro-arrays offer the promise of increasing precision as well as safer deployment.

In summary, this Special Issue contains a broad range of cutting edge studies showcasing progress toward more accurate, practical, and user-friendly BCI options. The designs and studies included here are representative of a growing body of literature that will increase the practical relevance of BCI technology and pave the way for additional useful applications.

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